CHAPTER - 15
ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT

SYNOPSIS

Electromagnetic Induction

Magnetic flux -The flux through an area $\vec{A}$ in a uniform magnetic field $\vec{B}$ is $\phi = \vec{B}.\vec{A} = BA\cos\theta$

θ is the angle between $\vec{B} \text{ and } \vec{A}$

Electromagnetic induction - If the magnetic flux through an area enclosed by a closed conducting loop changes with time, an e.m.f. is produced in the loop.

Faraday's law - The magnitude of induced e.m.f. is equal to the rate of change of magnetic flux. $|\varepsilon| = \frac{d\phi}{dt}$

Lenz's law - (conservation of energy)

The direction of induced current is such as to oppose the change in magnetic flux that produces it.

$$\varepsilon = -\frac{d\phi}{dt}$$

Motional e.m.f. - If a conducting rod of length *l* moves with velocity v in a magnetic field B, e.m.f .induced between the ends of the rod - Bv*l*

B, v and *l* are perpendicular to each other. If these quantities are not perpendicular, their perpendicular components must be used.

Induced e.m.f due to rotation

1. e.m.f induced in a conducting rod of length *l* rotating with angular velocity ω about its one end in a uniform perpendicular magnetic field :- $\frac{1}{2}B\omega l^2$
2. e.m.f induced between the centre and the edge of a disc of radius r, rotating in a perpendicular magnetic field :- $\frac{1}{2}B\omega r^2$

Self induction - Induction of e.m.f in a coil due to its own current change.

The flux linkage $N\phi \alpha I \quad \therefore N\phi = LI$

L - co-efficient of self induction or self inductance

L - Electromagnetic analogue of mass in mechanics

$\varepsilon = -\frac{d}{dt}(N\phi) = -L\frac{dI}{dt}$

$V_A - L\frac{dI}{dt} = V_B$

L of solenoid $L = \mu_0 n^2 A l$

$L_r = \mu_r L$. L_r - self inductance with a core of relative permeability μ_r.

Magnetic energy $U_B = \frac{1}{2}LI^2$

Magnetic energy density = $\frac{B^2}{2\mu_0}$

Mutual induction - Induction of e.m.f. in a coil due to change in current in a neighbouring coil.

Flux linkage with the neighbouring coil $N\phi \propto I$

$N\phi = MI$

M - coefficient of mutual induction or mutual inductance.

$\varepsilon = -\frac{d}{dt}(N\phi) = -M\frac{dI}{dt}$

Mutual inductance of a pair of co-axial solenoid of same length l, M = $\mu_0 n_1 n_2 A l$.

A - Area of cross section of inner solenoid.

L.C. oscillations - If a charged capacitor is connected across an inductance, the charge and current oscillates simple harmonically with a frequency $f = \frac{1}{2\pi\sqrt{LC}}$

Eddy currents - When the magnetic flux linked with a bulk piece of conducting material is varied, induced currents are produced. The flow pattern of this current resembles swirling eddies.

ALTERNATING CURRENT

A conducting loop is rotated in a uniform magnetic field with uniform angular velocity ω, a sinusoidal voltage is induced in the loop. v = NABω sinωt = $v_0$sin ωt

v_0 = NBAω - peak value of voltage.

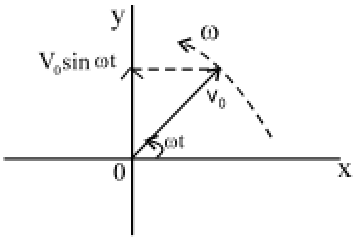
If R is the resistance of the loop, current in the loop i = $\frac{v_0}{R}\sin\omega t = i_0 \sin\omega t$.

i_0 - peak value of current.

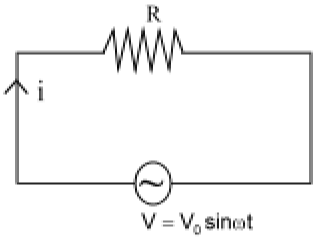
Average value of current over a half cycle $\langle i \rangle_{\frac{1}{2}\text{cycle}} = \frac{2i_0}{\pi}$

$<v>_{\frac{1}{2}\text{cycle}} = \frac{2v_0}{\pi}$ $\quad i_{r.m.s} = \sqrt{\langle i^2 \rangle_{\text{onecycle}}} = \frac{i_0}{\sqrt{2}}$ $\quad v_{r.m.s} = \frac{v_0}{\sqrt{2}}$

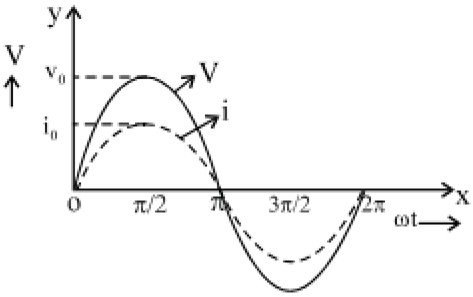
Phasors - The phase relationship between current and voltage in an a.c. circuit can be shown conveniently by representing voltage and current by rotating vectors called phasors.

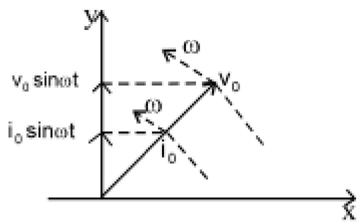


Purely resistive circuit :



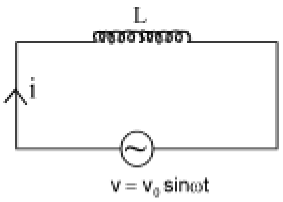
$$i = \frac{v_0}{R}\sin\omega t = i_0 \sin\omega t$$





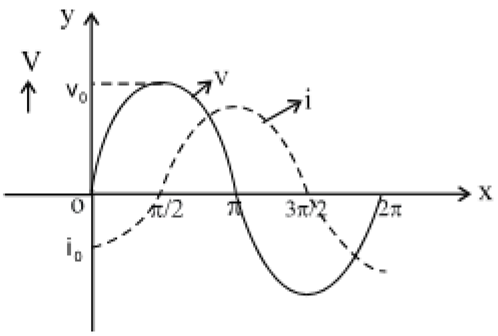
The current is in phase with applied voltage

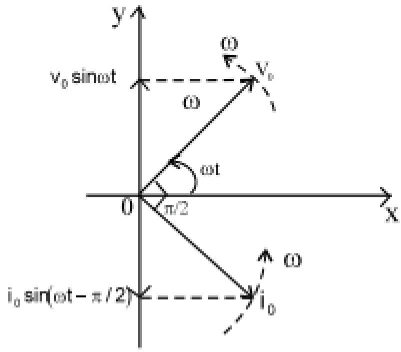
Purely inductive circuit :



$$i = i_0 \sin(\omega t - \pi/2)$$

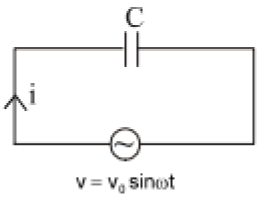
$i_0 = \frac{v_0}{X_L}$. $X_L = L\omega \rightarrow$ inductive reactance





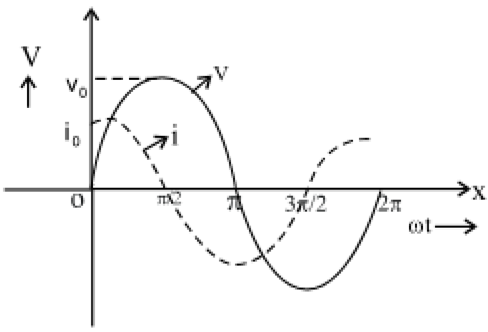
The current lags the applied voltage by $\pi/2$

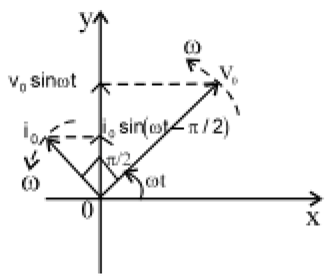
Purely capacitive circuit :-



$i = i_0 \sin(\omega t + \pi/2)$

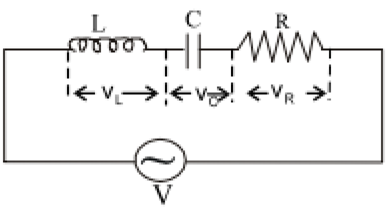
$i_0 = \dfrac{v_0}{X_C}$, $X_C = \dfrac{1}{c\omega} \rightarrow$ capacitive reactance.

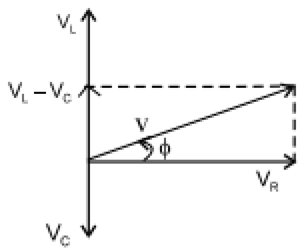




Current leads the applied voltage by $\pi/2$

Series LCR circuit :-





The phasor relationship between the voltage is $\vec{V} = \vec{V}_R + \vec{V}_L + \vec{V}_C$

$i = i_0 \sin(\omega t - \phi)$. $\quad i_0 = \dfrac{V_0}{Z}$

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

$\tan\phi = \frac{(L\omega - 1/C\omega)}{R}$. $\cos\phi = \frac{R}{Z}$

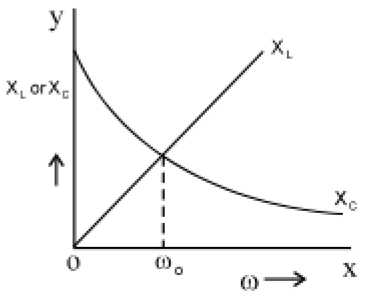
Resonance in series LCR circuit :-

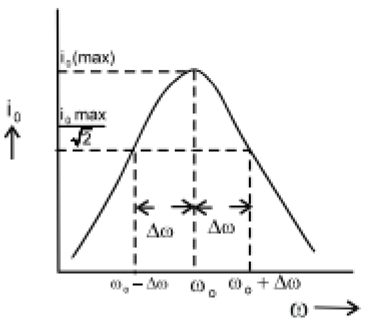
As ω increases X_L increases and X_C decreases.

At $\omega = \omega_0$, $X_L = X_C$ ie $L\omega_0 = \frac{1}{C\omega_0}$

The impedance of the circuit is minimum (Z = R) and current is maximum. This is called resonance.

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





Band width = $2\Delta\omega$

Quality factor = $Q = \frac{\omega_0}{2\Delta\omega} = \frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$

Power in a.c. circuit :-

Instantaneous power P = $v \times i = v_0 \sin\omega t \; i_0 \sin(\omega t - \phi)$

Average power over one cycle $< P >= \frac{v_0 i_0}{2}\cos\phi$

$= \frac{v_0}{\sqrt{2}} \times \frac{i_0}{\sqrt{2}}\cos\phi = VI\cos\phi = I^2 Z\cos\phi$

$\cos\phi$ - power factor

Resistive circuit $\phi = 0 \quad \therefore < P >= VI$

Purely inductive or capacitive circuit $\phi = \pi/2 \quad \therefore < P >= 0$

since <P> = 0, the current in a purely inductive or capacitive circuit is called wattles current.
Transformer : - Works on the principle of mutual induction.

$\frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P}$ (Ideal transformer - Efficiency = 1)

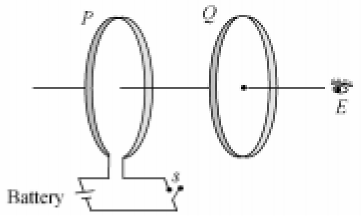
Efficiency = $\frac{V_S I_S}{V_P I_P}$

PART 1 - JEE MAIN
SECTION - I - Straight objective type questions

1. A circular loop of area 3m² and resistance 3Ω is lying in y-z plane. The magnetic induction at the location of the loop varies with time t as $\vec{B} = \left[\left(2t^3 - 6t^2\right)\hat{i} + 3t\,\hat{j}\right]T$. The magnitude of maximum current in the loop during the interval from t = 0 to t = 2 s is
1) 3.5 A 2) 12 A 3) 4 A 4) 6 A

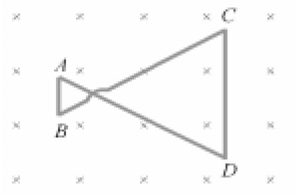
2. A circular coil of area 200 cm² and 1000 turns having resistance 5Ω is placed in a uniform magnetic field 1T. Initially the coil is placed with its plane perpendicular to the field. Now the coil is rotated about an axis at a constant rate of 2 rad/s such that the flux associated with it varies
i) The instantaneous emf induced in it when the plane of the loop makes an angle 60° with the field is 20V
ii) If the coil is rotated through an angle of 180° in 0.2 s, the average emf induced will be 200V
1) only (i) is correct 2) only (ii) is correct 3) both are correct 4) both are incorrect

3. As shown in the figure, P and Q are two coaxial conducting loops separated by some distance. When the switch S is closed, a clockwise current I_P flows in P (as seen by E) and an induced current I_{Q_1} flows in Q. The switch remains closed for a long time. When S is opened, a current I_{Q_2} flows in Q. Then the directions of I_{Q_1} and I_{Q_2} (as seen by E) are



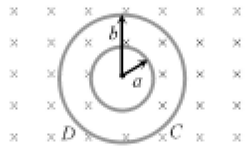
(1) Respectively clockwise and anticlockwise
(2) Both clockwise
(3) Both anticlockwise
(4) Respectively anticlockwise and clockwise

4. A conducting wire frame is placed in a magnetic field which is directed into the paper. The magnetic field is increasing at a constant rate. The directions of induced current in wires AB and CD are



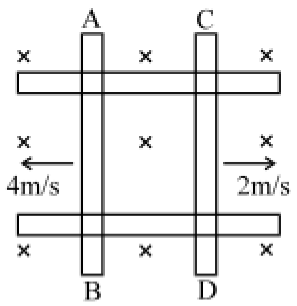
(1) B to A and D to C (2) A to B and C to D
(3) A to B and D to C (4) B to A and C to D

5. Plane figures made of thin wires of resistance R = 50 milli ohm/metre are located in a uniform magnetic field perpendicular into the plane of the figures and which decrease at the rate dB/dt = 0.1 m T/s. Then currents in the inner and outer boundary are. (The inner radius a = 10 cm and outer radius b = 20 cm)



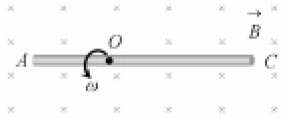
(1) 10^{-4} A (Clockwise), 2×10^{-4} A (Clockwise)
(2) 10^{-4} A (Anticlockwise), 2×10^{-4} A (Clockwise)
(3) 2×10^{-4} A (clockwise), 10^{-4} A (Anticlockwise)
(4) 2×10^{-4} A (Anticlockwise), 10^{-4} A (Anticlockwise)

6. Two parallel conducting rails with negligible resistance are 10cm apart. The circuit contains two metal rails AB and CD with resistance 2Ω each along the rails. A uniform magnetic field 0.01T is applied perpendicular to the plane of the rails. If AB and CD move with uniform speed 4m/s and 2m/s away from each other, the induced current in the circuit is:



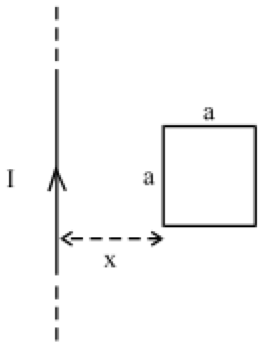
1) 0.5mA 2) 1.5mA 3) 1mA 4) 2mA

7. A conducting rod AC of length $4l$ is rotated about a point O in a uniform magnetic field $\vec{B}$ directed into the paper. AO = l and OC = $3l$. Then



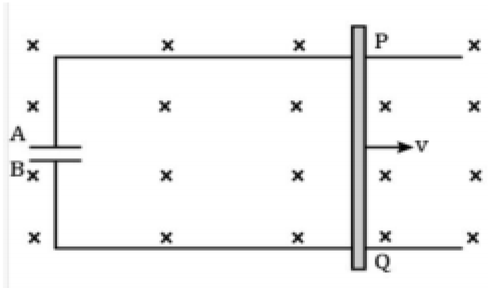
(1) $V_A - V_O = \frac{B\omega l^2}{2}$ (2) $V_O - V_C = \frac{7}{2}B\omega l^2$ (3) $V_A - V_C = 4B\omega l^2$ (4) $V_C - V_O = \frac{9}{2}B\omega l^2$

8. A square frame with side a as shown in figure is moved with uniform velocity v from an infinitely long straight wire carrying current I. The emf induced in the frame as a function of distance x



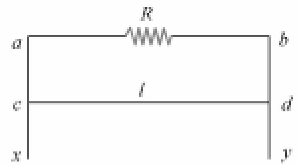
1) $\frac{\mu_0 I a^2 v}{2\pi x(x+a)}$ 2) $\frac{\mu_0 I a x v}{2\pi x(x+a)}$ 3) $\frac{\mu_0 I a^2 v}{4\pi x(x+a)}$ 4) zero

9. A conducting rod PQ of length L = 1.0 m is moving with a uniform speed v = 2 m/s in a uniform magnetic field $B = 4.0T$ directed into the paper. A capacitor of capacity C = 10 μF is connected as shown in figure. Then



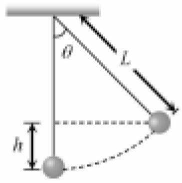
(1) $q_A = +80\ \mu C$ and $q_B = -80\ \mu C$
(2) $q_A = -80\ \mu C$ and $q_B = +80\ \mu C$
(3) $q_A = 0 = q_B$
(4) Charge stored in the capacitor increases exponentially with time

10. A wire cd of length l and mass m is sliding without friction on conducting rails ax and by as shown. The vertical rails are connected to each other with a resistance R between a and b. A uniform magnetic field B is applied perpendicular to the plane *abcd* such that cd moves with a constant velocity of



(1) $\frac{mgR}{B\ell}$ (2) $\frac{mgR}{B^2\ell^2}$ (3) $\frac{mgR}{B^3\ell^3}$ (4) $\frac{mgR}{B^2\ell}$

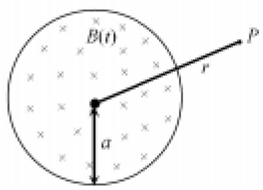
11. A simple pendulum with bob of mass m and conducting wire of length L swings under gravity through an angle 2θ. The earth's magnetic field component in the direction perpendicular to swing is B. Maximum potential difference induced across the pendulum is



(1) $2BL\sin\left(\frac{\theta}{2}\right)(gL)^{1/2}$ (2) $BL\sin\left(\frac{\theta}{2}\right)(gL)$

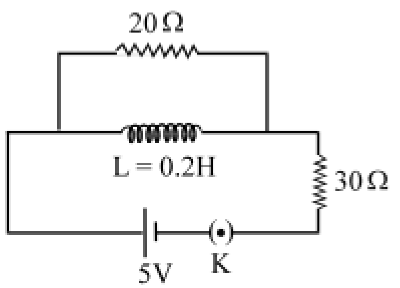
(3) $BL\sin\left(\frac{\theta}{2}\right)(gL)^{3/2}$ (4) $BL\sin\left(\frac{\theta}{2}\right)(gL)^2$

12. A uniform but time-varying magnetic field B(t) exists in a circular region of radius a and is directed into the plane of the paper, as shown. The magnitude of the induced electric field at point P at a distance r from the centre of the circular region



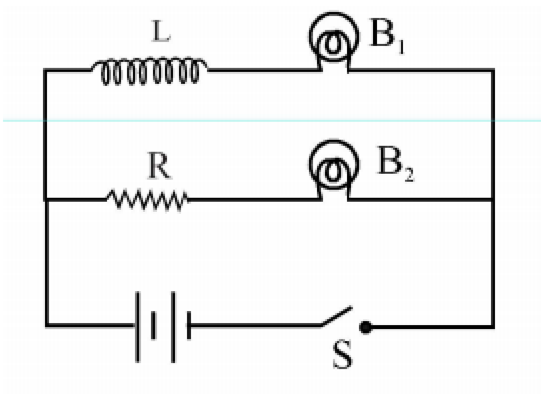
(1) Is zero (2) Decreases as $\frac{1}{r}$ (3) Increases as r (4) Decreases as $\frac{1}{r^2}$

13. An ideal inductance 0.2 H is connected as shown in figure. The current from the cell at the instant of closing key and long time after closing key K



1) $\frac{1}{10}$A and $\frac{1}{6}$A 2) $\frac{1}{5}$A and $\frac{1}{3}$A 3) $\frac{1}{10}$A and $\frac{1}{5}$A 4) $\frac{1}{5}$A and $\frac{1}{6}$A

14. Figure shows an inductor L and a resistance R connected in parallel to a battery through a switch. The resistance of R is the same as that of the coil that makes L. Two identical bulbs are put in each arm of the circuit.



Consider the following statements.
(i) The bulb B_2 lights up earlier when S is closed.
(ii) After some time both B_1 and B_2 become equally bright.
1) only (i) is correct 2) only (ii) is correct
3) both (i) and (ii) are correct 4) both are incorrect

15. An e.m.f. of 15 volt is applied in a circuit containing 5 henry inductance and 10 ohm resistance. The ratio of the currents at time $t=\infty$ and at $t=1$ second is

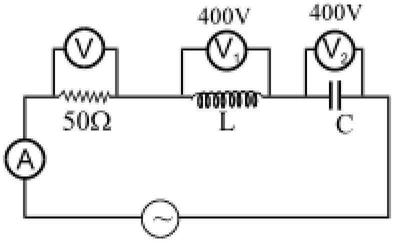
(1) $\frac{e^{1/2}}{e^{1/2}-1}$ (2) $\frac{e^2}{e^2-1}$ (3) $1-e^{-1}$ (4) e^{-1}

16. A small square loop of wire of side l is placed inside a large square loop of wire of side L (L > l). The loop are coplanar and their centre coincide. The mutual inductance of the system is proportional to

(1) l / L (2) ℓ^2/L (3) L/ℓ (4) L^2/ℓ

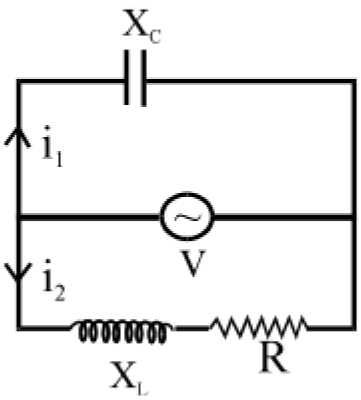
17. Statement I: Work done to move a charge once around a closed loop in an induced electric field is non zero
Statement II: Line integral of induced electric field over a closed loop is non zero
1) Statement I and statement II are correct
2) Statement I and statement II are incorrect
3) Statement I is correct and statement II is incorrect
4) Statement I is incorrect and statement II is correct

18. In the series LCR circuit , the voltmeter reading V and ammeter reading I are



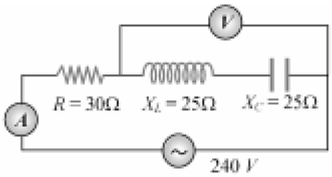
1) V = 100V, I =2A
2) V = 100V, I = 5A
3) V = 400V, I =2A
4) V = 300V, I = 1A

19. In the circuit shown, phase difference between i_1 and i_2 is $\left(\text{Take } X_L = \sqrt{3}\ R\right)$



1) 150°
2) 120°
3) 90°
4) 135°

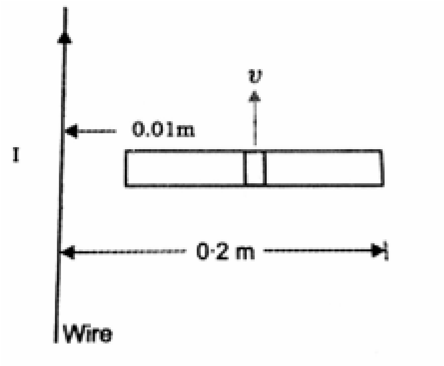
20. In the circuit shown in figure neglecting source resistance the voltmeter and ammeter reading will respectively, will be



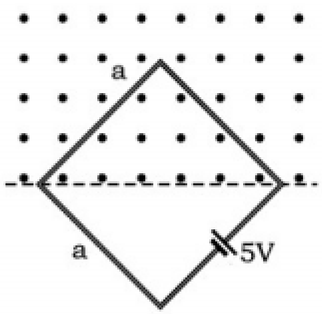
1) 0V, 3A
2) 150V, 3A
3) 150V, 6A
4) 0V, 8A

SECTION - II
Numerical Type Questions

21. A copper rod of length 0.19m is moving with uniform velocity 10m/s parallel to a long straight wire carrying current of 5A. The rod itself is perpendicular to the wire with its ends at distance 0.01m and 0.2m from it. If the induced emf in the rod is 5N μV, the value of N is

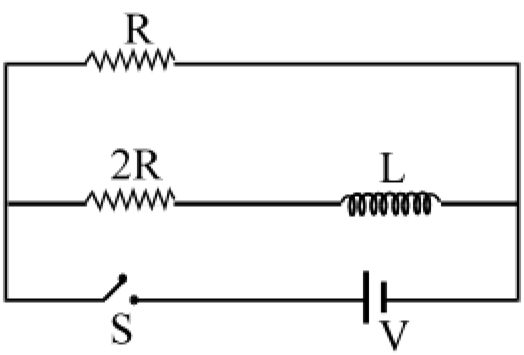


22. A square loop of side 2m and resistance 2.5Ω is placed in a time varying magnetic field $B = (5t + 2)T$

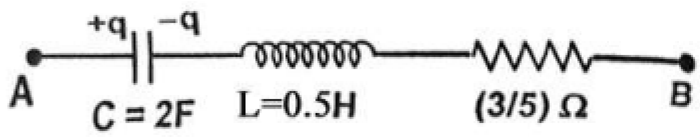


The current in loop in ampere is

23. The ratio of time constants of the circuit during growth of current and decay of current is $\frac{12}{K}$. Find K



24. In the circuit shown, charge q varies with time t as $q = t^3 - t^2 + 4t$, where q is in coulombs and time t is in second. Find potential difference $V_A - V_B$ at time t = 1s

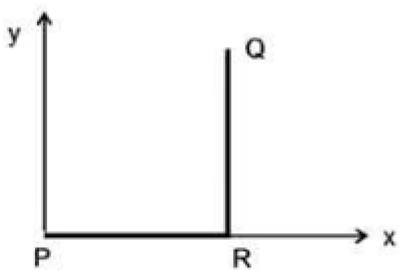


25. An LCR series circuit with a resistance of 100 ohm is connected to an ac source of 200 V (r.m.s.) and angular frequency 300 rad/s. When only the capacitor is removed, the current lags behind the voltage by 60^o. When only the inductor is removed the current leads the voltage by 60^o. The average power dissipated is______________ watts

PART - II (JEE ADVANCED)

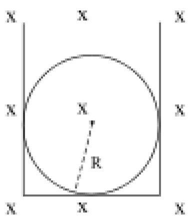
SECTION - III (Only one option correct type)

26. An inverted L shaped conductor PRQ is made by joining two perpendicular conducting rods, each of length 1.5L, at end R. This structure is moving in xy plane containing variable magnetic field $\vec{B} = -3x\hat{k}$ with a velocity $v\hat{i} + v\hat{j}$. If potential of P is V_p and that of Q is V_Q, then value of $V_P - V_Q$ at the instant when P is at origin as shown is



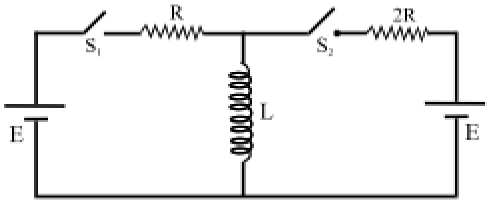
A) $\frac{9VL^2}{8}$ B) $\frac{27VL^2}{8}$ C) $-\frac{9VL^2}{8}$ D) $\frac{-27VL^2}{8}$

27. A uniformly charged ring has a charge Q, mass m and radius R, is placed as shown. Vertical surfaces are smooth and the coefficient of friction between the horizontal surface and the ring is μ. A magnetic field, perpendicular to the plane of ring is applied, and is given by, $B = \frac{1}{2}kt^2$ (where k = 1 T/s²). Find the time after which ring starts moving.



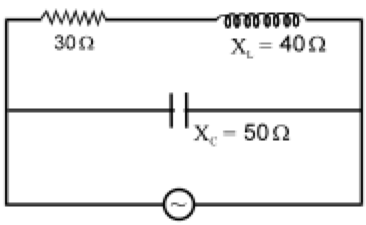
A) $\frac{\mu mg}{QR}$ B) $\frac{2\mu mg}{QR}$ C) $\frac{\mu mg}{2QR}$ D) $\frac{\mu mg}{4QR}$

28. In the following circuit, the switch s_2 remains closed for a long time. Now s_1 is also closed. Just after closing s_1, find the potential difference across R and L



A) $\frac{E}{3}, \frac{2E}{3}$ B) $\frac{2E}{3}, \frac{E}{3}$ C) $\frac{E}{2}, \frac{E}{2}$ D) $\frac{E}{4}, \frac{3E}{4}$

29. In the given AC circuit, if source voltage is $V = 200\sqrt{2}\sin(100\pi t)$, power delivered by source will have a power factor of



A) $\frac{1}{2}$ B) $\sqrt{\frac{3}{10}}$ C) $\frac{3}{\sqrt{10}}$ D) $\frac{1}{\sqrt{10}}$

30. In an L-R-C series circuit the current is given by $i = I\cos\omega t$. The voltage amplitudes for the resistor, inductor and capacitor are V_R, V_L and V_C respectively.

(a) The instantaneous power into the resistor is $p_R = V_R I\cos^2\omega t$.

(b) The instantaneous power into the inductor is $p_L = -V_L I\sin\omega t\cos\omega t$.

(c) The instantaneous power into the capacitor is $p_C = V_C I\sin\omega t\cos\omega t$.

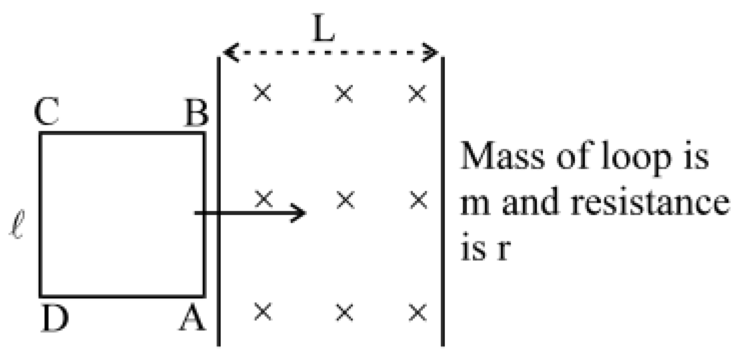
(d) $p_R + p_L + p_C$ equals total power p supplied by the source at each instant of time.

A) (a), (c), (d) are correct B) (b), (c) are correct

C) (a) is correct D) (a), (b), (c), (d) are correct

SECTION - IV (More than one correct answer type)

31. A region of width L contains a uniform magnetic field B directed into the plane of figure. A square conducting loop of side length $\ell\,[<L]$ is kept with its side AB at the boundary of the field region. The loop is pushed into the field region with a speed such that it just manages to exit the field region.

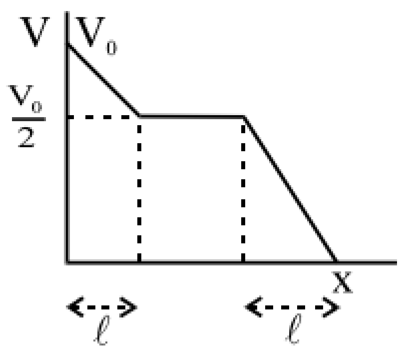


A) Velocity of loop as a function of distance x is $V = V_0 - \frac{B^2\ell^2}{2mR}x$

B) Speed of loop remains constant when the entire area of loop inside the field is constant at $\frac{V_0}{2}$

C) The time needed for the entire loop to enter the field region after it is pushed is $\frac{mR\ell n2}{B^2\ell^2}$

D) The V-x graph for the motion of loop is



32. A non - conducting disc of radius R contains a uniformly distributed charge q. It is placed in a uniform magnetic field B which varies as $B = B_o t$. The magnetic field is perpendicular to the plane of the disc. The mass of the disc is m and is free to rotate about an axis perpendicular to its plane and passing through its centre.

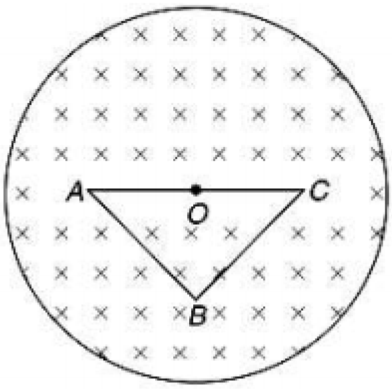
A) Net torque on the disc is $\frac{qB_oR^2}{4}$

B) Angular acceleration of the disc is $\frac{qB_o}{m}$

C) Induced electric field at a distance r from the centre of the ring (r < R) is $2rB_o$

D) The angular speed of the disc at time t is $\frac{B_oq}{2m}\times t$

33. A uniform magnetic field B exists in a regaion of circular cross section of radius R. The field is directed perpendiculary into the plane. There is a triangluar circuit ABC made of a uniform wire placed int he circular region. The triangle is a right angled isosceles triangle with equal sides AB=BC=l. The hypotenuse AC has its midpoint at the centre of the circle. Electrical resistance of triangular circuit per unit length is $\frac{r_0}{l}$. If the magnetic field is changed at a constant rate of $\frac{dB}{dt}=\alpha$



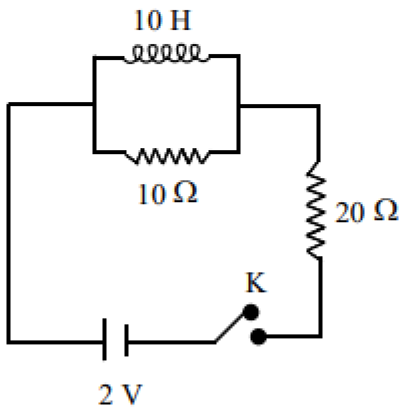
A) emf induced in AB is $\frac{l^2\alpha}{4}$

B) emf induced in BC is $\frac{l^2\alpha}{4}$

C) Potential difference between C and A is $\frac{l^2\alpha}{\sqrt{2}+1}$

D) Potential difference between B and A is $\frac{l^2\alpha}{4\left(\sqrt{2}+1\right)}$

34. Two parallel resistanceless rails are connected by an inductor of inductance L at one end as shown in Fig. A magnetic field B exists in the space which is perpendicular to the plane of the rails. Now a conductor of length ℓ and mass m is placed transverse on the rail and given an impulse J towards the rightward direction. Then choose the correct option(s).



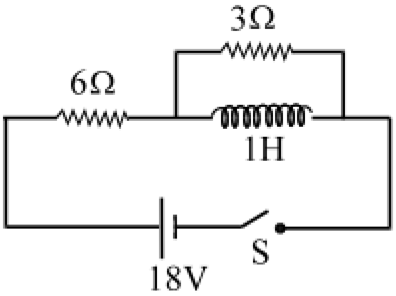
A) Velocity of the conductor is half of the initial velocity after a displacement of the conductor $d=\sqrt{\dfrac{3J^2L}{4B^2\ell^2 m}}$

B) Current flowing throgh the inducotr at the instant when velocity of the conductor is half of the initial velocity is $i=\sqrt{\dfrac{3J^2}{4Lm}}$

C) Velocity of the conductor is half of the initial velocity after a displacement of the conductor $d=\sqrt{\dfrac{3J^2L}{B^2\ell^2 m}}$

D) Current flowing through the inductor at the instnt when velocity of the conductor is half of the initial velocity is $i=\sqrt{\dfrac{3J^2}{mL}}$

35. In the given LR circuit , switch S is closed at t = 0

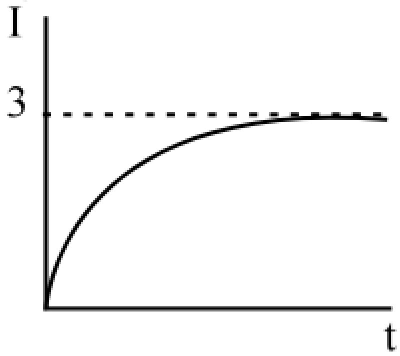


A) The potential difference across 3Ω at time t is given by $6e^{-2t}$

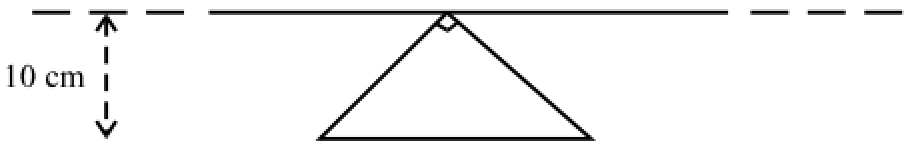
B) Current I from battery at time t is $3\left(1-e^{-2t}\right)$

C) The time at which current through 3Ω and 1H are equal is $\log_e\sqrt{5/3}$

D) Variation of current in inductor with time is



36. A conducting loop in the shape of a right angled isosceles triangle of height 10 cm is kept such that the 90° vertex is very close to an infinitely long conducting wire. The wire is electrically insulated from the loop. The hypotenuse of the triangle is parallel to the wire. The current in the triangular loop is in counter clockwise direction and increased at a constant rate of 10 A/s.

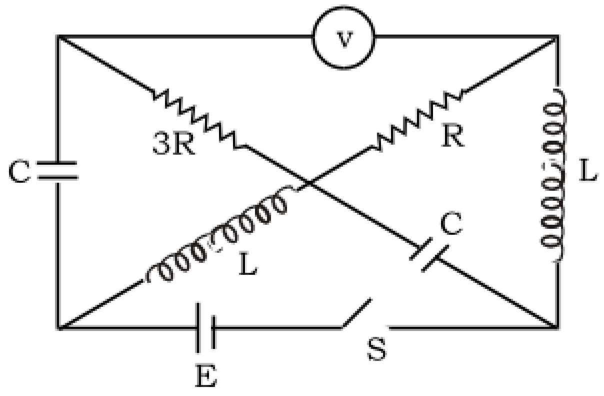


A) The mutual inductance of the arrangement is $\frac{10\mu_0}{\pi}$ Henry

B) The magnitude of induced emf in the wire is $\frac{\mu_0}{\pi}$ volt.

C) If the loop is rotated at a constant angular speed about the wire, an additional emf of $\frac{\mu_0}{\pi}$ volt is induced in the wire.

D) There is a repulsive force between the wire and the loop

37. 

Initially switch is closed. Voltmeter is ideal. Inductor and capacitor possess zero resistance

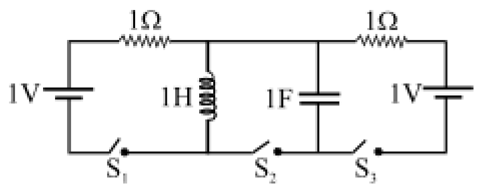
A) Reading of the voltmeter is E

B) No current flows through resistance 3R

C) Now the switch is open. Then, the reading of voltmeter becomes 2E, just after the switch is open

D) Reading of voltmeter does not change just after the switch is open

38. In the circuit shown, switches S_1 and S_3 have been closed for 1s and S_2 remained open. Just after 1s, switch S_2 is closed and S_1 and S_3 are opened at t = 0.



A) The maximum current in the circuit containing inductor and capacitor only $\sqrt{2}\left(1-\frac{1}{e}\right)$

B) The maximum charge on the capacitor $\sqrt{2}\left(1-\frac{1}{e}\right)$

C) The capacitor discharge at t = 0

D) The charge on the capacitor as a function of time is $\sqrt{2}\left(1-\frac{1}{e}\right)\sin\left(t+\frac{3\pi}{4}\right)$\

39. A resistance R and a capacitor C are connected to an alternating source having emf $V = V_0 \text{Sin}\omega t$ where $\omega = \frac{1}{\sqrt{3}RC}$

A) The maximum value of power is $\frac{3V_0^2}{8R}$

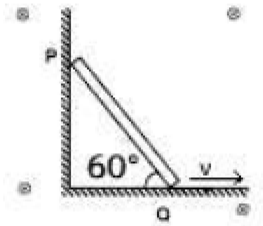
B) The minimum value of power is $\frac{-V_0^2}{8R}$

C) If the capacitor is removed from circuit, the minimum power value is zero

D) If the resistor is removed from circuit the maximum power value is $\frac{V_0^2}{2\sqrt{3}R}$

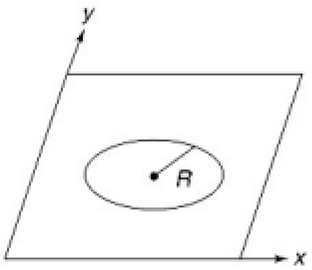
SECTION - V (Numerical Type - Upto two decimal place)

40. A conducting rod PQ of length *l* resting agains two perpendicular smooth non conducting walls. Initially rod makes angle 60° with horizontal surface. There exist uniform magnetic field directed into the plane of the paper. Now at t=0, we start pulling end Q of the rod with constant velocity v along horizontal surface.



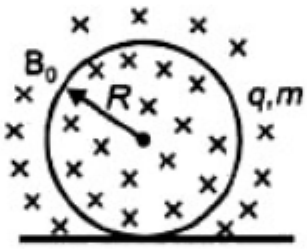
At time $t=\frac{1}{\alpha v}\left(\sqrt{\beta}-1\right)$, emf induced between the ends of the rod PQ is found to be zero. Here α and β constants. Find $\alpha+\beta$

41. A conducting ring of mass $m=\pi\ kg$ and radius $R=\frac{1}{2}m$ is kept on a flat horizontal surface (XY plane). A uniform magnetic field is switched ON in the region which changes with time as $\vec{B}=\left(2\hat{j}+t^2\hat{k}\right)T$. Resistance of the ring is $r=\pi\Omega$ and g = 10 m/s^2

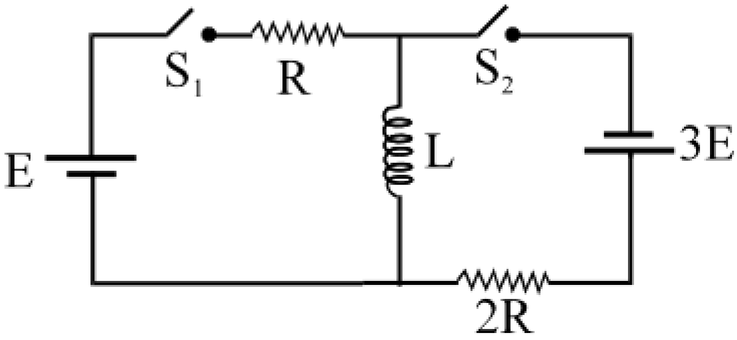


Calculate the heat generated in the ring till the instant it starts to topple in kilo joules

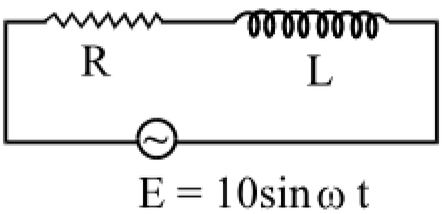
42. A circular non-conducting wire frame of mass m = 750 gram and radius R = 1m having charge q = 3C uniformly distributed on its periphery is placed on a horizontal rough surface. There exists a constant magnetic field of strength B_0 = 3T in a cylindrical region whose centre coincides with the centre of circular wire frame. Direction of magnetic field is perpendicularly inward to the plane of the ring as shown in figure. Sometime after the magnetic field is suddenly switched off, the ring starts pure rolling on the surface with linear speed p m/s. The value of p is



43. In the circuit shown, switch S_2 is open and S_1 is closed since long. Take E = 20V, L = 0.5H and R = 10Ω. Find the rate of change of energy stored in the inductor immediately after S_2 is closed.



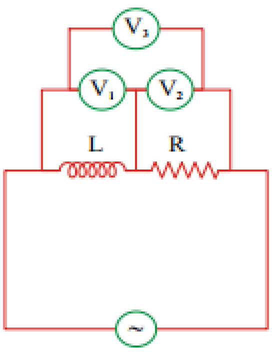
44. An ac circuit having supply voltage E consists of a resistor of resistance 3Ω and an inductor of reactance 4Ω as shown. The voltage across inductor at $t = \frac{T}{2}$ is:



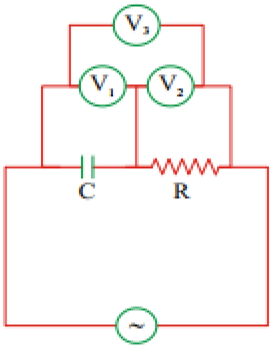
Matrix Match type

45. All voltmeters are ideal and reading of voltmeters V_1 *and* V_2 are given by $V_1 = 3$ volt and $V_2 = 4$ volt in all cases. Match the following:

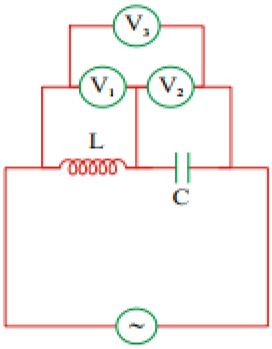
Column I | **Column II**

(A) 

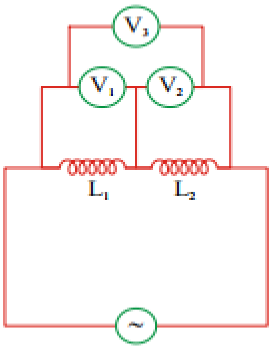
(P) $V_3 = 5\ Volt$

(B) 

(Q) $V_3 = 1\ Volt$

(C) 

(R) $V_3 = 7\ Volt$

(D) 

(s) Current is lagging in phase from applied voltage

(t) Applied voltage is lagging in phase from current