## Exercise-1

✎ **Marked Questions can be used as Revision Questions.**

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Flux and Faraday's laws of electromagnetic induction

A-1. If flux in a coil changes by $\Delta\phi$, and the resistance of the coil is R, prove that the charge flown in the coil during the flux change is $\Delta\phi$/R. (**Note :** It is independent of the time taken for the change in flux)

A-2. The north pole of a magnet is brought down along the axis of a horizontal circular coil (figure). As a result the flux through the coil changes from 0.4 Weber to 0.9 Weber in an interval of half of a second. Find the average emf induced during this period. Is the induced current clockwise or anticlockwise as you look into the coil from the side of the magnet?
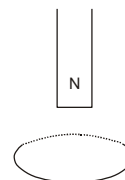
A-3.✎ The flux of magnetic field through a closed conducting loop of resistance 0.4 Ω changes with time according to the equation $\Phi = 0.20t^2 + 0.40t + 0.60$ where t is time in seconds. Find (i) the induced emf at t = 2s. (ii) the average induced emf in t = 0 to t = 5 s. (iii) charge passed through the loop in t = 0 to t = 5s (iv) average current in time interval t = 0 to t = 5 s (v) heat produced in t = 0 to t = 5s.
(i) 1.2 Volt   (ii) 1.4 volt   (iii) 17.5 C   (iv) 3.5 A
(v) 86/3 joule.

A-4. (a) The magnetic field in a region varies as shown in figure. Calculate the average induced emf in a conducting loop of area 10^{-3} m^2 placed perpendicular to the field in each of the 10 ms intervals shown.
(b) In which interval(s) is the emf not constant? Neglect the behavior near the ends of 10 ms intervals.
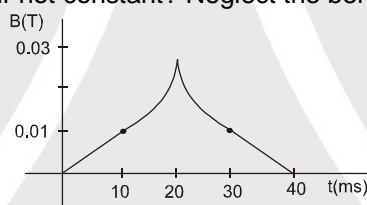

A-5. A conducting loop confined in a plane is rotated in its own plane with some angular velocity. A uniform and constant magnetic field exist in the region. Find the current induced in the loop.

A-6. A metallic ring of area 25 cm^2 is placed perpendicular to a magnetic field of 0.2T. It is removed from the field in 0.2 s. Find the average emf produced in the ring during this time.

A-7.✎ A solenoid has a cross sectional area of 6.0×10^{-4} m^2, consists of 400 turns per meter, and carries a current of 0.40 A. A 10 turn coil is wrapped tightly around the circumference of the solenoid. The ends of the coil are connected to a 1.5 Ω resistor. Suddenly, a switch is opened, and the current in the solenoid dies to zero in a time 0.050 s. Find the average current in the coil during this time.

A-8. A heart pacing device consists of a coil of 50 turns & radius 1 mm just inside the body with a coil of 1000 turns & radius 2 cm placed concentrically and coaxially just outside the body. Calculate the average induced EMF in the internal coil, if a current of 1A in the external coil collapses in 10 milliseconds.

A-9. Figure illustrates plane figures made of thin conductors which are located in a uniform magnetic field directed away from a reader beyond the plane of the drawing. The magnetic induction starts diminishing. Find how the currents induced in these loops are directed.
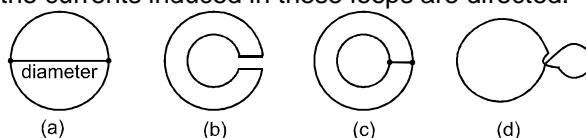
A-10. A uniform magnetic field B exists in a cylindrical region of radius 1 cm as shown in figure. A uniform wire of length 16 cm and resistance 4.0 Ω is bent into a square frame and is placed with one side along a diameters of the cylindrical region. If the magnetic field increases at a constant rate of 1 T/s find the current induced in the frame.
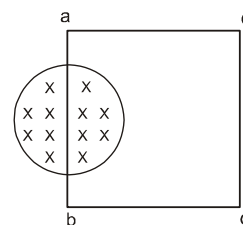
A-11. A coil ACD of N turns & radius R carries a current of I Amp & is placed on a horizontal table. K is a very small horizontal conducting ring of radius r placed at a distance Y_0 from the centre of the coil vertically above the coil ACD. Find an expression for the EMF established when the ring K is allowed to fall freely. Express the EMF in terms of instantaneous speed v & height Y.
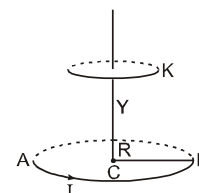
A-12. A closed circular loop of 200 turns of mean diameter 50 cm & having a total resistance of 10 Ω is placed with its plane at right angle to a magnetic field of strength 10^{-2} Tesla. Calculate the quantity of electric charge passed through it when the coil is turned through 180^0 about an axis in its plane.

A-13. Figure shows a square loop of resistance 1 Ω of side 1 m being moved towards right at a constant speed of 1 m/s. The front edge enters the 3 m wide magnetic field (B = 1 T) at t = 0. Draw the graph of current induced in the loop as time passes. (Take anticlockwise direction of current as positive)
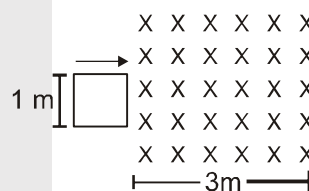
A-14. Find the total heat produced in the loop of the previous problem during the interval 0 to 5 s

Section (B) : Lenz's Law

B-1. Two straight long parallel conductors are moved towards each other. A constant current i is flowing through one of them. What is the direction of the current induced in other conductor? What is the direction of induced current when the conductors are drawn apart.

Section (C) : induced EMF in a moving rod in uniform magnetic field

C-1. A metallic wire PQ of length 1 cm moves with a velocity of 2 m/s in a direction perpendicular to its length and perpendicular to a uniform magnetic field of magnitude 0.2 T. Find the emf induced between the ends of the wire. Which end will be positively charged.
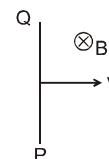
C-2. A right angled triangle abc, made of a metallic wire, moves at a uniform speed v in its plane as shown in the figure. A uniform magnetic field B exists in the perpendicular direction of plane of triangle. Find the emf induced (a) in the loop abc, (b) in the segment bc, (c) in the segment ac and (d) in the segment ab.
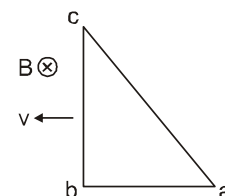
C-3. A metallic metre stick translates in a direction making an angle of 60^0 with its length. The plane of motion is perpendicular to a uniform magnetic field of 0.1 T that exists in the space. Find the emf induced between the ends of the rod if the speed of translation is 0.2 m/s.

C-4 The two rails, separated by 1m, of a railway track are connected to a voltmeter. What will be the reading of the voltmeter when a train travels on the rails with speed 5 m/s. The earth's magnetic field at the place is 4×10^{-4} T, and the angle of dip is 30^0.

C-5. A circular conducting-ring of radius r translates in its plane with a constant velocity v. A uniform magnetic field B exists in the space in a direction perpendicular to the plane of the ring. Consider different pairs of diametrically opposite points on the ring. (a) Between which pair of points is the emf maximum? (b) Between which pair of points is the emf minimum? What is the value of this minimum emf ?

Resonance®
Educating for better tomorrow

Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | **E-mail :** contact@resonance.ac.in
**Toll Free :** 1800 258 5555 | **CIN :** U80302RJ2007PLC024029

ADVEI - 30

C-6. A wire bent as a parabola $y = kx^2$ is located in a uniform magnetic field of induction B, the vector B being perpendicular to the plane xy. At the moment $t = 0$ a connector starts sliding translation wise from the parabola apex with a constant acceleration a (figure). Find the emf of electromagnetic induction in the loop thus formed as a function of y.
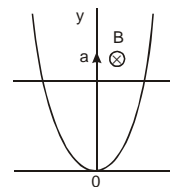
## Section (D) : Circuit Problems and Mechanics

D-1. A square frame of wire abcd of side 1 m has a total resistance of 4 Ω. It is pulled out of a magnetic field B = 1 T by applying a force of 1 N (figure). It is found that the frame moves with constant speed. Find (a) this constant speed, (b) the emf induced in the loop, (c) the potential difference between the points a and b and (d) the potential difference between the points c and d.
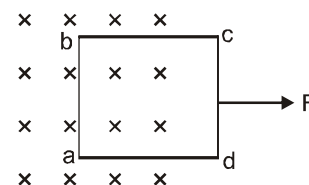
D-2. Consider the situation shown in figure. The wire CD has a negligible resistance and is made to slide on the three rails with a constant speed of 50 cm/s. Find the current in the 10 Ω resistor when the switch S is thrown to (a) the middle rail (b) bottom rail. (Neglect resistance of rails)
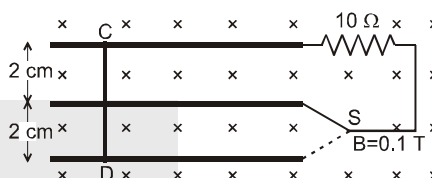
D-3. Figure shows a smooth pair of thick metallic rails connected across a battery of emf ε having a negligible internal resistance. A wire ab of length ℓ and resistance r can slide smoothly on the rails. The entire system lies in a horizontal plane and is immersed in a uniform vertical magnetic field B. At an instant t, the wire is given a small velocity v towards right. (a) Find the current in the wire at this instant. (b) What is the force acting on the wire at this instant. (c) Show that after some time the wire ab will slide with a constant velocity. Find this velocity.
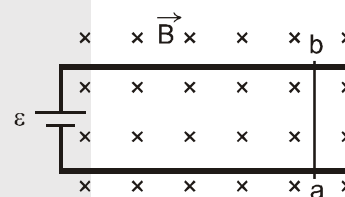
D-4. Figure shows a wire of resistance R sliding on two parallel, conducting fixed thick rails placed at a separation ℓ. A magnetic field B exists in a direction perpendicular to the plane of the rails. The wire is moving with a constant velocity v. Find current through the wire
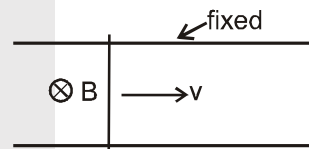
D-5. A long U-shaped wire of width ℓ placed in a perpendicular uniform and constant magnetic field B (figure). A wire of length ℓ is slid on the U-shaped wire with a constant velocity v towards right. The resistance of all the wires is r per unit length. At t = 0, the sliding wire is close to the left edge of the fixed U-shaped wire. Draw an equivalent circuit diagram at time t, showing the induced emf as a battery. Calculate the current in the circuit.
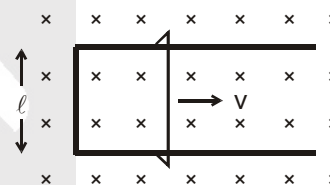
D-6. Consider the situation of the previous problem. (a) Calculate the force needed to keep the sliding wire moving with a constant velocity v. (b) If the force needed just after t = 0 is F_0, find the time at which the force needed will be $F_0/2$.

**D-7.** A wire of mass m and length ℓ can slide freely on a pair of fixed, smooth, vertical rails (figure). A magnetic field B exists in the region in the direction perpendicular to the plane of the rails. The rails are connected at the top end by an initially uncharged capacitor of capacitance C. Find the velocity of the wire at any time (t) after released. Neglecting any electric resistance. (initial velocity of wire is zero)
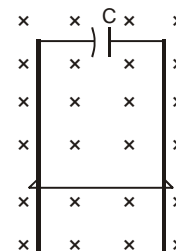
Section (E) : EMF Induced in a rod or loop in non uniform magnetic field

E-1. Figure shows a fixed square frame of wire having a total resistance r placed coplanarly with a long, straight wire. The wire carries a current i given by $i = i_0 \cos(2\pi t/T)$. Find (a) the flux of the magnetic field through the square frame, (b) the emf induced in the frame and (c) the heat developed in the frame in the time interval 0 to 10 T.
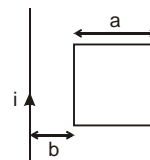
E-2. The magnetic field in a region is given by $\vec{B} = \dfrac{B_0}{L} x \hat{k}$, where L is a fixed length. A conducting rod of length L lies along the X-axis between the origin and the point (L, 0, 0). If the rod moves with a velocity $\vec{v} = v_0 \; \hat{j}$, find the emf induced between the ends of the rod.

E-3. A straight wire with a resistance of r per unit length is bent to form an angle 2α. A rod of the same wire perpendicular to the angle bisector (of 2α) forms a closed triangular loop. This loop is placed in a uniform magnetic field of induction B. Calculate the current in the wires when the rod moves at a constant speed V.
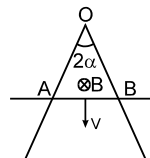
Section (F) : Induced emf in a rod, Ring, Disc rotating in a uniform magnetic field

F-1. A metal rod of length 15×10^{-2} m rotates about an axis passing through one end with a uniform angular velocity of 60 rad s^{-1}. A uniform magnetic field of 0.1 Tesla exists in the direction of the axis of rotation. Calculate the EMF induced between the ends of the rod.

F-2. In the figure there are two identical conducting rods each of length 'a' rotating with angular speed ω in the directions shown. One end of each rod touches a conducting ring. Magnetic field B exists perpendicular to the plane of the rings. The rods, the conducting rings and the lead wires are resistanceless. Find the magnitude and direction of current in the resistance R.
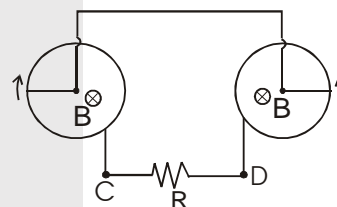
F-3. A bicycle is resting on its stand in the east-west direction and the rear wheel is rotated at an angular speed of 50 revolutions per minute. If the length of each spoke is 30.0 cm and the horizontal component of the earth's magnetic field is 4×10^{-5} T, find the emf induced between the axis and the outer end of a spoke. Neglect centripetal force acting on the free electrons of the spoke.

F-4. A thin wire of negligible mass & a small spherical bob constitute a simple pendulum of effective length ℓ. If this pendulum is made to swing through a semi-vertical angle θ, under gravity in a plane normal to a uniform magnetic field of induction B, find the maximum potential difference between the ends of the wire.

F-5. A conducting disc of radius R is rolling without sliding on a horizontal surface with a constant velocity 'v'. A uniform magnetic field of strength B is applied normal to the plane of the disc. Find the EMF induced between (at this moment)
(a) P & Q   (b) P & C   (c) Q & C
(C is centre, P&Q are opposite points on vertical diameter of the disc)
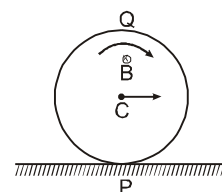
F-6. A closed coil having 50 turns is rotated in a uniform magnetic field $B = 2 \times 10^{-4}$ T about a diameter which is perpendicular to the field. The angular velocity of rotation is 300 revolutions per minute. The area of the coil is 100 cm^2 and its resistance is 4 Ω. Find (a) the average emf developed in half a turn from a position where the coil is perpendicular to the magnetic field, (b) the average emf in a full turn, (c) the net charge flown in part (a) and (d) the emf induced as a function of time if it is zero at t=0 and is increasing in positive direction. (e) the maximum emf induced. (f) the average of the squares of emf induced over a long period

| **Resonance®** Educating for better tomorrow | **Reg. & Corp. Office :** CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005 |
| | **Website :** www.resonance.ac.in \| **E-mail :** contact@resonance.ac.in |
| | **Toll Free :** 1800 258 5555 \| **CIN :** U80302RJ2007PLC024029 |

ADVEI - 32

## Section (G) : Fixed loop in a time varying magnetic field & Induced electric field

G-1. A circular loop of radius 1m is placed in a varying magnetic field given as B = 6t Tesla, where t is time in sec.
(a) Find the emf induced in the coil if the plane of the coil is perpendicular to the magnetic field.
(b) Find the electric field in the tangential direction, induced due to the changing magnetic field.
(c) Find the current in the loop if its resistance is 1Ω/m.

G-2 The current in an ideal, long solenoid is varied at a uniform rate of 0.01 A/s. The solenoid has 2000 turns/m and its radius is 6.0 cm. (a) Consider a circle of radius 1.0 cm inside the solenoid with its axis coinciding with the axis of the solenoid. Write the change in the magnetic flux through this circle in 2.0 seconds. (b) Find the electric field induced at a point on the circumference of the circle. (c) Find the electric field induced at a point outside the solenoid at a distance 8.0 cm from its axis.

G-3. A uniform field of induction B is changing in magnitude at a constant rate dB/dt. You are given a mass m of copper which is to be drawn into a wire of radius r & formed into a circular loop of radius R. Show that the induced current in the loop does not depend on the size of the wire or of the loop. Assuming B perpendicular to the loop prove that the induced current $i = \dfrac{m}{4\pi\rho\delta}\dfrac{dB}{dt}$, where ρ is the resistivity and δ the density of copper.

## Section (H) : Self induction, Self inductance self induced emf & Magnetic energy density

H-1. The figure shows an inductor of 2 H through which a current increasing at the rate of 5A/sec, is flowing. Find the potential difference $V_X - V_Y$.

i, increasing with the rate 5A/sec

x   L=2H   y
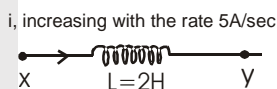
H-2. Figure shows a part of a circuit. Find the rate of change of the current, as shown.

5V   2Ω 3V
10V   2A   10H   20V
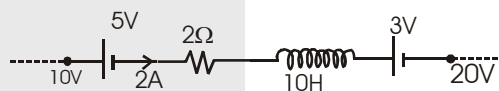
**H-3.** In the circuit shown find (a) the power drawn from the cell, (b) the power consumed by the resistor which is converted into heat and (c) the power given to the inductor.

1A   2H
5V   3Ω
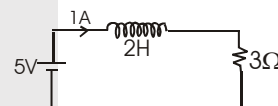
H-4. Find the energy stored in the magnetic field inside a volume of 1.00 mm³ at a distance of 10.0 cm from a long wire carrying a current of 4 A.

H-5. What is the magnetic energy density (in terms of standard constant & r) at the centre of a circulating electron in the hydrogen atom in first orbit. (Radius of the orbit is r)

H-6. Suppose the EMF of the battery, the circuit shown varies with time t so the current is given by i (t) = 3 + 5 t, where i is in amperes & t is in seconds. Take R = 4 Ω, L = 6 H & find an expression for the battery EMF as a function of time.

R   I
ε L
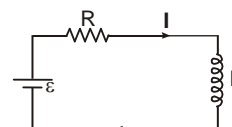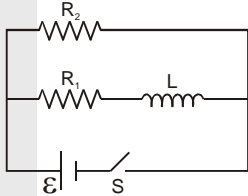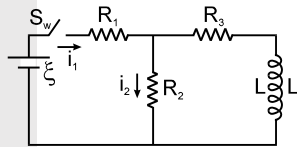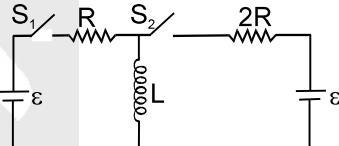
H-7. The network shown in Fig. is a part of a complete circuit. What is the potential difference $V_B - V_A$, when the current I is 5A and is decreasing at a rate of 10^3 (A/s)?
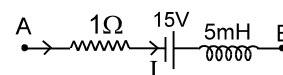
A   1Ω 15V   5mH   B
I

Section (I) : Circuit containing inductance, Resistance & battery, Growth and decay Of Current in a circuit containing inductor

I-1. A coil having resistance 20 Ω and inductance 2 H is connected to a battery of emf 4.0 V. Find (a) the current at 0.20 s after the connection is made and (b) the magnetic field energy in the coil at this instant.

I–2. A solenoid of resistance 50 Ω and inductance 80 Henry is connected to a 200 V battery. How long will the current take to reach 50 % of its final equilibrium value? Calculate the maximum energy stored.

I-3. A solenoid has an inductance of 10 Henry and a resistance of 2Ω. It is connected to a 10 volt battery. How long will it take for the magnetic energy to reach 1/4th of its maximum value?

I-4. A coil of resistance 4 Ω is connected across a 0.4 V battery. The current in the coil is 63 mA. 1sec after the battery is connected. Find the inductance of the coil. [$e^{-1} \approx 0.37$]

I-5. A coil of negligible resistance and inductance 5H, is connected in series with a 100 Ω resistor and a battery of emf 2.0 V. Find the potential difference across the resistor 20 ms after the circuit is switched on. ($e^{-0.4} = 0.67$)

I-6. An LR circuit has L = 1.0 H and R = 20 Ω. It is connected across an emf of 2.0 V at t = 0. Find di/dt and Ldi/dt at t = 50 ms.

I-7. An inductor-coil of inductance 20 mH having resistance 10 Ω is joined to an ideal battery of emf 5.0 V. Find the rate of change of the magnitude of induced emf at (a) t = 0, (b) t = 10 ms.

I–8. Consider the circuit shown in figure. (a) Find the current through the battery a long time after the switch S is closed. (b) Suppose the switch is opened at t = 0. What is the time constant of the decay circuit? (c) Find the current through the inductor after one time constant.

I–9. A superconducting loop of radius R has self inductance L. A uniform & constant magnetic field B is applied perpendicular to the plane of the loop. Initially current in this loop is zero. The loop is rotated about its diameter by 180⁰. Find the current in the loop after rotation.

I-10. In figure, ξ = 100 V, R_1 = 10 Ω, R_2 = 20 Ω, R_3 = 30 Ω and L = 2 H. Find i_1 & i_2.
(a) immediately after switch S_w is closed
(b) a long time after
(c) immediately after S_w is opened again
(d) a long time later.

I-11. In the circuit shown S_1 & S_2 are switches. S_2 remains closed for a long time and S_1 open. Now S_1 is also closed. Just after S_1 is closed. The potential difference (V) across R and $\dfrac{di}{dt}$ (with sign) in L.

I-12. Show that if two inductors with equal inductance L are connected in parallel then the equivalent inductance of the combination is L/2. The inductors are separated by a large distance.

I-13. Two inductances L_1 & L_2 are connected in series & are separated by a large distance
(a) Show that their equivalent inductance is $L_1 + L_2$.
(b) Why must their separation be large?

Section (J) : Mutual Induction & Mutual inductance
J-1. The average emf induced in the secondary coil is 0.1 V when the current in the primary coil changes from 1 to 2 A in 0.1 s. What is the mutual inductance of the coils?

J-2. The mutual inductance between two coils is 0.5 H. It the current in one coil is changed at the rate of 5 A/s, what will be the emf induced in the other coil?

J-3. A small square loop of wire of side ℓ is placed inside a large square loop of wire of side L(L >> ℓ). The loops are co – planar and their centres coincide. Find the mutual inductance of the system.

Resonance®
Educating for better tomorrow
Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | E-mail : contact@resonance.ac.in
Toll Free : 1800 258 5555 | CIN : U80302RJ2007PLC024029
ADVEI - 34

Section (K) : LC Oscillations

K-1. An LC circuit contains a 20 mH inductor and a $50\mu F$ capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be t = 0.

(a) What is the total energy stored initially? Is it conserved during LC oscillations?

(b) What is the natural frequency of the circuit?

(c) At what time is the energy stored

(i) Completely electric (i.e., stored in the capacitor)? (ii) Completely magnetic (i.e., stored in the inductor)?

(d) At what times is the total energy shared equally between the inductor and the capacitor?

K-2. The circuit shown in figure is in the steady state with switch S_1 closed. At t = 0, S_1 is opened and switch S_2 is closed.
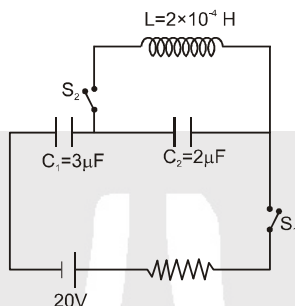

Find the first instant t, when energy in inductor becomes one third of that in capacitor

K-3. A radio can tune over the frequency range of a portion of MW broadcast band: (800 kHz to 1200 kHz). If its LC circuit has an effective inductance of 200 μH, what must be the range of its variable capacitor?

PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Flux and Faraday's laws of electromagnetic induction

A-1. The radius of the circular conducting loop shown in figure is R. Magnetic field is decreasing at a constant rate α. Resistance per unit length of the loop is ρ. Then current in wire AB is (AB is one of the diameters)
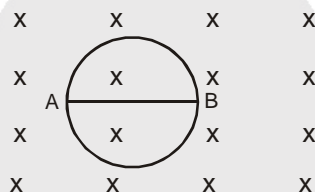
(A) $\dfrac{R\alpha}{2\rho}$ from A to B   (B) $\dfrac{R\alpha}{2\rho}$ from B to A   (C) $\dfrac{2R\alpha}{\rho}$ from A to B   (D) Zero

A-2. Consider the conducting square loop shown in fig. If the switch is closed and after some time it is opened again, the closed loop will show
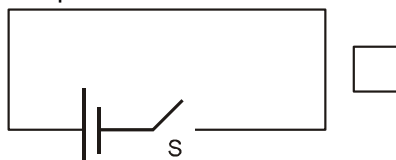
(A) a clockwise current-pulse

(B) an anticlockwise current-pulse

(C) an anticlockwise current-pulse and then a clockwise current-pulse

(D) a clockwise current-pulse and then an anticlockwise current-pulse

Resonance® Educating for better tomorrow	**Reg. & Corp. Office :** CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005	
	Website : www.resonance.ac.in | **E-mail :** contact@resonance.ac.in	**ADVEI - 35**
	Toll Free : 1800 258 5555 | **CIN :** U80302RJ2007PLC024029	

A-3. Solve the previous question if the square loop is completely enclosed in the circuit containing the switch.
(A) a clockwise current-pulse
(B) an anticlockwise current-pulse
(C) an anticlockwise current-pulse and then a clockwise current-pulse
(D) a clockwise current-pulse and then an anticlockwise current-pulse

A-4. A small, circular loop of wire is placed inside a long solenoid carrying a current. The plane of the loop contains the axis of the solenoid. If the current in the solenoid is varied, the current induced in the loop is -
(A) anticlockwise   (B) clockwise   (C) zero
(D) clockwise or anticlockwise depending on whether the resistance in increased or decreased.

A-5. Some magnetic flux is changed in a coil of resistance 10 ohm. As a result an induced current is developed in it, which varies with time as shown in figure. The magnitude of change in flux through the coil in Webers is (Neglect self inductance of the coil)
(A) 2   (B) 4
(C) 6   (D) 8
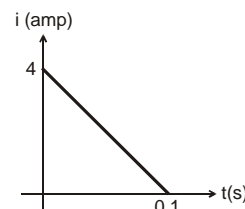
Section (B) : Lenz's Law

B-1. A horizontal solenoid is connected to a battery and a switch (figure). A conducting ring is placed on a frictionless surface, the axis of the ring being along the axis of the solenoid. As the switch is closed, the ring will
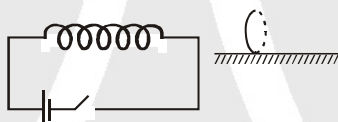
(A) move towards the solenoid
(B) remain stationary
(C) move away from the solenoid
(D) move towards the solenoid or away from it depending on which terminal (positive or negative) of the battery is connected to the left end of the solenoid.

B-2. Two circular coils A and B are facing each other as shown in figure. The current i through A can be altered
(A) there will be repulsion between A and B if i is increased
(B) there will be attraction between A and B if i is increased
(C) there will be neither attraction nor repulsion when i is changed
(D) attraction or repulsion between A and B depends on the direction of current. It does not depend whether the current is increased or decreased.
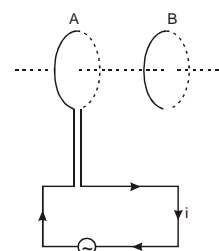
B-3. Two identical conductors P and Q are placed on two frictionless fixed conducting rails R and S in a uniform magnetic field directed into the plane. If P is moved in the direction shown in figure with a constant speed, then rod Q
(A) will be attracted towards P
(B) will be repelled away from P
(C) will remain stationary
(D) may be repelled or attracted towards P
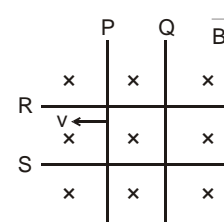
B-4. Two identical coaxial circular loops carry a current i each circulating in the same direction. If the loops approach each other
(A) the current in each loop will decrease
(B) the current in each loop will increase
(C) the current in each loop will remain the same
(D) the current in one loop will increase and in the other loop will decrease

Resonance®
Educating for better tomorrow

Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | E-mail : contact@resonance.ac.in
Toll Free : 1800 258 5555 | CIN : U80302RJ2007PLC024029

ADVEI - 36

**B-5.** A square coil ACDE with its plane vertical is released from rest in a horizontal uniform magnetic field $\vec{B}$ of length 2L. The acceleration of the coil is
(A) less than g for all the time till the loop crosses the magnetic field completely
(B) less than g when it enters the field and greater than g when it comes out of the field
(C) g all the time
(D) less than g when it enters and comes out of the field but equal to g when it is within the field
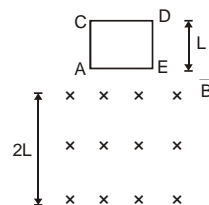
B-6. In the figure shown, the magnet is pushed towards the fixed ring along the axis of the ring and it passes through the ring.
(A) when magnet goes towards the ring the face B becomes south pole and the face A becomes north pole
(B) when magnet goes away from the ring the face B becomes north pole and the face A becomes south pole
(C) when magnet goes away from the ring the face A becomes north pole and the face B becomes south pole
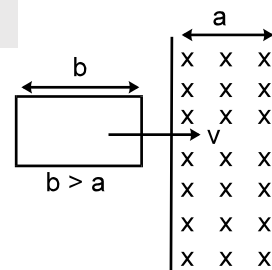(D) the face A will always be a north pole.
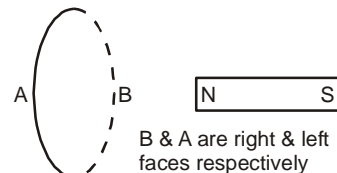
B-7. A metallic ring with a small cut is held horizontally and a magnet is allowed to fall vertically through the ring then the acceleration of the magnet is :
(A) always equal to g
(B) initially less than g but greater than g once it passes through the ring
(C) initially greater than g but less than g once it passes through the ring
(D) always less than g

B-8. A and B are two metallic rings placed at opposite sides of an infinitely long straight conducting wire as shown. If current in the wire is slowly decreased, the direction of induced current will be :
(A) clockwise in A and anticlockwise in B
(B) anticlockwise in A and clockwise in B
(C) clockwise in both A and B
(D) anticlockwise in both A & B
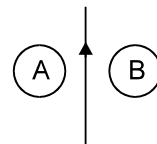
Section (C) : induced EMF in a moving rod in uniform magnetic field

C-1. A wire of length ℓ is moved with a constant velocity $\vec{\upsilon}$ in a magnetic field. A potential difference appears across the two ends
(A) if $\vec{\upsilon} | \vec{\ell} |$
(B) if $\vec{\upsilon} || \vec{B}$
(C) if $\vec{\ell} || \vec{B}$
(D) none of these

C-2. In the given arrangement, the loop is moved with constant velocity v in a uniform magnetic field B in a restricted region of width a. The time for which the emf is induced in the circuit is:
(A) $\dfrac{2b}{v}$
(B) $\dfrac{2a}{v}$
(C) $\dfrac{(a+b)}{v}$
(D) $\dfrac{2(a-b)}{v}$

C-3. A uniform magnetic field exists in region given by $\vec{B} = 3\hat{i} + 4\hat{j} + 5\hat{k}$. A rod of length 5 m is placed along y- axis is moved along x-axis with constant speed 1 m/sec. Then induced e.m.f. in the rod will be:
(A) zero
(B) 25 v
(C) 20 v
(D) 15 v

Resonance®
Educating for better tomorrow
Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | E-mail : contact@resonance.ac.in
Toll Free : 1800 258 5555 | CIN : U80302RJ2007PLC024029
ADVEI - 37

C-4. The resistanceless wire AB (in figure) is slid on the fixed rails with a constant velocity. If the wire AB is replaced by a resistanceless semicircular wire, the magnitude of the induced current will
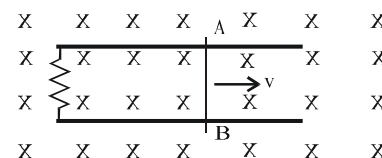
(A) decrease

(B) remain the same

(C) increase

(D) increase or decrease depending on whether the semicircle bulges towards the resistance or away from it.

C-5. A thin semicircular conducting ring of radius R is falling with its plane vertical in a horizontal magnetic induction $\vec{B}$. At the position MNQ the speed of the ring is v then the potential difference developed across the ring is:
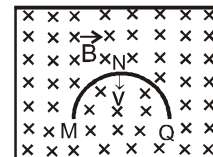
(A) zero

(B) $\dfrac{Bv\pi R^2}{2}$ and M is at higher potential

(C) π RBV and Q is at higher potential

(D) 2 RBV and Q is at higher potential.

Section (D) : Circuit Problems with dynamics

D-1. A constant force F is being applied on a rod of length 'ℓ' kept at rest on two parallel conducting rails connected at ends by resistance R in uniform magnetic field B as shown.
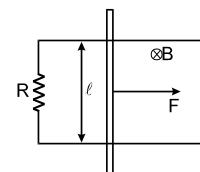
(A) the power delivered by force will be constant with time

(B) the power delivered by force will be increasing first and then it will decrease

(C) the rate of power delivered by the external force will be increasing continuously

(D) the rate of power delivered by external force will be decreasing continuously before becoming zero.

D-2. Figure shows a square loop of side 1 m and resistance 1 Ω. The magnetic field on left side of line PQ has a magnitude B = 1.0T. The work done in pulling the loop out of the field uniformly in 1 s is
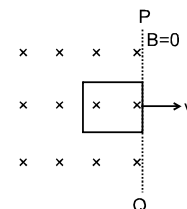
(A) 1 J

(B) 10 J

(C) 0.1 J

(D) 100 J

D-3. AB and CD are fixed conducting smooth rails placed in a vertical plane and joined by a constant current source at its upper end. PQ is a conducting rod which is free to slide on the rails. A horizontal uniform magnetic field exists in space as shown. If the rod PQ is released from rest then :
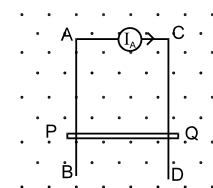
(A) The rod PQ may move downward with constant acceleration

(B) The rod PQ may move upward with constant acceleration

(C) The rod will move downward with decreasing acceleration and finally acquire a constant velocity

(D) either A or B.

D-4. Fig. shows a conducting loop being pulled out of a magnetic field with a constant speed v. Which of the four plots shown in fig. may represent the power delivered by the pulling agent as a function of the constant speed v.
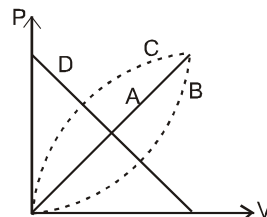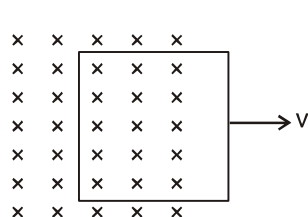
(A) A   (B) B   (C) C   (D) D

Section (E) : EMF Induced in a rod or loop in nonuniform magnetic field

E-1. For the situation shown in the figure, flux through the square loop is

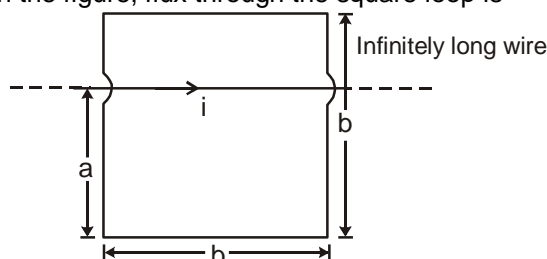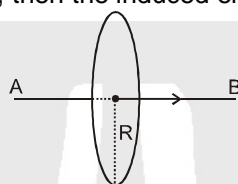(A) $\left(\dfrac{\mu_0 ia}{2\pi}\right)\ell n\left(\dfrac{a}{2a-b}\right)$ (B) $\left(\dfrac{\mu_0 ib}{2\pi}\right)\ell n\left(\dfrac{a}{2b-a}\right)$ (C) $\left(\dfrac{\mu_0 ib}{2\pi}\right)\ell n\left(\dfrac{a}{b-a}\right)$ (D) $\left(\dfrac{\mu_0 ia}{2\pi}\right)\ell n\left(\dfrac{2a}{b-a}\right)$

E-2. A long conductor AB lies along the axis of a circular loop of radius R. If the current in the conductor AB varies at the rate of I ampere/second, then the induced emf in the loop is

(A) $\dfrac{\mu_0 IR}{2}$ (B) $\dfrac{\mu_0 IR}{4}$ (C) $\dfrac{\mu_0 \pi IR}{2}$ (D) zero

Section (F) : Induced emf in a rod, Ring, Disc rotating in a uniform magnetic field

F-1. A conducting rod of length ℓ rotates with a uniform angular velocity ω about its perpendicular bisector. A uniform magnetic field B exists parallel to the axis of rotation. The potential difference between the two ends of the rod is

(A) $2B\omega\ell^2$ (B) $1/2\ \omega B\ell^2$ (C) $B\omega\ell^2$ (D) zero

F-2. A rod of length 10 cm made up of conducting and non-conducting material (shaded part is non-conducting). The rod is rotated with constant angular velocity 10 rad/sec about point O, in constant and uniform magnetic field of 2 Tesla as shown in the figure. The induced emf between the point A and B of rod will be

(A) 0.029 v (B) 0.1 v

(C) 0.051 v (D) 0.064 v
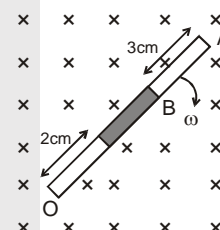
F-3. A semicircular wire of radius R is rotated with constant angular velocity ω about an axis passing through one end and perpendicular to the plane of the wire. There is a uniform magnetic field of strength B. The induced e.m.f. between the ends is:

(A) B ωR^2/2 (B) 2 B ωR^2 (C) is variable (D) none of these
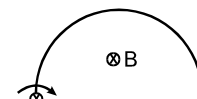
F-4. Figure shows a conducting disc rotating about its axis in a perpendicular uniform and constnat magnetic field B. A resistor of resistance R is connected between the centre and the rim. The radius of the disc is 5.0 cm, angular speed ω = 40 rad/s, B = 0.10 T and R = 1 Ω. The current through the resistor is

(A) 5 mA (B) 50 A (C) 5 A (D) 10 mA

| Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005 |
| Website : www.resonance.ac.in \| E-mail : contact@resonance.ac.in |
| Toll Free : 1800 258 5555 \| CIN : U80302RJ2007PLC024029 |

Resonance® Educating for better tomorrow

ADVEI - 39
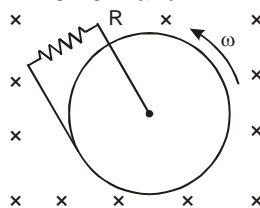
F-5. Two identical conducting rings A & B of radius r are in pure rolling over a horizontal conducting plane with same speed (of center of mass) υ but in opposite direction. A constant magnetic field B is present pointing inside the plane of paper. Then the potential difference between the highest points of the two rings, is :

(A) zero   (B) 2 Bvr   (C) 4Bvr   (D) none of these
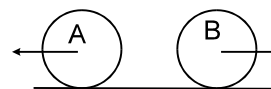
Section (G) : Fixed loop in a time varying magnetic field & Induced electric field

G-1. A cylindrical space of radius R is filled with a uniform magnetic induction B parallel to the axis of the cylinder. If B changes at a constant rate, the graph showing the variation of induced electric field with distance r from the axis of cylinder is

(A)   (B)   (C)   (D)

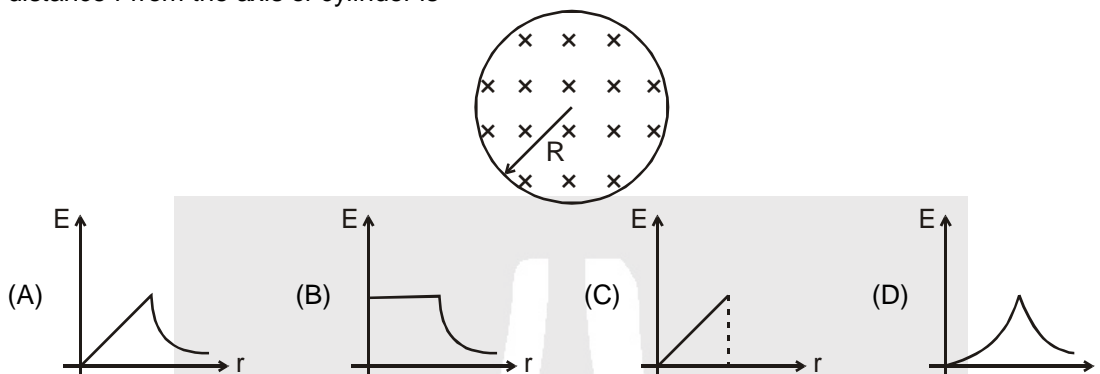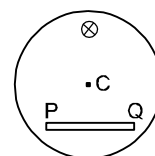**G-2.** In a cylindrical region uniform magnetic field which is perpendicular to the plane of the figure is increasing with time and a conducting rod PQ is placed in the region. If C is the centre of the circle then

(A) P will be at higher potential than Q.
(B) Q will be at higher potential than P.
(C) Both P and Q will be equipotential.
(D) no emf will be developed across rod as it is not crossing / cutting any line of force.

G-3. A uniform magnetic field of induction B is confined to a cylindrical region of radius R. The magnetic field is increasing at a constant rate of $\dfrac{dB}{dt}$ (Tesla/second). An electron of charge q, placed at the point P on the periphery of the field experiences an acceleration :
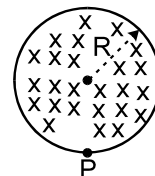
(A) $\dfrac{1}{2}\dfrac{eR}{m}\dfrac{dB}{dt}$ toward left

(B) $\dfrac{1}{2}\dfrac{eR}{m}\dfrac{dB}{dt}$ toward right

(C) $\dfrac{eR}{m}\dfrac{dB}{dt}$ toward left

(D) $\dfrac{1}{2}\dfrac{eR}{m}\dfrac{dB}{dt}$ zero

G-4. A neutral metallic ring is placed in a circular symmetrical uniform magnetic field with its plane perpendicular to the field. If the magnitude of field starts increasing with time, then:
(A) the ring starts translating   (B) the ring starts rotating about its axis
(C) the ring slightly contracts   (D) the ring starts rotating about a diameter

G-5. A bar magnet is released at one end from rest coaxially along the axis of a very long fixed, vertical copper tube. After some time the magnet
(A) will move with an acceleration g   (B) will move with almost constant speed
(C) will stop in the tube   (D) will oscillate

Section (H) : Self induction, self inductance self induced emF & Magnetic energy density

H-1. A wire of fixed length is wound on a solenoid of length 'ℓ' and radius 'r'. Its self inductance is found to be L. Now if another wire is wound on a solenoid of length $\ell/2$ and radius r/2, then the self inductance will be:
(A) 2 L   (B) L   (C) 4 L   (D) 8 L

Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | **E-mail :** contact@resonance.ac.in
Toll Free : 1800 258 5555 | **CIN :** U80302RJ2007PLC024029

ADVEI - 40

H-2. The number of turns, cross-sectional area and length for four solenoids are given in the following table.

| Solenoid	Total Turns	Area	Length
1	2N	2A	ℓ
2	2N	A	ℓ
3	3N	3A	2ℓ
4	2N	2A	$\ell/2$

The solenoid with maximum self inductance is :
(A) 1   (B) 2   (C) 3   (D) 4

Section (I) : Circuit containing inductance, Resistance & battery, Growth and decay Of Current in a circuit containing inductor

I -1. Two inductors L_1 and L_2 are connected in parallel and a time varying current i flows as shown. The ratio of currents i_1/i_2 at any time t is
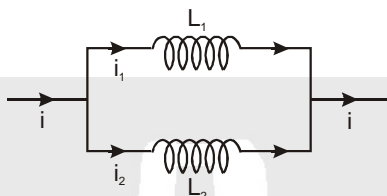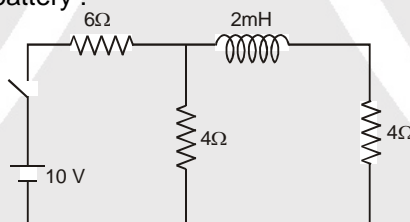

(A) L_1/L_2 (B) L_2/L_1 (C) $\dfrac{L_1^2}{(L_1+L_2)^2}$ (D) $\dfrac{L_2^2}{(L_1+L_2)^2}$

I-2. In an LR circuit current at t = 0 is 20 A. After 2s it reduces to 18 A. The time constant of the circuit is (in second):

(A) $\ln\left(\dfrac{10}{9}\right)$ (B) 2   (C) $\dfrac{2}{\ln\left(\dfrac{10}{9}\right)}$ (D) $2\ln\left(\dfrac{10}{9}\right)$

I-3. In the given circuit find the ratio of i_1 to i_2. Where i_1 is the initial (at t = 0) current, and i_2 is steady state (at t = ∞) current through the battery :

(A) 1.0   (B) 0.8   (C) 1.2   (D) 1.5

I-4. In a series L–R growth circuit, if maximum current and maximum induced emf in an inductor of inductance 3mH are 2A and 6V respectively, then the time constant of the circuit is :
(A) 1 ms.   (B) 1/3 ms.   (C) 1/6 ms   (D) 1/2 ms

I-5. A solenoid having an iron core has its terminals connected across an ideal DC source and it is in steady state. If the iron core is removed, the current flowing through the solenoid just after removal of rod
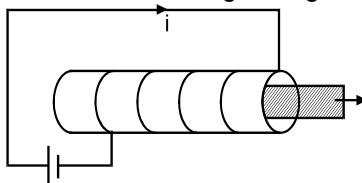
(A) increases   (B) decreases   (C) remains unchanged (D) nothing can be said

	Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Resonance® Educating for better tomorrow	Website : www.resonance.ac.in | E-mail : contact@resonance.ac.in
	Toll Free : 1800 258 5555 | CIN : U80302RJ2007PLC024029 **ADVEI - 41**

I-6. Two inductor coils of self inductance 3H and 6H respectively are connected with a resistance 10Ω and a battery 10 V as shown in figure. The ratio of total energy stored at steady state in the inductors to that of heat developed in resistance in 10 seconds at the steady state is (neglect mutual inductance between L_1 and L_2) :
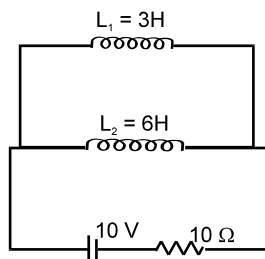
(A) 1/10   (B) 1/100   (C) 1/1000   (D) 1

I-7. The battery shown in the figure is ideal. The values are ε = 10 V, R = 5Ω, L = 2H. Initially the current in the inductor is zero. The current through the battery at t = 2s is
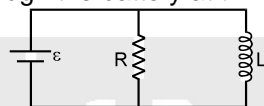
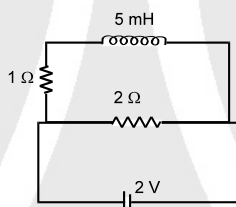(A) 12 A   (B) 7 A   (C) 3 A   (D) none of these

I-8. When induced emf in inductor coil is 50% of its maximum value then stored energy in inductor coil in the given circuit at that instant will be

(A) 2.5 mJ   (B) 5mJ   (C) 15 mJ   (D) 20 mJ

I-9. An inductor coil stores energy U when a current i is passed through it and dissipates heat energy at the rate of P. The time constant of the circuit when this coil is connected across a battery of zero internal resistance is :

(A) $\dfrac{4U}{P}$ (B) $\dfrac{U}{P}$ (C) $\dfrac{2U}{P}$ (D) $\dfrac{2P}{U}$

Section (J) : Mutual Induction & Mutual Inductance

J-1. Two coils are at fixed locations. When coil 1 has no current and the current in coil 2 increases at the rate 15.0 A/s the e.m.f. in coil 1 in 25.0 mV, when coil 2 has no current and coil 1 has a current of 3.6 A, flux linkage in coil 2 is
(A) 16 mWb   (B) 10 mWb   (C) 4.00 mWb   (D) 6.00 mWb

J-2. A rectangular loop of sides 'a' and ' b ' is placed in xy plane. A very long wire is also placed in xy plane such that side of length 'a' of the loop is parallel to the wire. The distance between the wire and the nearest edge of the loop is ' d '. The mutual inductance of this system is proportional to:
(A) a   (B) b   (C) 1/d   (D) current in wire

J-3. Two coils of self inductance 100 mH and 400 mH are placed very close to each other. Find the maximum mutual inductance between the two when 4 A current passes through them

(A) 200 mH   (B) 300 mH   (C) $100\sqrt{2}$ mH   (D) none of these

J-4. A long straight wire is placed along the axis of a circular ring of radius R. The mutual inductance of this system is

(A) $\dfrac{\mu_0 R}{2}$ (B) $\dfrac{\mu_0 \pi R}{2}$ (C) $\dfrac{\mu_0}{2}$ (D) 0
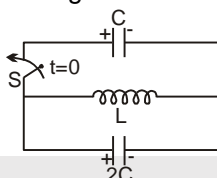
Section (K) : LC Oscillations

**K-1.** The frequency of oscillation of current in the inductor is:
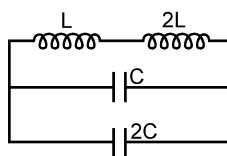
(A) $\dfrac{1}{3\sqrt{L\,C}}$ 　　　　(B) $\dfrac{1}{6\pi\sqrt{L\,C}}$ 　　　　(C) $\dfrac{1}{\sqrt{L\,C}}$ 　　　　(D) $\dfrac{1}{2\pi\sqrt{L\,C}}$

K-2. In the given LC circuit if initially capacitor C has charge Q on it and 2C has charge 2Q .The polarities are as shown in the figure. Then after closing switch S at t = 0

(A) energy will get equally distributed in both the capacitor just after closing the switch.
(B) initial rate of growth of current in inductor will be $2Q/3CL$
(C) maximum energy in the inductor will be $3Q^2/2C$
(D) none of these

K-3. A circuit containing capacitors C_1 and C_2 as shown in the figure are in steady state with key K_1 closed. At the instant t = 0, if K_1 is opened and K_2 is closed then the maximum current in the circuit will be :
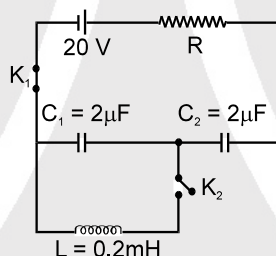
(A) 1 A 　　　　(B) A 　　　　(C) 2 A 　　　　(D) None of these

PART - III : MATCH THE COLUMN

1. The magnetic field in the cylindrical region shown in figure increases at a constant rate of 10.0 mT/s Each side of the square loop abcd and defa has a length of 2.00 cm and resistance of 2.00 Ω . Correctly match the current in the wire 'ad' in four different situations as listed in column-I with the values given in column-II.
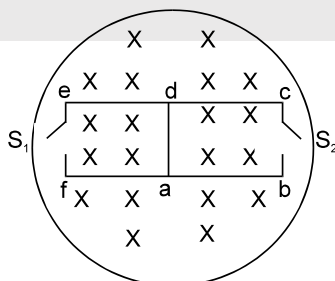
Column-I	Column-II
(A) The switch S_1 is closed but S_2 is open	(p) 5×10^{-7} A, d to a
(B) S_1 is open but S_2 is closed	(q) 5×10^{-7} A, a to d
(C) Both S_1 and S_2 are open	(r) 2.5×10^{-8} A, d to a
(D) Both S_1 and S_2 are closed.	(s) 2.5×10^{-8} A, a to d
	(t) No current flows

2. A square loop of conducting wire is placed symmetrically near a long straight current carrying wire as shown. Match the statements in column-I with the corresponding results in column-II.
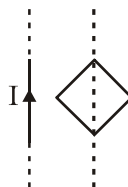
Column-I	**Column-II**
(A) If the magnitude of current I is increased in the loop	(p) Current will induce in clockwise direction
(B) If the magnitude of current I is decreased in the loop	(q) Current will induce in anticlockwise direction
(C) If the loop is moved away from the wire	(r) wire will attract the loop
(D) If the loop is moved towards the wire	(s) wire will repel the loop
	(t) loop will rotate when current changes.

Exercise-2

✎ **Marked Questions can be used as Revision Questions.**

PART - I : ONLY ONE OPTION CORRECT TYPE

1. As shown in the fig. 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_{Q1} flows in Q. The switch remains closed for a long time. When S is opened, a current I_{Q2} flows in Q. Then the directions of I_{Q1} and I_{Q2} (as seen by E) are **[JEE 2002 (Screening) 3/90, –1]**
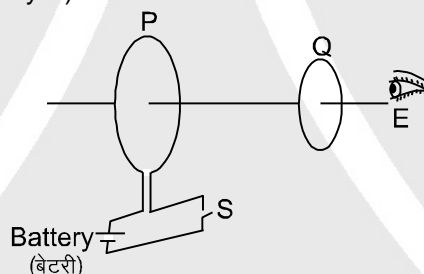
(A) respectively clockwise and anti-clockwise (B) both clockwise
(C) both anti-clockwise (D) respectively anti-clockwise and clockwise.

2. A close loop is placed in a time-varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled and the wire radius halved keeping the radius of the loop unchanged, the electrical power dissipated would be:
(A) halved (B) the same (C) doubled (D) quadrupled

3.✎ Loop A of radius r(r << R) moves towards loop B with a constant velocity V in such a way that their planes are always parallel. What is the distance between the two loops (x) when the induced emf in loop A is maximum
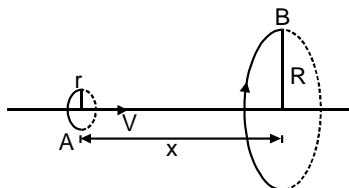
(A) R (B) $\dfrac{R}{\sqrt{2}}$ (C) $\dfrac{R}{2}$ (D) R $\left(1-\dfrac{1}{\sqrt{2}}\right)$

4. A magnetic field (B), uniform between two magnets can be determined measuring the induced voltage in the loop as it is pulled through the gap at uniform speed 20 m/sec. Size of magnet and coil is 2cm × 1cm × 2cm and 4cm × 6cm as shown in figure. The correct variation of induced emf with time is : Assume at t = 0, the coil enters in the magnetic field) :

(A)

(B)

(C)

(D)
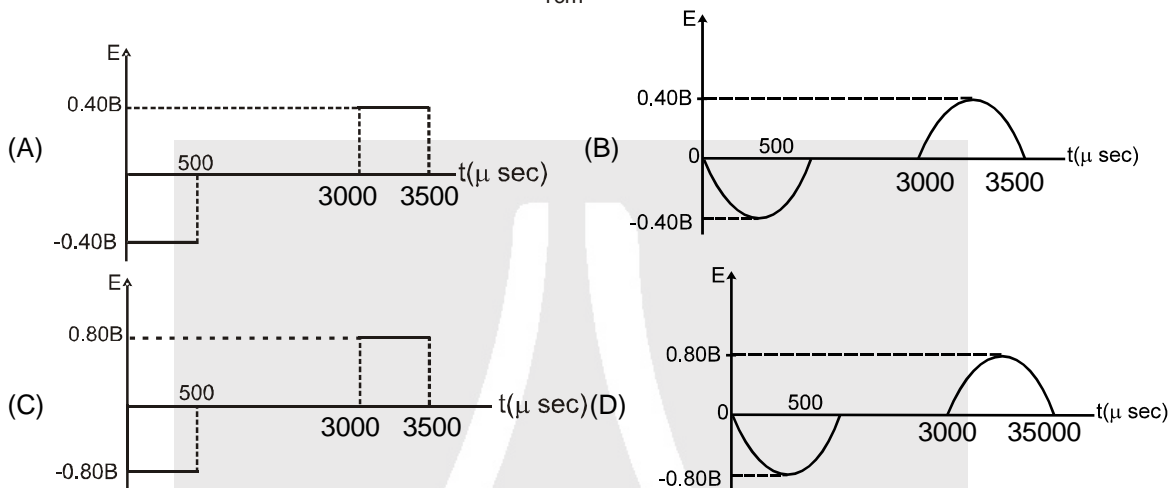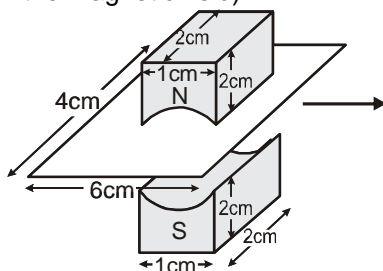
5. Radius of a circular ring is changing with time and the coil is placed in uniform magnetic field perpendicular to its plane. The variation of ' r ' with time ' t ' is shown in the figure. Then induced e.m.f. ε with time will be best represented by :

(A)

(B)

(C)

(D)
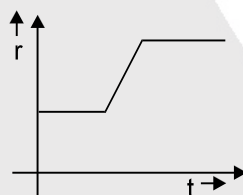
6. A triangular loop as shown in the figure is started to being pulled out at t = 0 from a uniform magnetic field with a constant velocity v. Total resistance of the loop is constant and equals to R. Then the variation of power produced in the loop with time will be:
(A) linearly increasing with time till whole loop comes out
(B) increases parabolically till whole loop comes out
(C) P α t³ till whole loop come out
(D) will be constant with time
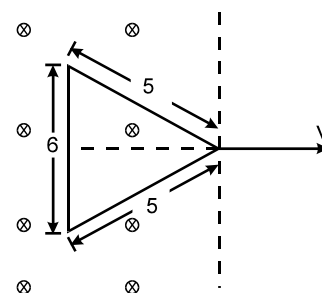
7. A metal rod of resistance 20 Ω is fixed along a diameter of conducting ring of radius 0.1 m and lies in x-y plane. There is a magnetic field $\vec{B} = (50T)\ \hat{k}$. The ring rotates with an angular velocity ω = 20 rad/s about its axis. An external resistance of 10 Ω is connected across the centre of the ring and rim. The current through external resistance is

(A) $\dfrac{1}{4}$ A   (B) $\dfrac{1}{2}$ A   (C) $\dfrac{1}{3}$ A   (D) zero

8. Earth is a spherical conductor with a uniform surface charge density σ. It rotates about its axis with angular velocity ω. Suppose the magnetic field due to Sun at Earth at some instant is a uniform field B pointing along earth's axis. Then the emf developed between the pole and equator of earth due to this field is. (R_e = radius of earth)

(A) $\dfrac{1}{2}B\omega R_e^2$ (B) $B\omega R_e^2$ (C) $\dfrac{3}{2}B\omega R_e^2$ (D) zero

9. A non conducting ring of radius R and mass m having charge q uniformly distributed over its circumference is placed on a rough horizontal surface. A vertical time varying uniform magnetic field $B = 4t^2$ is switched on at time t = 0. The coefficient of friction between the ring and the table, if the ring starts rotating at t = 2 sec, is :
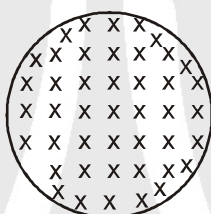
(A) $\dfrac{4qmR}{g}$ (B) $\dfrac{2qmR}{g}$ (C) $\dfrac{8qR}{mg}$ (D) $\dfrac{qR}{2mg}$

10. A uniform magnetic field, $B = B_0 t$ (where B_0 is a positive constant), fills a cylindrical volume of radius R, then the potential difference in the conducting rod PQ due to electrostatic field is :
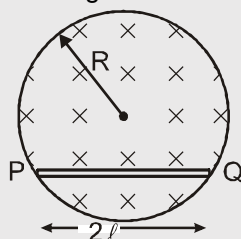
(A) $B_0\ell\ \sqrt{R^2 + \ell^2}$ (B) $B_0\ell\ \sqrt{R^2 - \dfrac{\ell^2}{4}}$ (C) $B_0\ell\ \sqrt{R^2 - \ell^2}$ (D) $B_0 R\ \sqrt{R^2 - \ell^2}$

11. A conducting disc of radius R is placed in a uniform and constant magnetic field B parallel to the axis of the disc. With what angular speed should the disc be rotated about its axis such that no electric field develops in the disc. (The electronic charge and mass are e and m)
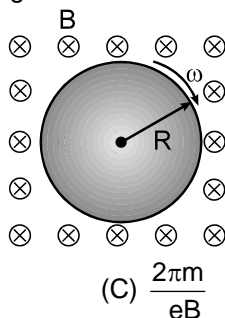
(A) $\dfrac{eB}{2m}$ (B) $\dfrac{eB}{m}$ (C) $\dfrac{2\pi m}{eB}$ (D) $\dfrac{\pi m}{eB}$

12. When the current in a certain inductor coil is 5.0 A and is increasing at the rate of 10.0 A/s, the of potential difference across the coil is 140 V. When the current is 5.0 A and decreasing at the rate of 10.0 A/s, the potential difference is 60 V. The self inductance of the coil is :

(A) 2H   (B) 4H   (C) 10H   (D) 12H

13. Rate of increment of energy in an inductor with time in series LR circuit getting charge with battery of e.m.f. E is best represented by: [Inductor has initially zero current]

(A) $\frac{dU}{dt}$ (B) $\frac{dU}{dt}$ (C) $\frac{dU}{dt}$ (D) $\frac{dU}{dt}$

14. When the current in the portion of the circuit shown in the figure is 2A and increasing at the rate of 1A/s, the measured potential difference $V_a - V_b = 8V$. However when the current is 2A and decreasing at the rate of 1A/s, the measured potential difference $V_a - V_b = 4V$. The values of R and L are :

(A) 3 ohm and 2 Henry respectively   (B) 2 ohm and 3 Henry respectively
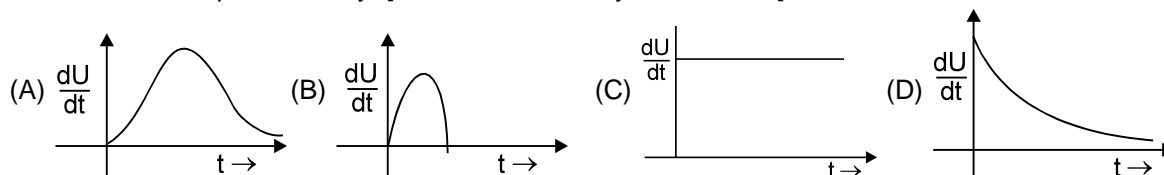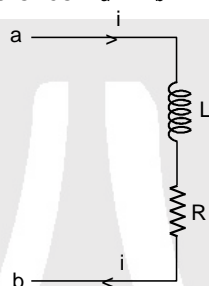(C) 10 ohm and 6 Henry respectively   (D) 6 ohm and 1 Henry respectively

15. In the circuit shown switch S is connected to position 2 for a long time and then joined to position 1. The total heat produced in resistance R_1 is :
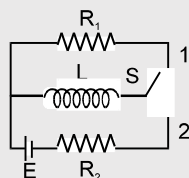
(A) $\frac{L}{2R_2{}^2}E^2$ (B) $\frac{L}{2R_1{}^2}E^2$ (C) $\frac{L}{2R_1R_2}E^2$ (D) $\frac{L}{2R_1{}^2R_2{}^2}E^2(R_1+R_2)^2$

16. Two identical coils each of self-inductance L, are connected in series and are placed so close to each other that all the flux from one coil links with the other. The total self-inductance of the system is :

(A) L   (B) 2L   (C) 3L   (D) 4L

17. A neutral metal bar moves at a constant velocity v to the right through a region of uniform magnetic field directed out the page, as shown. Therefore,
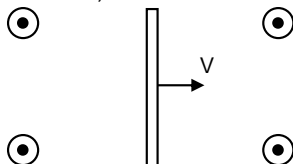
(A) positive charges accumulate to the left side and negative charges to the right side of the rod
(B) negative charges accumulate to the left side and positive charges to the right side of the rod.
(C) positive charges accumulate to the top end and negative charges to the bottom end of the rod
(D) negative charges accumulate to the top end and positive charges to the bottom end of the rod

PART - II : NUMERICAL VALUE

1. A plane spiral with a great number N of turns wound tightly to one another is located in a uniform magnetic field perpendicular to the spiral's plane. The outside radius of the spiral's turns is equal to 'a' and inner radius is zero. The magnetic induction varies with time as $B = B_0 \sin \omega t$, where B_0 and ω are constants. The amplitude of emf induced in the spiral is $\varepsilon_{im} = \dfrac{1}{x} \pi a^2 N \omega B_0$. Find out value of x.

2. In the figure, CDEF is a fixed conducting smooth frame in vertical plane. A conducting uniform rod GH of mass 'm' = 1 g can move vertically and smoothly without losing contact with the frame. GH always remains horizontal. It is given velocity 'u = 1 m/s' upwards and released. Taking the acceleration due to gravity as 'g' and assuming that no resistance is present other than 'R'. Time taken by rod to reach the highest point is equal to $\dfrac{\ell n 10}{x}$ second. Find out value of x.
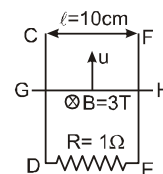
3. Two parallel vertical metallic rails AB and CD are separated by 1 m. They are connected at the two ends by resistance R_1 and R_2 as shown in the figure. A horizontal metallic bar L of mass 0.2 kg slides without friction, vertically down the rails under the action of gravity. There is a uniform horizontal 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 and R_2 are 0.76 W and 1.2 W respectively. If the terminal velocity of bar L is x m/s and R_1 is y Ω and R_2 is ZΩ then find the value of x + 76y + 10z. (g = 9.8 m/s²)

[JEE - 1994]
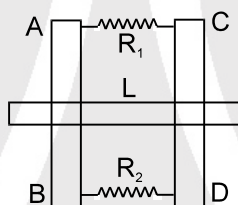
4. Two parallel long smooth conducting rails separated by a distance ℓ = 10 cm are connected by a movable conducting connector of mass m = 4mg. Terminals of the rails are connected by the resistor R = 2Ω & the capacitor C = 1μF as shown. A uniform magnetic field B = 20T perpendicular to the plane of the rails is switched on. The connector is dragged by a constant force F=10N. The speed of the connector as function of time if the force F is applied at t = 0 is equal to $v = 5(1 - e^{-x \times 10^4 \times t})$ m/s. Find the value of x.
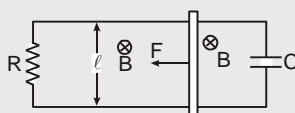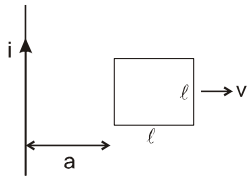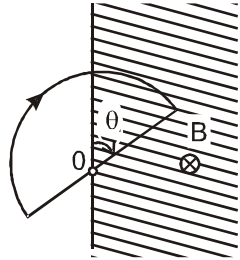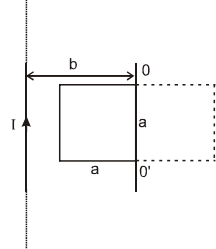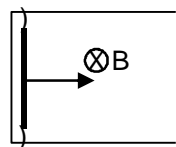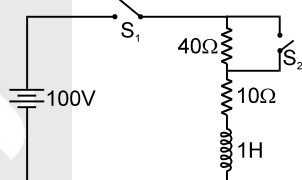
5. A long straight wire carries a current I_0. At distance a and b = 3a from it there are two other wires, parallel to the former one, which are interconnected by a resistance R (figure). A connector slides without friction along the wires with a constant velocity v. Assuming the resistances of the wires, the connector, the sliding contacts, and the self-inductance of the frame to be negligible ;
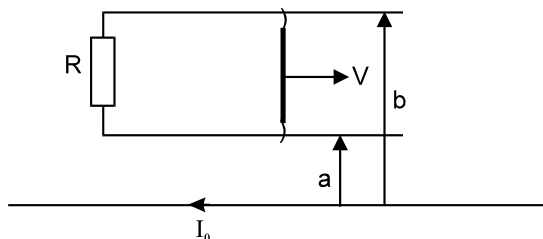
The point of application (distance from the long wire) of magnetic force on sliding wire due to the long wire is $\dfrac{2a}{\ell n x}$ from long wire. Then findout value of x.

Resonance® Educating for better tomorrow

Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | E-mail : contact@resonance.ac.in
Toll Free : 1800 258 5555 | CIN : U80302RJ2007PLC024029

ADVEI - 48

6. A square metallic loop of side ℓ is placed near a fixed long wire carrying a current i (figure). The loop is moved towards right perpendicular to the wire with a speed v in the plane containing the wire and the loop. The emf induced in the loop when the rear end of the loop is at a distance a = 2ℓ from the wire is $\dfrac{\mu_0 iv}{x\pi}$. Find out value of x.

7. A wire loop enclosing a semi-circle of radius a = 2cm is located on the boundary of a uniform magnetic field of induction B=1T (Figure). At the moment t = 0 the loop is set into rotation with a constant angular acceleration β = 2 rad/sec^2 about an axis O coinciding with a line of vector B on the boundary. The emf induced in the loop as a function of time t is [x $\times$ 10^{-4} (–1)^n $\times$ t] volts, where n = 1, 2, ... is the number of the half-revolution that the loop performs at the given moment t. Find the value of x. (The arrow in the figure shows the emf direction taken to be positive, at t = 0 loop was completely outside)

8. A square wire frame (initially current is zero) with side a and a straight conductor carrying a constant current I are located in the same plane (figure). The inductance and the resistance of the frame are equal to L and R respectively. The frame was turned through 180° about the axis OO' separated from the current-carrying conductor by a distance b = 2a. The total electric charge having flown through the frame if i = 0 at t = 0 in the loop is equal to $\dfrac{\mu_0 aI}{2\pi R}\ell nx$. Find the value of x.

9. A Π-shaped conductor is located in a uniform magnetic field perpendicular to the plane of the conductor and varying with time at the rate $\dfrac{dB}{dt}$ = 0.10 T/s. A conducting connector starts moving with a constant acceleration w = 10 cm/s^2 along the parallel bars of the conductor.
The length of the connector is equal to ℓ = 20 cm. Find the emf induced (in mV) in the loop t = 2.0 s after the beginning of the motion, if at the moment t = 0 the loop area and the magnetic induction (B) are equal to zero. The self inductance of the loop is to be neglected.

10. In the circuit diagram shown in the figure the switches S_1 and S_2 are closed at time t = 0. After time t = (0.1) ℓn 2 sec, switch S_2 is opened.
The current in the circuit at time, t = (0.2) ln 2 sec is equal to $\dfrac{x}{32}$ amp. Findout value of x.

11. A closed circuit consists of a source of constant emf E and a choke coil of inductance L connected in series. The active resistance of the whole circuit is equal to R. It is in steady state. At the moment t = 0 the choke coil inductance was decreased abruptly 4 times. The current in the circuit as a function of time t is E/R [1 + xe$^{-4tR/L}$]. Findout value of x.

12. A very small circular loop of radius 'a' is initially coplanar & concentric with a much larger circular loop of radius b (>> a). A constant current I is passed in the large loop which is kept fixed in space & the small loop is rotated with constant angular velocity ω about a diameter. The resistance of the small loop is R & its inductance is negligible. The induced emf in the large loop due to current induced in smaller loop as a function of time is equal to $\dfrac{1}{x}\left(\dfrac{\pi a^2 \mu_0 \omega}{b}\right)^2 \dfrac{I\cos 2\omega t}{R}$. Findout value of x.

13. In the figure shown two loops ABCD & EFGH are in the same plane. The smaller loop carries time varying current I = bt, where b is a positive constant and t is time. The resistance of the smaller loop is r and that of the larger loop is R : (Neglect the self inductance of large loop)
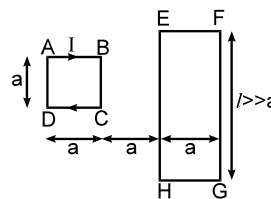
The magnetic force on the loop EFGH due to loop ABCD is $\dfrac{\mu_0^2 \, Iab}{x \, \pi^2 \, R} \, \ell n \, \dfrac{4}{3}$.
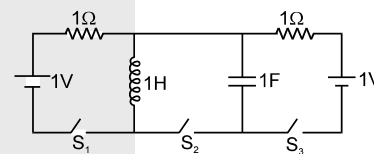
Findout value of x.

14. A solenoid of length 1 m, area of cross-section 4.0 cm^2 and having 4000 turns is placed inside another solenoid of 2000 turns having a cross-sectional area 6 cm^2 and length 2 m. The mutual inductance between the solenoids is x $\pi \times 10^{-5}$ H. Findout value of x.

15. Initially the 900 μF capacitor is charged to 100 V and the 100 μF capacitor is uncharged in the figure shown. Then the switch S$_2$ is closed for a time t$_1$, after which it is opened and at the same instant switch S$_1$ is closed for a time t$_2$ and then opened. It is now found that the 100 μF capacitor is charged to 300 V. If t$_1$ and t$_2$ minimum possible values of the time intervals, then findout t$_1$/t$_2$.
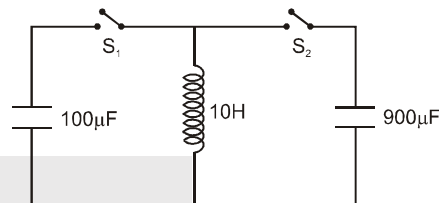
16. In the circuit shown switches S$_1$ and S$_3$ have been closed for 1 sec and S$_2$ remained open. Just after 1 second is over switch S$_2$ is closed and S$_1$, S$_3$ are opened. The charge on the upper plate of the capacitor as function of time taking the instant of switching on of S$_2$ and switching off all the switches to be t = 0 is q = x × 10^{-2}

$\cos\left(t + \dfrac{\pi}{4}\right)$. Findout value of x. (Given $\left(1 - \dfrac{1}{e}\right)\sqrt{2} \cong 0.89$)

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. A resistance R is connected between the two ends of the parallel smooth conducting rails. A conducting rod lies on these fixed horizontal rails and a uniform constant magnetic field B exists perpendicular to the plane of the rails as shown in the figure. If the rod is given a velocity v and released as shown in figure, it will stop after some time, which option are correct:
(A) The total work done by magnetic field is negative.
(B) The total work done by magnetic field is positive.
(C) The total work done by magnetic field is zero.
(D) loss in kinetic energy of conducting rod is equal to heat generate between R.
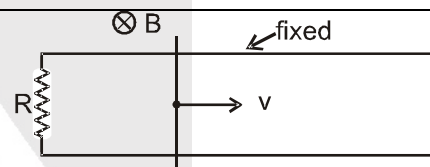
2. A conducting rod of length ℓ is moved at constant velocity 'v$_0$' on two parallel, conducting, smooth, fixed rails, that are placed in a uniform constant magnetic field B perpendicular to the plane of the rails as shown in figure. A resistance R is connected between the two ends of the rail. Then which of the following is/are correct :
(A) The thermal power dissipated in the resistor is equal to rate of work done by external person pulling the rod.
(B) If applied external force is doubled than a part of external power increases the velocity of rod.
(C) Lenz's Law is not satisfied if the rod is accelerated by external force
(D) If resistance R is doubled then power required to maintain the constant velocity v$_0$ becomes half.
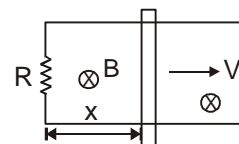
3. A conducting ring is placed in a uniform magnetic field with its plane perpendicular to the field. An emf is induced in the ring if
(A) it is rotated about its axis   (B) it is translated
(C) it is rotated about a diameter   (D) it is deformed

4. A conducting loop rotates with constant angular velocity about its fixed diameter in a uniform magnetic field in a direction perpendicular to that fixed diameter.
(A) The emf will be maximum at the moment when flux is zero.
(B) The emf will be '0' at the moment when flux is maximum.
(C) The emf will be maximum at the moment when plane of the loop is parallel to the magnetic field
(D) The phase difference between the flux and the emf is $\pi/2$

5. A copper wire ab of length ℓ, resistance r and mass m starts sliding at t = 0 down a smooth, vertical, thick pair of connected condcuting rails as shown in figure. A uniform magnetic field B exists in the space in a direction perpendicular to the plane of the rails which opctions are correct.
(A) The magnitude and direction of the induced current in the wire when speed of the wire v is $\dfrac{vB\ell}{r}$, a to b

(B) The downward acceleration of the wire at this instant $g - \dfrac{B^2\ell^2}{mr}$ v.

(C) The velocity of the wire as a function of time $v_m(1 - e^{-gt/v_m})$, (where $v_m = \dfrac{mgr}{B^2\ell^2}$)

(D) The displacement of the wire as a function of time $v_mt - \dfrac{v_m^2}{g}(1 - e^{-gt/v_m})$, (where $v_m = \dfrac{mgr}{B^2\ell^2}$)

6. A super conducting loop having an inductance 'L' is kept in a magnetic field which is varying with respect to time. If ϕ is the total flux, ε = total induced emf, then:
(A) ϕ = constant (B) I = 0 (C) $\varepsilon = 0$ (D) $\varepsilon \neq 0$

7. An LR series circuit with a battery is connected at t =0. Which of the following quantities are zero just after the connection ?
(A) current in the circuit (B) magnetic field energy in the inductor
(C) power delivered by the battery (D) emf induced in the inductor

8. An LR series circuit has L = 1 H and R = 1 Ω. It is connected across an emf of 2 V. The maximum rate at which energy is stored in the magnetic field is :
(A) The maximum rate at which energy is stored in the magnetic field is 1W
(B) The maximum rate at which energy is stored in the magnetic field is 2W
(C) The current at that instant is 1 A
(D) The current at that instant is 2 A

9. In figure a bar magnet is moved along the axis of a copper ring, an anticlockwise (as seen from the side of magnet) current is found to be induced in the ring. Which of the following may be true ?
(A) The north pole faces the ring and the magnet moves away from it.
(B) The north pole faces the ring and the magnet moves towards it
(C) The south pole faces the ring and the magnet moves away from it.
(D) The south pole faces the ring and the magnet moves towards it

10. Two different coils have self-inductance L_1 = 8 mH, L_2 = 2 mH. The current in one coil is increased at a constant rate. The current in the second coil is also increased at the same rate. At a certain instant of time, the power given to the two coils is the same. At that time the current, the induced voltage and the energy stored in the first coil are i_1, V_1 and W_1 respectively. Corresponding values for the second coil at the same instant are i_2, V_2 and W_2 respectively. Then

(A) $\dfrac{i_1}{i_2} = \dfrac{1}{4}$ (B) $\dfrac{i_1}{i_2} = 4$ (C) $\dfrac{W_2}{W_1} = 4$ (D) $\dfrac{V_2}{V_1} = \dfrac{1}{4}$
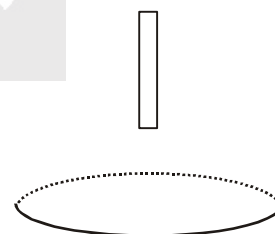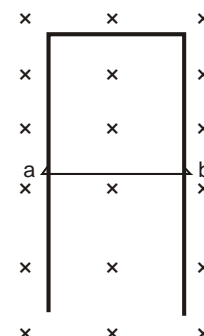
PART - IV : COMPREHENSION

COMPREHENSION-1.

Figure shows a conducting rod of negligible resistance that can slide on smooth U-shaped rail made of wire of resistance $1\Omega/m$. Position of the conducting rod at t = 0 is shown. A time t dependent magnetic field B = 2t Tesla is switched on at t = 0.
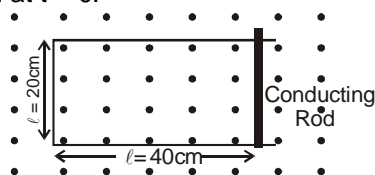
1. The current in the loop at t = 0 due to induced emf is
(A) 0.16 A, clockwise (B) 0.08 A, clockwise
(C) 0.08 A, anticlockwise (D) zero

2. At t = 0, when the magnetic field is switched on, the conducting rod is moved to the left at constant speed 5 cm/s by some external means. The rod moves remaining perpendicular to the rails. At t = 2s, induced emf has magnitude.
(A) 0.12 V (B) 0.08 V (C) 0.04 V (D) 0.02 V

3. Following situation of the previous question, the magnitude of the force required at the same instant t = 2s to move the conducting rod at constant speed 5 cm/s, is equal to
(A) 0.16 N (B) 0.12 N (C) 0.08 N (D) 0.06 N

COMPREHENSION 2

An inductor having self inductance L with its coil resistance R is connected across a battery of emf ε. When the circuit is in steady state at t = 0 an iron rod is inserted into the inductor due to which its inductance becomes n L (n > 1).
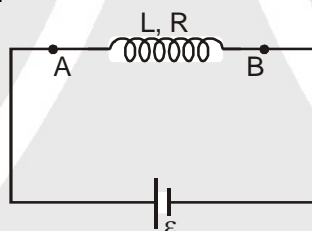
4. After insertion of rod which of the following quantities will change with time ?
(1) Potential difference across terminals A and B.
(2) Inductance.
(3) Rate of heat produced in coil
(A) only (1) (B) (1) & (3) (C) Only (3) (D) (1), (2) & (3)

5. After insertion of the rod, current in the circuit :
(A) Increases with time (B) Decreases with time
(C) Remains constant with time (D) First decreases with time then becomes constant

6. When again circuit is in steady state, the current in it is :
(A) $I < \varepsilon/R$ (B) $I > \varepsilon/R$ (C) $I = \varepsilon/R$ (D) None of these

Exercise-3

✎ **Marked Questions may have for Revision Questions.**
* Marked Questions may have more than one correct option.

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

Paragraph for Question No. 1 to 2

Electrical resistance of certain materials, known as superconductors, changes abruptly from a nonzero value to zero as their temperature is lowered below a critical temperature $T_C(0)$. An interesting property of superconductors is that their critical temperature becomes smaller than $T_C(0)$ if they are placed in a magnetic field, i.e., the critical temperature $T_C(B)$ is a function of the magnetic field strength B. The dependence of $T_C(B)$ on B is shown in the figure.
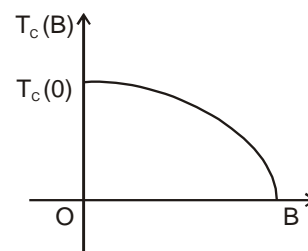
1. In the graphs below, the resistance R of a superconductor is shown as a function of its temperature T for two different magnetic fields B_1 (solid line) and B_2 (dashed line). If B_2 is larger than B_1, which of the following graphs shows the correct variation of R with T in these fields? **[JEE 2010' 3/163, –1]**
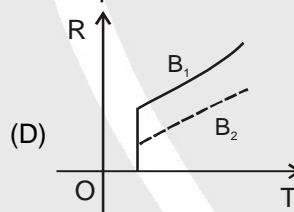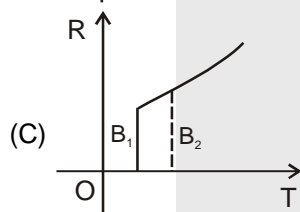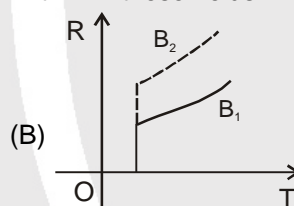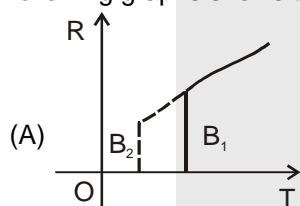
2. A superconductor has $T_C(0) = 100$ K. When a magnetic field of 7.5 Tesla is applied, its T_C decreases to 75 K. For this material one can definitely say that when : **[JEE 2010' 3/163, –1]**
    (A) B = 5 Tesla, $T_C(B) = 80$ K   (B) B = 5 Tesla, 75 K < $T_C(B)$ < 100 K
    (C) B = 10 Tesla, 75 K < $T_C(B)$ < 100 K   (D) B = 10 Tesla, $T_C(B) = 70$ K

3.✎ A long circular tube of length 10 m and radius 0.3 m carries a current I along its curved surface as shown. A wire-loop of resistance 0.005 ohm and of radius 0.1 m is placed inside the tube with its axis coinciding with the axis of the tube. The current varies as $I = I_0 \cos(300 t)$ where I_0 is constant. If the magnetic moment of the loop is $N \mu_0 I_0 \sin(300 t)$, then 'N' is **[JEE 2011' 4/160]**
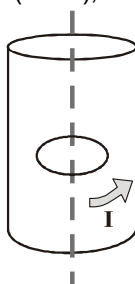
4. Which of the field patterns given below is valid for electric field as well as for magnetic field? **[JEE 2011' 3/160, –1]**

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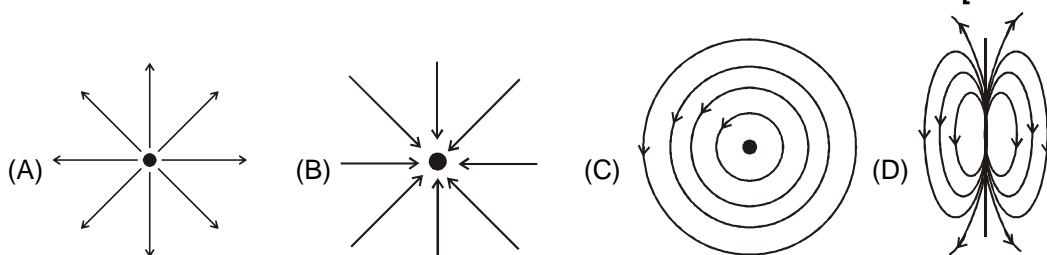
5. A circular wire loop of radius R is placed in the x-y plane centered at the origin O. A square loop of side a (a << R) having two turns is placed with its center at $z = \sqrt{3}R$ along the axis of the circular wire loop, as shown in figure. The plane of the square loop makes an angle of 45° with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

[IIT-JEE-2012, Paper-1; 4/70]
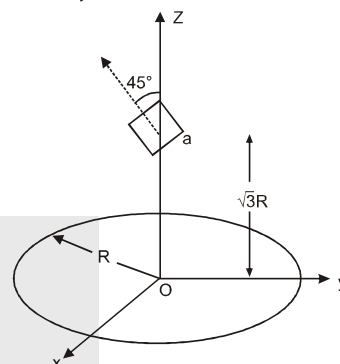
6. A current carrying infinitely long wire is kept along the diameter of a circular wire loop, without touching it. The correct statement (s) is (are) : **[IIT-JEE-2012, Paper-2; 4/66]**
(A) the emf induced in the loop is zero if the current is constant.
(B) The emf induced in the loop is finite if the current is constant.
(C) The emf induced in the loop is zero if the current decreases at a steady rate.
(D) The emf induced in the loop is finite if the current decreases at a steady rate.

Paragraph for Questions 7 and 8

A point charge Q is moving in a circular orbit of radius R in the x-y plane with an angular velocity ω. This can be considered as equivalent to a loop carrying a steady current $\dfrac{Q\omega}{2\pi}$. A uniform magnetic field along the positive z-axis is now switched on, which increases at a constant rate from 0 to B in one second. Assume that the radius of the orbit remains constant. The application of the magnetic field induces an emf in the orbit. The induced emf is defined as the work done by an induced electric field in moving a unit positive charge around a closed loop. It is known that, for an orbiting charge, the magnetic dipole moment is proportional to the angular momentum with a proportionally constant γ.

[JEE (ADV.) 2013, 3×2/60]

7. The magnitude of the induced electric field in the orbit at any instant of time during the time interval of the magnetic field change is :

(A) $\dfrac{BR}{4}$ (B) $\dfrac{BR}{2}$ (C) BR   (D) 2BR

8. The change in the magnetic dipole moment associated with the orbit, at the end of the time interval of the magnetic field change, is :

(A) $-\gamma BQR^2$ (B) $-\gamma\dfrac{BQR^2}{2}$ (C) $\gamma\dfrac{BQR^2}{2}$ (D) γBQR^2

Resonance®
Educating for better tomorrow

Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | **E-mail :** contact@resonance.ac.in
Toll Free : 1800 258 5555 | **CIN :** U80302RJ2007PLC024029

ADVEI - 54

9. A conducting loop in the shape of a right angled isosceles triangle of height 10cm is kept such that the 90° vertex is very closed to an infinitely long conducting wire (see the figure). 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 counterclockwise direction and increased at a constant rate of 10 A s^{-1}. Which of the following statement (s) is (are) true ? **[JEE (Advanced) 2016 ; P-1, 4/62, –2]**
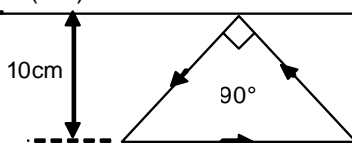
(A) The magnitude of induced emf in the wire is $\left(\dfrac{\mu_0}{\pi}\right)$ volt

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

(C) The induced current in the wire is in opposite direction to the current along the hypotenuse.

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

10. Two inductors L_1 (inductance 1 mH, internal resistance 3 Ω) and L_2 (inductance 2 mH, internal resistance 4 Ω), and a resistor R (resistance 12 Ω) are all connected in parallel across a 5V battery. The circuit is switched on at time t = 0. The ratio of the maximum to the minimum current (I_{max} / I_{min}) drawn from the battery is : **[JEE (Advanced) 2016 ; P-1, 3/62]**

11. A rigid wire loop of square shape having side of length L and resistance R is moving along the x-axis with a constant velocity v_0 in the plane of the paper. At t = 0, the right edge of the loop enters a region of length 3L where there is a uniform magnetic field B_0 into the plane of the paper; as shown in the figure. For sufficiently large v_0, the loop eventually crosses the region.
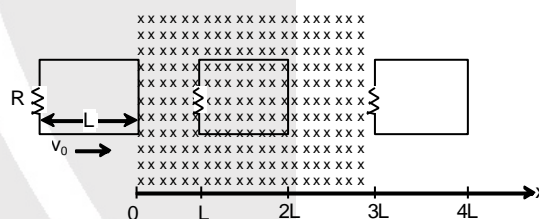
Let x be the location of the right edge of the loop. Let v(x), I(x) and F(x) represent the velocity of the loop, current in the loop, and force on the loop, respectively, as a function of x. Counter-clockwise current is taken as positive. **[JEE (Advanced) 2016 ; P-2, 4/62, –2]**

Which of the following schematic plot(s) is(are) correct? (Ignore gravity)

Resonance®
Educating for better tomorrow

Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | **E-mail :** contact@resonance.ac.in
Toll Free : 1800 258 5555 | **CIN :** U80302RJ2007PLC024029

ADVEI - 55
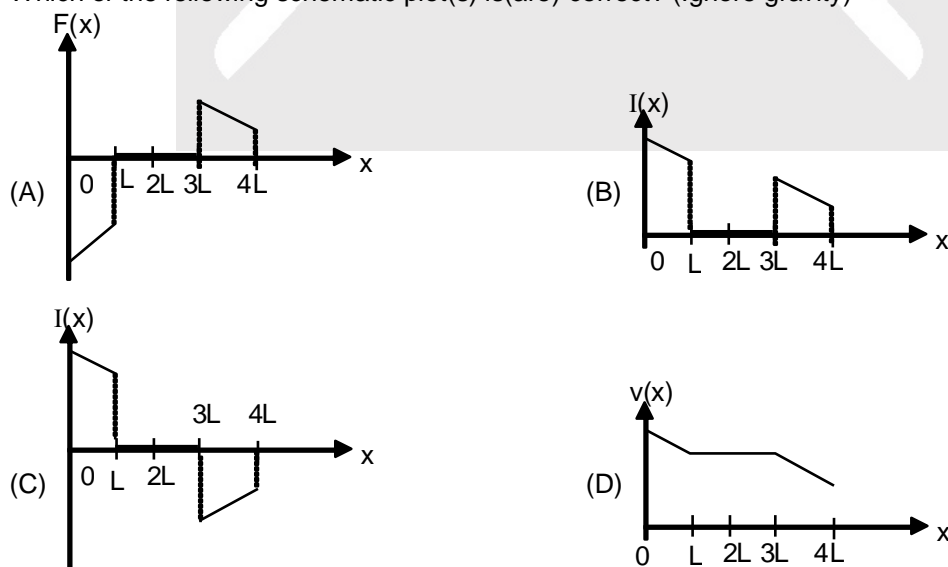
12*. A circular insulated copper wire loop is twisted to form two loops of are A and 2A as shown in the figure. At the point of crossing the wires remain electrically insulated from each other. The entire loop lies in the plane (of the paper). A uniform magnetic field $\vec{B}$ points into the plane of the paper. At t = 0, the loop starts rotation 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 (Advanced) 2017 ; P-1, 4/61, –2]

(A) The net emf induced due to both the loops is proportional to cos ωt
(B) The rate of change of the flux is maximum when the plane of the loops is perpendicular to plane of the paper
(C) 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
(D) The emf induced in the loop is proportional to the sum of the area of the two loops
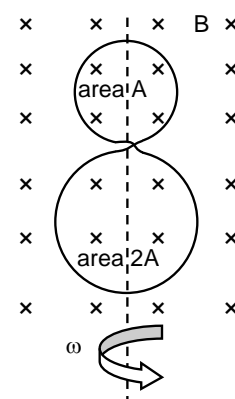
13*. A source of constant voltage V is connected to a resistance R and two ideal inductor L_1 and L_2 through a switch S as shown. There is no mutual inductance between the two inductors. The switch S is initially open. At t = 0, the switch is closed and current begins to flow. Which of the following options is/are correct ? **[JEE (Advanced) 2017 ; P-2, 4/61, –2]**

(A) After a long time, the current through L_2 will be $\dfrac{V}{R}\dfrac{L_1}{L_1+L_2}$

(B) At t = 0, the current through the resistance R is V/R

(C) After a long time, the current through L_1 will be $\dfrac{V}{R}\dfrac{L_2}{L_1+L_2}$

(D) The ratio of the currents through L_1 and L_2 is fixed at all times (t > 0)
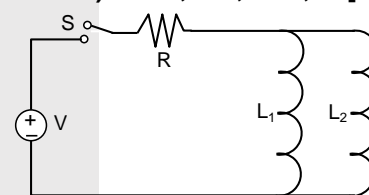
14*. In the figure below, the switches S_1 and S_2 are closed simultaneously at t = 0 and a current starts to flow in the circuit. Both the batteries have the same magnitude of the electromotive force (emf) and the polarities are as indicated in the figure. Ignore mutual inductance between the inductors. The current I in the middle wire reaches its maximum magnitude I_{max} at time t = τ. Which of the following statements is (are) true? **[JEE (Advanced) 2018 ; P-1, 4/60, –2]**
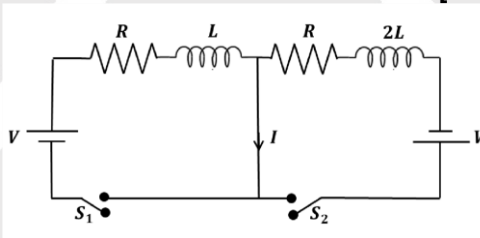
(A) $I_{max}=\dfrac{V}{2R}$ (B) $I_{max}=\dfrac{V}{4R}$ (C) $\tau=\dfrac{L}{R}\ell n2$ (D) $\tau=\dfrac{2L}{R}\ell n2$

15. A conducting wire of parabolic shape, $y = x^2$, is moving with velocity $\vec{V}=V_0\hat{i}$ in a non-uniform magnetic field $\vec{B}=B_0\left(1+\left(\dfrac{y}{L}\right)^{\beta}\right)\hat{k}$, as shown in figure. If V_0, B_0, L and β are positive constants and $\Delta\phi$ is the potential difference developed between the ends of the wire, then the correct statements(s) is/are :
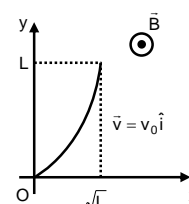
(1) $|\Delta\phi|=\dfrac{4}{3}B_0V_0L$ for $\beta=2$ **[JEE (Advanced) 2019 ; P-1, 4/62, –1]**

(2) $|\Delta\phi|$ remains same if the parabolic wire is replaced by a straight wire, y = x, initially, of length $\sqrt{2}\ell$

(3) $|\Delta\phi|=\dfrac{1}{2}B_0V_0L$ for $\beta=0$

(4) $|\Delta\phi|$ is proportional to the length of wire projected on y-axis

Resonance® Educating for better tomorrow

Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | **E-mail :** contact@resonance.ac.in
Toll Free : 1800 258 5555 | **CIN :** U80302RJ2007PLC024029

ADVEI - 56

16. A 10 cm long perfectly conducting wire PQ is moving with a velocity 1 cm/s on a pair of horizontal rails of zero resistance. One side of the rails is connected to an inductor L = 1 mH and a resistance R = 1Ω as shown in figure. The horizontal rails, L and R lie in the same plane with a uniform magnetic field B = 1T perpendicular to the plane. If the key S is closed at certain instant, the current in the circuit after 1 millisecond is x × 10⁻³A, where the value of x is _____.
[Assume the velocity of wire PQ remains constant (1 cm/s) after key S is closed. Given : e⁻¹ = 0.37, where e is base of the natural logarithm] **[JEE (Advanced) 2019 ; P-2, 3/62,]**
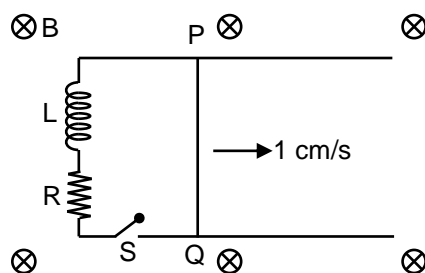
PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1. 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 : **[AIEEE 2010, 8/144, –2]**
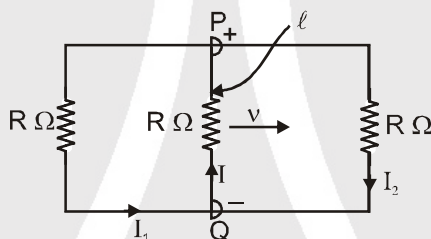
(1) $I_1 = -I_2 = \dfrac{B\ell v}{R}$, $I = \dfrac{2B\ell v}{R}$ (2) $I_1 = I_2 = \dfrac{B\ell v}{3R}$, $I = \dfrac{2B\ell v}{3R}$

(3) $I_1 = I_2 = I = \dfrac{B\ell v}{R}$ (4) $I_1 = I_2 = \dfrac{B\ell v}{6R}$, $I = \dfrac{B\ell v}{3R}$

2. 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 :
[AIEEE 2011, 1 May, 4/120, –1]

(1) $\pi\sqrt{LC}$ (2) $\dfrac{\pi}{4}\sqrt{LC}$ (3) $2\pi\sqrt{LC}$ (4) $\sqrt{LC}$

3. A boat is moving due east in a region where the earth's magnetic field is 5.0 × 10⁻⁵ NA⁻¹m⁻¹ due north and horizontal. The boat carries a vertical aerial 2m long. If the speed of the boat is 1.50 ms⁻¹, the magnitude of the induced emf in the wire of aerial is : **[AIEEE - 2011, 1 May, 4/120, –1]**
(1) 1 mV   (2) 0.75 mV   (3) 0.50 mV   (4) 0.15 mV

**4.** A horizontal straight wire 20 m long extending from to 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/m². The instantaneous Value of the e.m. f. induced in the wire will be : **[AIEEE 2011, 11 May; 4/120, –1]**
(1) 3 mV   (2) 4.5 mV   (3) 1.5 mV   (4) 6.0mV

5. 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 : **[AIEEE 2012 ; 4/120, –1]**
(1) developement of air current when the plate is placed.
(2) induction of electrical charge on the plate
(3) shielding of magnetic lines of force as aluminium is a paramagnetic material.
(4) Electromagnetic induction in the aluminium plate giving rise to electromagnetic damping.

6. 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: **[JEE (Main) 2013, 4/120, −1]**
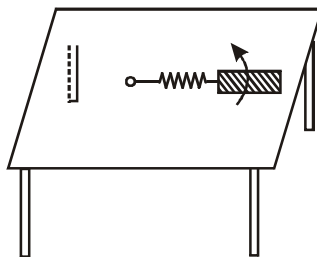
(1) $\dfrac{2B\omega l^2}{2}$ (2) $\dfrac{3B\omega l^2}{2}$ (3) $\dfrac{4B\omega l^2}{2}$ (4) $\dfrac{5B\omega l^2}{2}$

7. A circular loop of radius 0.3 cm lies parallel to a much 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 :

[JEE (Main) 2013, 4/120]

(1) 9.1×10^{-11} weber (2) 6×10^{-11} weber (3) 3.3×10^{-11} weber (4) 6.6×10^{-9} weber

8. 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, 4/120]**
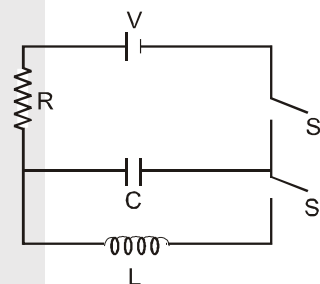
(1) Work done by the battery is half of the energy dissipated in the resistor

(2) At t = τ, q = CV/2

(3) At t = 2τ, q = CV $(1 − e^{-2})$

(4) At t = τ/2, q = CV $(1 − e^{-1})$

9. 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 :

[JEE (Main) 2014, 4/120, −1]
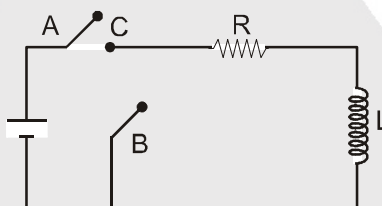
(1) $\dfrac{e}{1-e}$ (2) 1 (3) −1 (4) $\dfrac{1-e}{e}$

10. An inductor (L = 0.03H) 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 = 1ms, the current in the circuit will be : ($e^5 \cong 150$)

[JEE(Main) 2015; 4/120, −1]
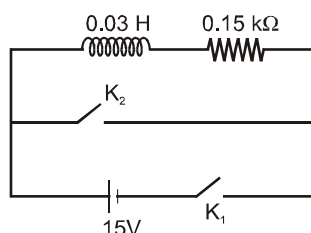
(1) 100 mA (2) 67 mA (3) 6.7 mA (4) 0.67 mA

Resonance®
Educating for better tomorrow

Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | E-mail : contact@resonance.ac.in
Toll Free : 1800 258 5555 | CIN : U80302RJ2007PLC024029

ADVEI - 58

11. 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 : **[JEE(Main) 2015; 4/120, −1]**
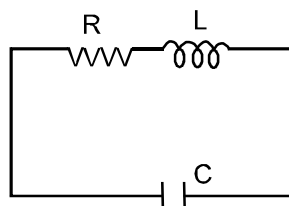
If a student plots graphs of the square of maximum charge (Q^2_{Max}) on the capacitor with time (t) for two different values L_1 and $L_2(L_1> L_2)$ of L then which of the following represents this graph correctly ? (plots are schematic and not drawn to scale)

(1)

(2)

(3)

(4)
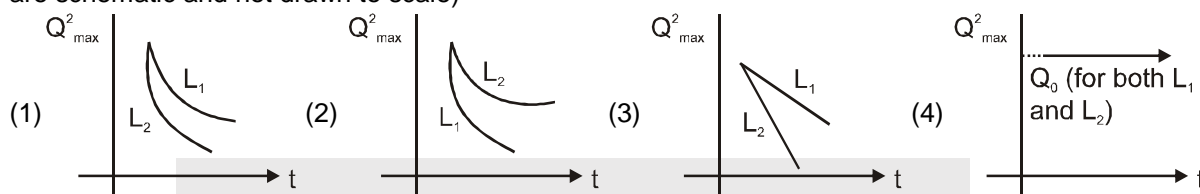
12. In a coil resistance 100Ω, a current is induced by changing the magnetic flux through it as shown in the figure. The magnitude of change in flux through the coil is : **[JEE (Main) 2017, 4/120, −1]**
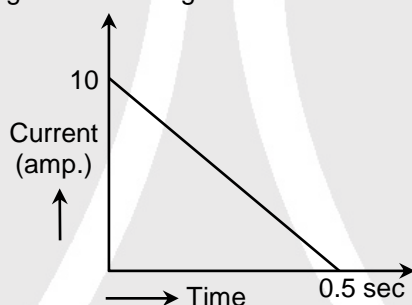
(1) 275 Wb   (2) 200 Wb   (3) 225 Wb   (4) 250 Wb

13. A very long solenoid of radius R is carrying current $I(t) = kte^{-\alpha t}$ (k > 0), as a function of time (t ≥ 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, as a function of time by : **[JEE (Main) 2019 April, 4/120, −1]**

(1)

(2)

(3)

(4)

Resonance®
Educating for better tomorrow

Reg. & Corp. Office : CG Tower, A-46 & 52, IPIA, Near City Mall, Jhalawar Road, Kota (Raj.) – 324005
Website : www.resonance.ac.in | **E-mail :** contact@resonance.ac.in
Toll Free : 1800 258 5555 | **CIN :** U80302RJ2007PLC024029

ADVEI - 59
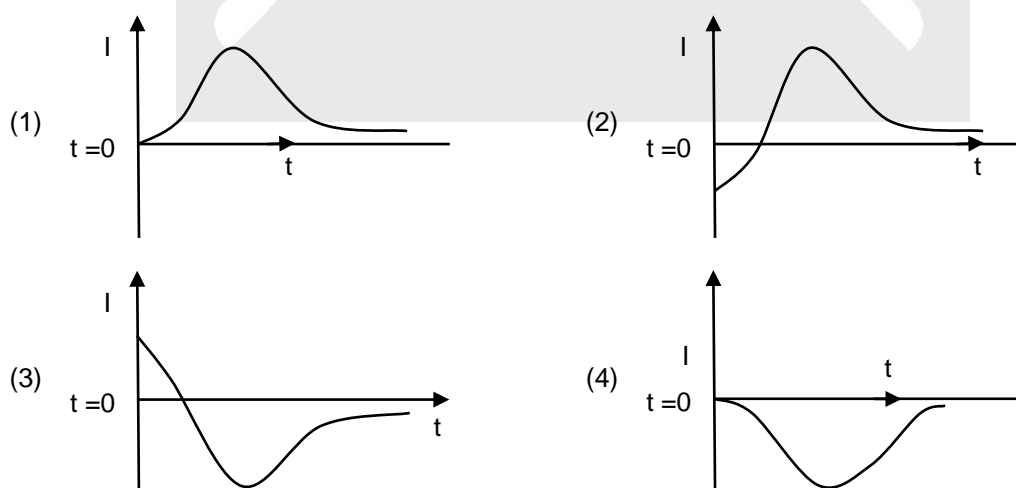
14. The figure shows a square loop L of side 5 cm which is connected to a network of resistance. The whole setup is moving towards right with a constant speed of 1 cm s^{-1}. At some instant, a part of L is in a uniform magnetic field of 1 T, perpendicular to the plane of the loop. If the resistance of L is 1.7 Ω, the current in the loop at that instant will be close to : **[JEE (Main) 2019 April, 4/120, –1]**
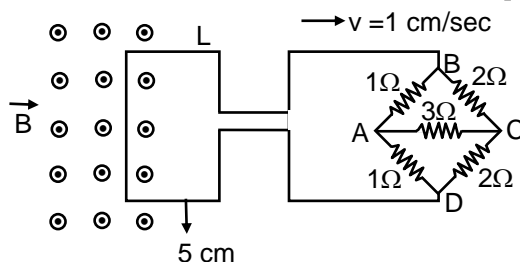
(1) 170 μA   (2) 150μA   (3) 115μA   (4) 60μA

15. 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 $\leq$ t $\leq$ 1, the induced current (I$_R$) and the induced EMF(V$_R$) in the ring change as : **[JEE (Main) 2020, 07 January; 4/100, –1]**
(1) Direction of I$_R$ remains unchanged and V$_R$ is zero at t = 0.25
(2) At t = 0.5 direction of I$_R$ reverses and V$_R$ is zero
(3) At t = 0.25 direction of I$_R$ reverses and V$_R$ is maximum
(4) Direction of I$_R$ remains unchanged and V$_R$ is maximum at t = 0.5

16. 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 $\vec{B} = \left(3\hat{i} + 4\hat{k}\right)T$. The quantity of flux through the loop ABCDEFA (in Wb) is ……. . **[JEE (Main) 2020, 07 January; 4/100]**

17. 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 : **[JEE (Main) 2020, 07 January; 4/100, –1]**
(1) 5.0 s and 7.5 s   (2) 5.0 s and 10.0 s   (3) 2.5 s and 7.5 s   (4) 2.5 s and 5.0 s

18. 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 = ∞ and at t = 40 s is close to : (Take e^2 = 7.389) **[JEE (Main) 2020, 07 January; 4/100, –1]**
(1) 1.46   (2) 1.06   (3) 0.84   (4) 1.15
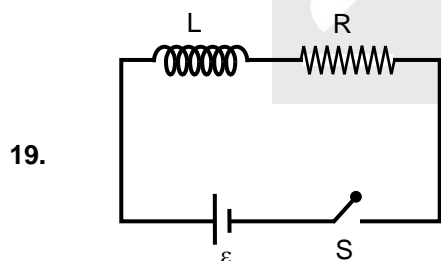
19.

As shown in the figure, a battery of emf ε 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 : **[JEE (Main) 2020, 08 January; 4/100, –1]**

(1) $\dfrac{\varepsilon L}{R^2}\left(1 - \dfrac{1}{e}\right)$ (2) $\dfrac{\varepsilon R}{eL^2}$ (3) $\dfrac{\varepsilon L}{R^2}$ (4) $\dfrac{\varepsilon L}{eR^2}$

Answers

EXERCISE # 1
PART - I

Section (A)

A-2. 1.0 V, anticlockwise.

A-3. (i) 1.2 Volt (ii) 1.4 volt (iii) 17.5 C (iv) 3.5 A
(v) 86/3 joule.

A-4. (a) –1 mV, –2 mV, 2 mV, 1mV
(b) 10 ms to 20 ms and 20 ms to 30 ms.

A-5. zero

A-6. 2.5 mV

A-7. 1.6×10^{-5} A

A-8. 493 μV

A-9.

(a)　(b)　(c)　(d)
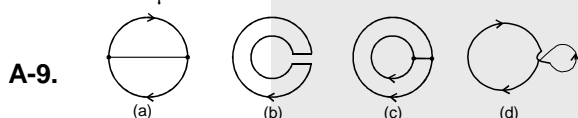
A-10. $\dfrac{\pi}{8} \times 10^{-4}$ A

A-11. $\dfrac{3}{2} \dfrac{\mu_0 \pi R^2 r^2 NI y v}{\left(R^2 + y^2\right)^{5/2}}$

A-12. $25\pi \times 10^{-3}$ C = 0.078 C

A-13.
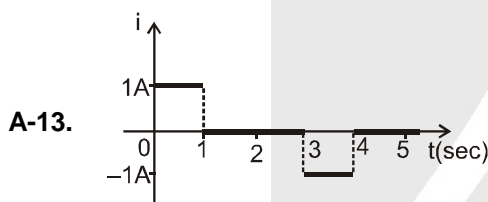
A-14. 2 J

Section (B)

B-1. Opposite direction, Same direction.

Section (C)

C-1. 4 mV, Q

C-2. (a) zero　(b) vB (bc), positive at b
(c) vB(bc), positive at a　(d) zero

C-3. $\sqrt{3} \times 10^{-2}$ V

C-4 1 mV

C-5. (a) at the ends of the diameter perpendicular to the velocity, 2rvB (b) at the ends of the diameter parallel to the velocity, zero.

C-6. By $\sqrt{8a/k}$

Section (D)

D-1. (a) 4 m/s (b) 4 V (c) 3 V (d) 1 V.

D-2. (a) 0.1 mA　(b) 0.2 mA

D-3. (a) 1/r (ε – vBℓ), from b to a

(b) $\dfrac{\ell B}{r}$ (ε – vBℓ) towards right (c) $\dfrac{\varepsilon}{B\ell}$.

D-4. zero　　**D-5.** i = $\dfrac{Bv\ell}{2(\ell + vt)r}$

D-6. (a) $\dfrac{B^2\ell^2 v}{2 \ \ r(\ell + vt)}$ (b) ℓ/v.

D-7. $\dfrac{mgt}{m + CB^2\ell^2}$

Section (E)

E-1. (a) $\phi = \dfrac{\mu_0 ia}{2\pi} \ell n\left(\dfrac{a+b}{b}\right)$;

(b) $\varepsilon = \dfrac{\mu_0 i_0 a}{T} \ell n\left(\dfrac{a+b}{b}\right) \sin\left(\dfrac{2\pi t}{T}\right)$

(c) heat = $\left(\dfrac{5\mu_0^2 \ i_0^2 \ a^2}{Tr}\right)\left[\ell n\left(\dfrac{a+b}{b}\right)\right]^2$

E-2. $\dfrac{B_0 v_0 L}{2}$

E-3. (BV sin α) / r(1 + sin α)

Section (F)

F-1. 67.5 mV　　**F-2.** $\dfrac{B\omega a^2}{R}$ from C to D

F-3. $3\pi \times 10^{-6}$ V　　**F-4.** $B\ell \sqrt{g\ell} \sin \dfrac{\theta}{2}$

F-5. (a) 2BRv (b) $\dfrac{BRv}{2}$ (c) $\dfrac{3 \ BRv}{2}$

F-6. (a) 2.0×10^{-3} V (b) zero
(c) 50 μC　(d) $\pi \times 10^{-3}$ sin (10πt)
(e) π mV　(f) $\dfrac{\pi^2}{2} \times 10^{-6}$ V

Section (G)

G-1. **(a)** 6π Volt **(b)** 3 N/C **(c)** 3 A

G-2 (a) $16\pi^2 \times 10^{-10}$ = 1.6×10^{-8} Weber
(b) $4\pi \times 10^{-8}$ V/m (c) $18\pi \times 10^{-8}$
= 5.6×10^{-7} V/m

Section (H)

H-1. 10V

H-2. 2.2 A/s, decreasing

H-3. (a) 5 W (b) 3W (c) 2 W

H-4. 2.55×10^{-14} J

H-5. $\dfrac{\mu_0 \ e^4}{128\pi^3 \varepsilon_0 mR^5}$

H-6. 42 + 20 t volt

H-7. 15V

Section (I)

I -1. (a) $\dfrac{1}{5}(1-e^{-2}) \simeq 0.17$ A

(b) $\dfrac{1}{25}(1-e^{-2})^2 \ 0.03$ J

I–2. (L/R) ln 2 = 1.109 s, 640 J

I-3. t = (L/R) $\ell n \, 2$ = 3.47 s   **I-4.**   4.0 H

I-5. $2[1 - e^{-0.4}]$ = 0.66 V   **I-6.** $\dfrac{2}{e}$ A/s, 2/e

I-7. (a) -2.5×10^3 V/s   (b) $-2.5 \times 10^3 \times e^{-5}$ V/s

I–8. (a) $\dfrac{\varepsilon(R_1 + R_2)}{R_1 R_2}$ (b) $\dfrac{L}{R_1 + R_2}$ (c) $\dfrac{\varepsilon}{R_1 e}$

I–9. $\dfrac{2 B \pi R^2}{L}$

I-10. (a) $i_1 = i_2 = \dfrac{10}{3} = 3.33$ A

(b) $i_1 = \dfrac{50}{11} = 4.55$ A; $i_2 = \dfrac{30}{11} = 2.73$ A

(c) $i_1 = 0$, $i_2 = -\dfrac{20}{11} = -1.82$ A

(d) $i_1 = i_2 = 0$

I -11. $\dfrac{\varepsilon}{3} , \dfrac{2 \varepsilon}{3 L}$ **I -12.** $L_{eq} = \dfrac{L}{2}$

I-13. (b) Separation is large to neglect mutual inductance

Section (J)

J-1. 0.01 H   **J-2.** 2.5 V

J-3. $\dfrac{2\sqrt{2}\mu_0 \ell^2}{\pi L}$

Section (K)

K-1. (a) 1.0 J. Yes, sum of the energies stored in L and C is conserved if R = 0.

(b) $\omega = 10^3$ rads^{-1}, ν = 159 Hz

(c) $q = q_0 \cos \omega t$

(i) Energy stored is completely electrical at

$t = 0, \dfrac{T}{2}, T, \dfrac{3T}{2}, ...$

(ii) Energy stored is completely magnetic (i.e., electrical energy is zero) at

$t = \dfrac{T}{4}, \dfrac{3T}{4}, \dfrac{5T}{4} ......$, where $T = \dfrac{1}{\nu} = 6.3$ms

(d) At $t = \dfrac{T}{8}, \dfrac{3T}{8}, \dfrac{5T}{8}, ...$, because q = q$_0$

$\cos \omega t = \dfrac{q_0}{\sqrt{2}}$ (when energy shared equally between the inductor and the capacitor).

K-2. $\dfrac{\pi \times 10^{-5}}{3}$ sec.   **K-3.** 88 pF to 198 pF

PART - II

Section (A)

A-1.	(D)	**A-2.**	(D)	**A-3.**	(C)
A-4.	(C)	**A-5.**	(A)		

Section (B)

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

Section (C)

C-1.	(D)	**C-2.**	(B)	**C-3.**	(B)
C-4.	(B)	**C-5.**	(D)		

Section (D)

D-1.	(D)	**D-2.**	(A)	**D-3.**	(D)
D-4.	(B)				

Section (E)

E-1.	(C)	**E-2.**	(D)

Section (F)

F-1.	(D)	**F-2.**	(C)	**F-3.**	(B)
F-4.	(A)	**F-5.**	(C)		

Section (G)

G-1.	(A)	**G-2.**	(B)	**G-3.**	(A)
G-4.	(C)	**G-5.**	(B)		

Section (H)

H-1.	(A)	**H-2.**	(D)

Section (I)

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

Section (J)

J-1.	(D)	**J-2.**	(A)	**J-3.**	(A)
J-4.	(D)				

Section (K)

K-1.	(B)	**K-2.**	(C)	**K-3.**	(A)

PART - III

1. (A) q (B) p (C) t (D) t
2. (A) q,s (B) p,r (C) p,r (D) q,s

EXERCISE # 2

PART - I

1.	(D)	**2.**	(B)	**3.**	(C)
4.	(A)	**5.**	(B)	**6.**	(B)
7.	(C)	**8.**	(A)	**9.**	(C)
10.	(C)	**11.**	(B)	**12.**	(B)
13.	(A)	**14.**	(A)	**15.**	(A)
16.	(D)	**17.**	(D)		

PART - II

1.	03.00	**2.**	90.00	**3.**	40.00
4.	25.00	**5.**	03.00	**6.**	12.00
7.	04.00	**8.**	03.00	**9.**	12.00
10.	67.00	**11.**	03.00	**12.**	04.00
13.	12.00	**14.**	64.00	**15.**	03.00
16.	89.00				

PART - III

1.	(CD)	**2.**	(A)	**3.**	(CD)
4.	(ABCD)	**5.**	(ABCD)	**6.**	(AC)
7.	(ABC)	**8.**	(AC)	**9.**	(BC)
10.	(ACD)				

PART - IV

1.	(A)	**2.**	(B)	**3.**	(C)
4.	(C)	**5.**	(A)	**6.**	(C)

EXERCISE # 3

PART - I

1.	(A)	**2.**	(B)	**3.**	6
4.	(C)	**5.**	7	**6.**	(AC)
7.	(B)	**8.**	(B)	**9.**	(AD)
10.	(8)	**11.**	(CD)	**12.**	(BC)
13.	(ACD)	**14.**	(BD)	**15.**	(ABD)
16.	0.63				

PART - II

1.	(2)	**2.**	(2)	**3.**	(4)
4.	(1)	**5.**	(4)	**6.**	(4)
7.	(1)	**8.**	(3)	**9.**	(3)
10.	(4)	**11.**	(1)	**12.**	(4)
13.	(2)	**14.**	(1)	**15.**	(2)
16.	175	**17.**	(4)	**18.**	(2)
19.	(4)				