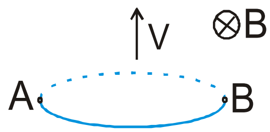
SOLVED EXAMPLES

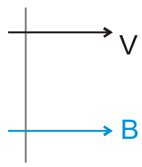
Ex. 1 A circular coil of radius R is moving in a magnetic field **B** with a velocity **v** as shown in the figure.

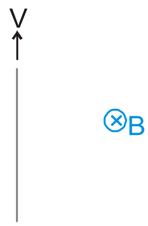


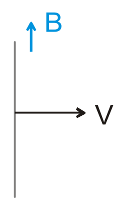
Find the emf across the diametrically opposite points A and B.

Sol. emf $= BVl_{effective} = 2RvB$

Ex. 2 Find the emf induced in the rod in the following cases. The figures are self explanatory.

(a)


(b)


(c)


Sol. **(a)** here $\vec{v} \parallel \vec{B}$ So $\vec{v} \times \vec{B} = 0$

emf $= \vec{\ell} \cdot (\vec{v} \times \vec{B}) = 0$

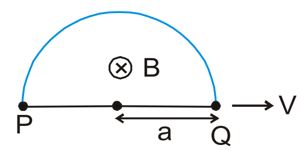
(b) here $\vec{v} \parallel \vec{\ell}$

So emf $= \vec{\ell} \cdot (\vec{v} \times \vec{B}) = 0$

(c) here $\vec{B} \parallel \vec{\ell}$

So emf $= \vec{\ell} \cdot (\vec{v} \times \vec{B}) = 0$

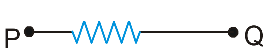
Ex. 3 Find the emf across the points P and Q which are diametrically opposite points of a semicircular closed loop moving in a magnetic field as shown. Also draw the electrical equivalent circuit of each branch.

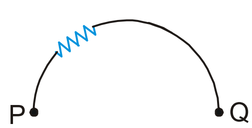


Sol. here $\vec{v} \parallel \vec{\ell}$

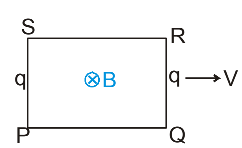
So emf $= \vec{\ell} \cdot (\vec{v} \times \vec{B}) = 0$

Induced emf = 0

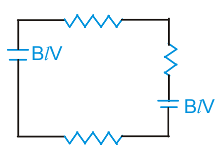




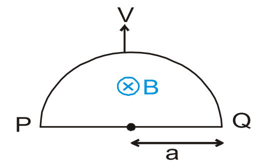
Ex. 4 Figure shows a rectangular loop moving in a uniform magnetic field. Show the electrical equivalence of each branch.



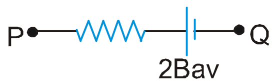
Sol.

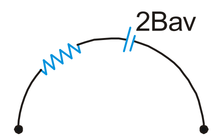


Ex. 5 Find the emf across the points P and Q which are diametrically opposite points of a semicircular closed loop moving in a magnetic field as shown. Also draw the electrical equivalence of each branch.

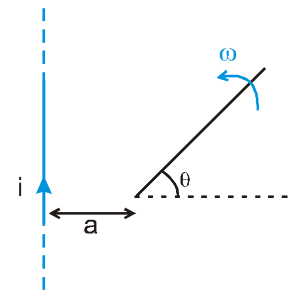


Sol. Induced emf = 2Bav





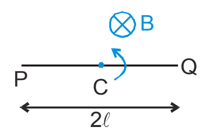
Ex. 6 A rod of length l is rotating with an angular speed ω about its one end which is at a distance 'a' from an infinitely long wire carrying current i. Find the emf induced in the rod at the instant shown in the figure.



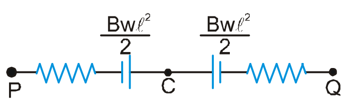
Sol. $E = \int \frac{\mu_0 i}{2\pi(a + r\cos\theta)} \times (r\omega) . (dr)$ $\Rightarrow$ $E = \frac{\mu_0 \omega i}{2\pi} \int_0^{\ell} \frac{r}{a + r\cos\theta} dr$

$$E = \frac{\mu_0 i\omega}{2\pi\cos\theta}\left[\ell - \frac{a}{\cos\theta}\ell n\left(\frac{a + \ell\cos\theta}{a}\right)\right]$$

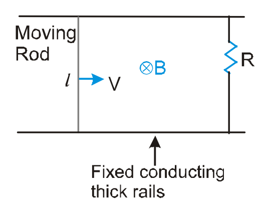
Ex. 7 A rod PQ of length 2ℓ is rotating about its mid point C, in a uniform magnetic field B which is perpendicular to the plane of rotation of the rod. Find the induced emf between P Q and PC. Draw the circuit diagram of parts PC and CQ.



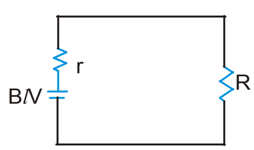
Sol. $emf_{PQ} = 0$; $emf_{PC} = \frac{B\omega\ell^2}{2}$



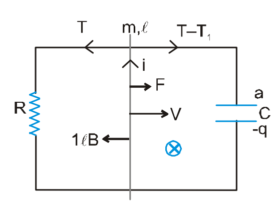
Ex. 8 Figure shows a rod of length ℓ and resistance r moving on two rails shorted by a resistance R.A uniform magnetic field B is present normal to the plane of rod and rails .Show the electrical equivalence of each branch.



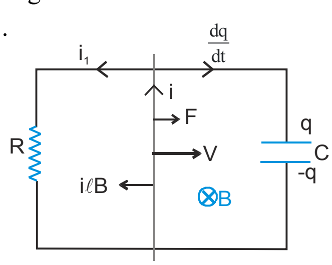
Sol.



Ex. 9 Find the velocity of the moving rod at time t if the initial velocity of the rod is v and a constant force F is applied on the rod. Neglect the resistance of the rod.



Sol. At any time t, let the velocity of the rod be v .



Applying Newtons law: $F - ilB = ma$ ... **(1)**

Also $B\ell v = i_1 R = \frac{q}{c}$

Applying Kcl,

$$i = i_1 + \frac{dq}{dt} = \frac{B\ell V}{R} + \frac{d}{dt}(B\ell vC) \quad \text{or} \quad i = \frac{B\ell V}{R} + B\ell C a$$

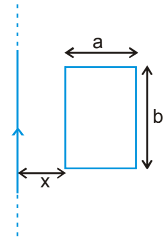
Putting the value of i in eq **(1)**, $F - \frac{B^2\ell^2 V}{R} = (m + B^2\ell^2 C)a = (m + B^2\ell^2 C)\frac{dv}{dt}$

$$(m + B^2\ell^2 C)\frac{dv}{F - \frac{B^2\ell^2 v}{R}} = dt$$

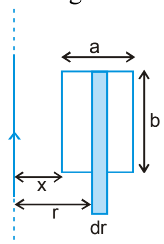
Integrating both sides, and solving we get

$$v = \frac{FR}{B^2\ell^2}\left(1 - e^{-\frac{tB^2\ell^2}{R(m+CB^2\ell^2)}}\right)$$

Ex. 10 Find the mutual inductance of a straight long wire and a rectangular loop, as shown in the figure



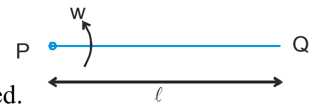
Sol.



$$d\phi = \frac{\mu_0 i}{2\pi r} \times bdr \quad \Rightarrow \quad \phi = \int_x^{x+a} \frac{\mu_0 i}{2\pi r} \times bdr$$

$$M = \phi/i \quad \Rightarrow \quad M = \frac{\mu_0 b}{2\pi}\ln\left(1 + \frac{a}{x}\right)$$

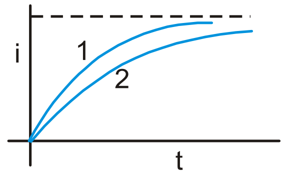
Ex. 11 A rod PQ of length ℓ is rotating about end P, with an angular velocity ω. Due to centrifugal forces the free electrons in the rod move towards the end Q and an emf is created. Find the induced emf.



Sol. The accumulation of free electrons will create an electric field which will finally balance the centrifugal forces and a steady state will be reached. In the steady state $m_e\omega^2 x = e\,E$.

$$V_P - V_Q = \int_{x=0}^{x=\ell} \bar{E}.d\bar{x} = \int_0^{\ell} \frac{m_e\omega^2 x}{e}dx = \frac{m_e\omega^2\ell^2}{2e}$$

Ex. 12 Which of the two curves shown has less time constant.



Sol. curve 1

Exercise # 1

[Single Correct Choice Type Questions]

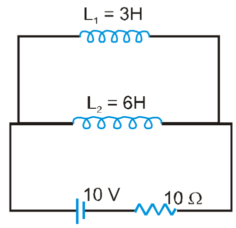
1. An inductor coil stores energy U when a current i is passed through it and dissipates heat energy at the rate of P. The time constant of the circuit when this coil is connected across a battery of zero internal resistance is :

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

2. 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 $\omega = 20$ 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

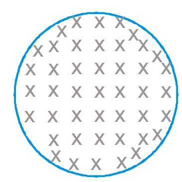
(A) $\frac{1}{4}$ A **(B)** $\frac{1}{2}$ A **(C)** $\frac{1}{3}$ A **(D)** zero

3. 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 mu tual inductance between L_1 and L_2):



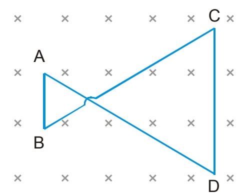
(A) $\frac{1}{10}$ **(B)** $\frac{1}{100}$ **(C)** $\frac{1}{1000}$ **(D)** 1

4. 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 :



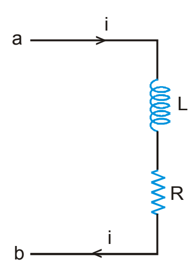
(A) $\frac{4qmR}{g}$ **(B)** $\frac{2qmR}{g}$ **(C)** $\frac{8qR}{mg}$ **(D)** $\frac{qR}{2mg}$

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



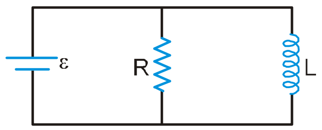
(A) B to A and D to C **(B)** A to B and C to D
(C) A to B and D to C **(D)** B to A and C to D

6. 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 :



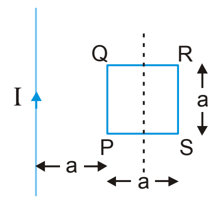
(A) 3 ohm and 2 Henry respectively **(B)** 2 ohm and 3 Henry respectively
(C) 10 ohm and 6 Henry respectively **(D)** 6 ohm and 1 Henry respectively

7. The battery shown in the figure is ideal. The values are $\varepsilon = 10$ V, $R = 5\Omega$, $L = 2H$. 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

8. In the figure shown a square loop PQRS of side 'a' and resistance 'r' is placed near an infinitely long wire carrying a constant current I. The sides PQ and RS are parallel to the wire. The wire and the loop are in the same plane. The loop is rotated by 180° about an axis parallel to the long wire and passing through the mid points of the side QR and PS. The total amount of charge which passes through any point of the loop during rotation is :



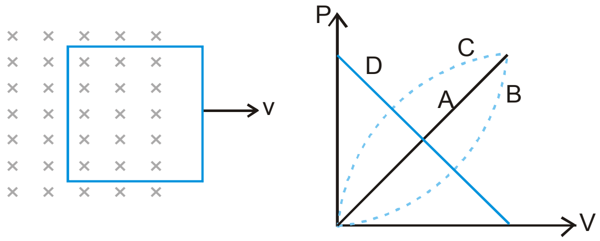
(A) $\frac{\mu_0 Ia}{2\pi r}\ \ell n2$

(B) $\frac{\mu_0 Ia}{\pi r}\ \ell n2$

(C) $\frac{\mu_0 Ia^2}{2\pi r}$

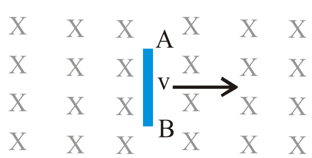
(D) cannot be found because time of rotation not give.

9. 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

10. A conducting rod AB moves with a uniform velocity v in a constant magnetic field as shown in fig.

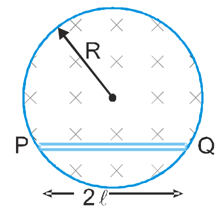


(A) The rod becomes hot because of Joule heating (B) The end A becomes positively charged
(C) The end B become positively charged (D) The rod becomes electrically charged

11. A conducting ring lies fixed on a horizontal plane. If a charged nonmagnetic particle is released from a point (on the axis) at some height from the plane, then :

(A) an induced current will flow in clockwise or anticlockwise direction in the loop depending upon the nature of the charge
(B) the acceleration of the particle will decrease as it comes down
(C) the rate of production of heat in the ring will increase as the particle comes down
(D) no heat will be produced in the ring.

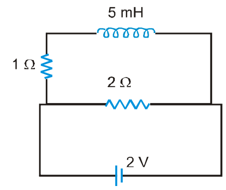
12. A uniform magnetic field, $B = B_0 t$ (where B_0 is a positive constant), fills a cylindrical volume of radius R, then the potential difference in the conducting rod PQ due to electrostatic field is :



(A) $B_0\ell\sqrt{R^2+\ell^2}$ (B) $B_0\ell\sqrt{R^2-\frac{\ell^2}{4}}$

(C) $B_0\ell\sqrt{R^2-\ell^2}$ (D) $B_0R\sqrt{R^2-\ell^2}$]

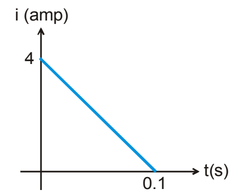
13. When induced emf in inductor coil is 50% of its maximum value then stored energy in inductor coil in the given circuit will be : -



(A) 2.5 mJ (B) 5mJ

(C) 15 mJ (D) 20 mJ

14. 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

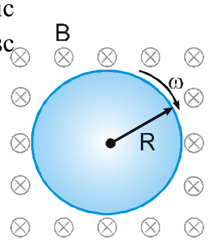
(C) 6 (D) 8

15. 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

16. 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)



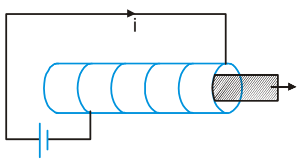
(A) $\frac{eB}{2m}$ (B) $\frac{eB}{m}$

(C) $\frac{2\pi m}{eB}$ (D) $\frac{\pi m}{eB}$

17. A closed circuit consists of a resistor R, inductor of inductance L and a source of emf E are connected in series. If the inductance of the coil is abruptly decreased to L/4 (by removing its magnetic core), the new current immediately after this moment is : (before decreasing the inductance the circuit is in steady state)

(A) zero (B) E/R (C) $4\frac{E}{R}$ (D) $\frac{E}{4R}$

18. 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

19. When the current in a certain inductor coil is 5.0 A and is increasing at the rate of 10.0 A/s, the magnitude 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 :

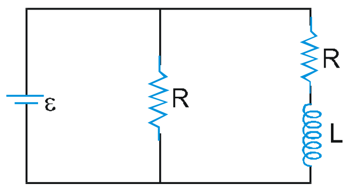
(A) 2H **(B)** 4H **(C)** 10H **(D)** 12H

20. The SI unit of inductance, the Henry, can be written as:

(A) Weber/ampere **(B)** Volt – second/ampere

(C) Joule/(ampere)^2 **(D)** Ohm – second

21. In the circuit diagram shown



(A) time constant is L/R **(B)** time constant is 2L/R

(C) steady state current in inductor is 2ε/R **(D)** steady state current in inductor is ε/R

22. 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.

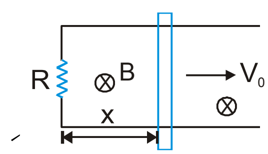
(C) The emf will be maximum at the moment when plane of the loop is parallel to the magnetic field

(D) The phase difference between the flux and the emf is π/2

23. 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)** ε = 0 **(D)** ε ≠ 0

24. 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.

25. 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

26. 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

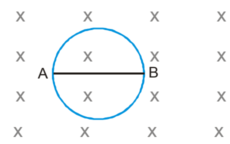
(A) it is rotated about its axis
(B) it is translated
(C) it is rotated about a diameter
(D) it is deformed

27. 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

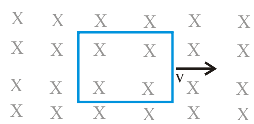
Exercise # 2 Part # I [Multiple Correct Choice Type Questions]

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)



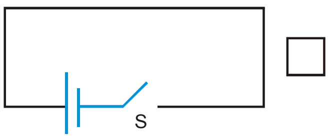
(A) $\frac{R\alpha}{2\rho}$ from A to B **(B)** $\frac{R\alpha}{2\rho}$ from B to A **(C)** $\frac{2R\alpha}{\rho}$ from A to B **(D)** Zero

2. A square frame of wire of side l and resistance R moves in its plane with a uniform velocity v perpendicular to one of its sides. A uniform and constant magnetic field B exists along the perpendicular to the plane of the loop in fig. The current induced in the 3loop is -



(A) $2Bl\upsilon/R$ anticlockwise **(B)** $Bl\upsilon/R$ anticlockwise **(C)** $Bl\upsilon/R$ clockise **(D)** zero

3. 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

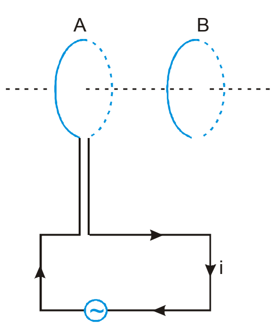


(A) a clockwise current-pulse
(B) an anticlockwise current-pulse
(C) an anticlockwise current-pulse and then a clockwise current-pulse
(D) a clockwise current-pulse and then an anticlockwise current-pulse

4. 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

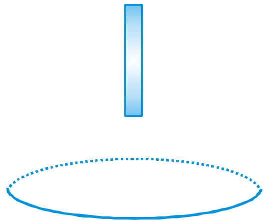
5. A small, circular loop of wire is placed inside a long solenoid carrying a current. The plane of the loop contains the axis of the solenoid. If the current in the solenoid is varied, the current induced in the loop is
(A) anticlockwise **(B)** clockwise **(C)** zero
(D) clockwise or anticlockwise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

6. Two circular coils A and B are facing each other as shown in figure. The current i through A can be altered



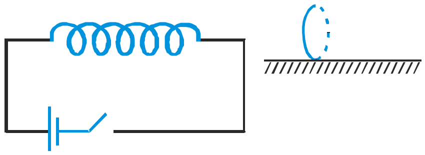
(A) there will be repulsion between A and B if i is increased
(B) there will be attraction between A and B if i is increased
(C) there will be neither attraction nor repulsion when i is changed
(D) attraction or repulsion between A and B depends on the direction of current.
It does not depend whether the current is increased or decreased.

7. 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 ?



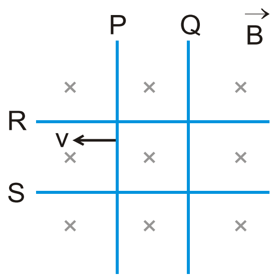
(A) The north pole faces the ring and the magnet moves away from it.
(B) The north pole faces the ring and the magnet moves towards it
(C) The south pole faces the ring and the magnet moves away from it.
(D) The south pole faces the ring and the magnet moves towards it

8. 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



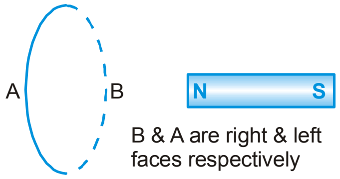
(A) move towards the solenoid
(B) remain stationary
(C) move away from the solenoid
(D) move towards the solenoid or away from it depending on which terminal (positive or negative) of the battery is connected to the left end of the solenoid.

9. 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

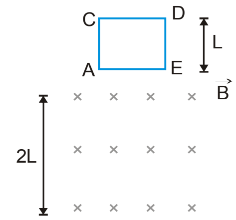
10. In the figure shown, the magnet is pushed towards the fixed ring along the axis of the ring and it passes through the ring.



(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 northpole 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.

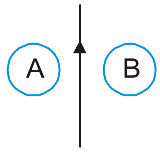
11. Two identical coaxial circular loops carry a current i each circulating in the same direction. If the loops approach each other
(A) the current in each loop will decrease
(B) the current in each loop will increase
(C) the current in each loop will remain the same
(D) the current in one loop will increase and in the other loop will decrease

12. 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

13. 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 :



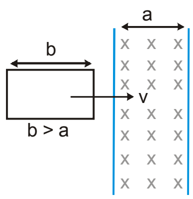
(A) clockwise in A and anticlockwise in B **(B)** anticlockwise in A and clockwise in B
(C) clockwise in both A and B **(D)** anticlockwise in both A & B

14. 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

15. 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

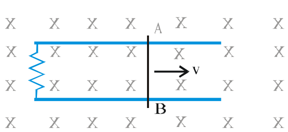
16. A neutral metallic ring is placed in a circular symmetrical uniform magnetic field with its plane perpendicular to the field. If the magnitude of field starts increasing with time, then:
(A) the ring starts translating **(B)** the ring starts rotating about its axis
(C) the ring slightly contracts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

17. 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) $\frac{2b}{v}$ **(B)** $\frac{2a}{v}$
(C) $\frac{(a+b)}{v}$ **(D)** $\frac{2(a-b)}{v}$

18. 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 semi circular wire, the magnitude of the induced current will

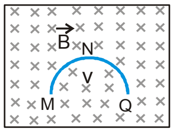


(A) decrease
(B) remain the same
(C) increase
(D) increase or decrease depending on whether the semicircle bulges towards the resistance or away from it.

19. 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

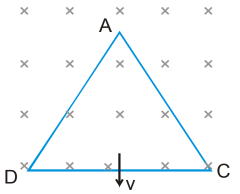
20. A thin semicircular conducting ring of radius R is falling with its plane vertical in a horizontal magnetic induction $\vec{B}$. At the position MNQ the speed of the ring is v then the potential difference developed across the ring is:

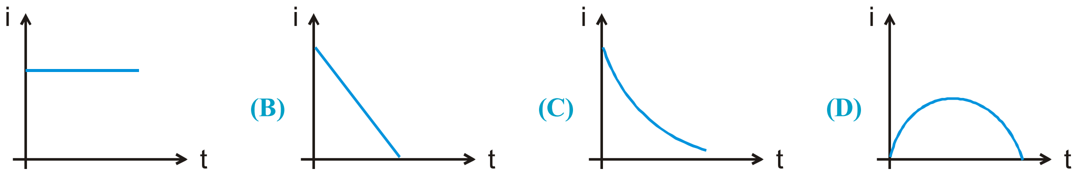


(A) zero **(B)** $\frac{Bv\pi R^2}{2}$ and M is at higher potential

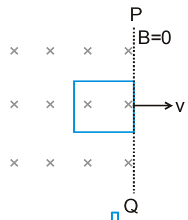
(C) π RBV and Q is at higher potential **(D)** 2 RBV and Q is at higher potential.

21. An equilateral triangular loop ADC having some resistance is pulled with a constant velocity v out of a uniform magnetic field directed into the paper. At time t = 0, side DC of the loop is at edge of the magnetic field. The induced current (i) versus time (T) graph will be as



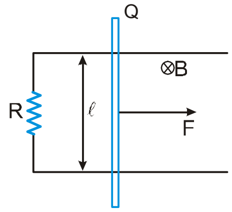


22. Figure shows a square loop of side 1 m and resistance 1 Ω. The magnetic field on left side of line PQ has a magnitude B = 1.0T. The work done in pulling the loop out of the field uniformly in 1 s is



(A) 1 J **(B)** 10 J
(C) 0.1 J **(D)** 100 J

23. 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.



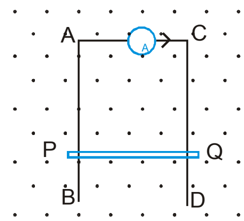
(A) the power delivered by force will be constant with time
(B) the power delivered by force will be increasing first and then it will decrease
(C) the rate of power delivered by the external force will be increasing continuously
(D) the rate of power delivered by external force will be decreasing continuously before becoming zero.

24. For the situation shown in the figure, flux through the square loop is :

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

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

25. 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,



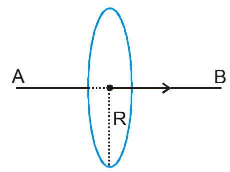
(A) The rod PQ may move downward with constant acceleration

(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

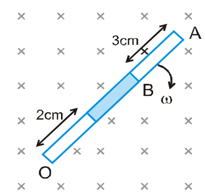
(D) either A or B.

26. 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/sec ond, then the induced emf in the loop is



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

27. 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

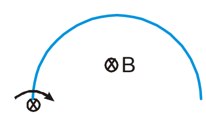


(A) 0.029 v **(B)** 0.1 v **(C)** 0.051 v **(D)** 0.064 v

28. 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

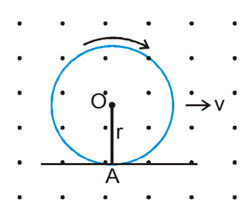
(A) $2B\omega \ell^2$ **(B)** $\frac{1}{2}\omega B \ell^2$ **(C)** $B\omega \ell^2$ **(D)** zero

29. 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) $B\omega R^2/2$ **(B)** $2B\omega R^2$ **(C)** is variable **(D)** none of these

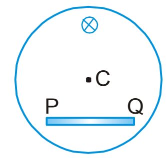
30. A conducting ring of radius r with a conducting spoke is in pure rolling on a horizontal surface in a region having a uniform magnetic field B as shown, v being the velocity of the centre of the ring. Then the potential difference $V_0 - V_A$ is



(A) $\frac{Bvr}{2}$ **(B)** $\frac{3Bvr}{2}$

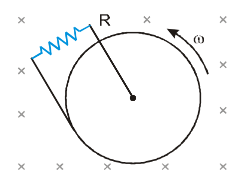
(C) $\frac{-Bvr}{2}$ **(D)** $\frac{3Bvr}{2}$

31. 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



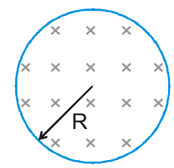
(A) P will be at higher potential than Q.
(B) Q will be at higher potential than P.
(C) Both P and Q will be equipotential.
(D) no emf will be developed across rod as it is not crossing / cutting any line of force.

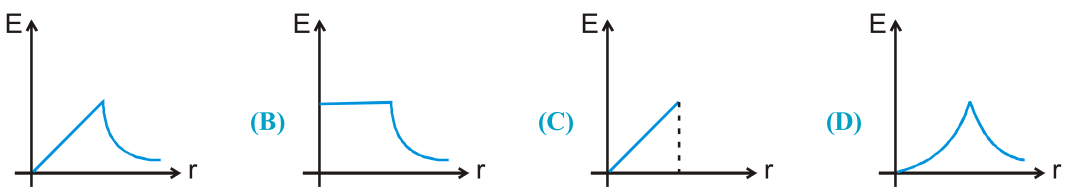
32. Figure shows a conducting disc rotating about its axis in a perpendicular uniform and constnat magnetic field B. A resistor of resistance R is connected between the centre and the rim. The radius of the disc is 5.0 cm, angular speed $\omega = 40$ rad/s, B = 0.10 T and R = 1 Ω.
The current through the resistor is



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

33. 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



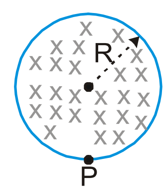


34. Two different coils have self-inductance $L_1 = 8$ mH, $L_2 = 2$ mH. The current in one coil is increased at a constant rate. The current in the second coil is also increased at the same rate. At a certain instant of time, the power given to the two coils is the same. At that time the current, the 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 **[JEE - 94]**

(A) $\frac{i_1}{i_2} = \frac{1}{4}$ (B) $\frac{i_1}{i_2} = 4$

(C) $\frac{W_2}{W_1} = 4$ (D) $\frac{V_2}{V_1} = \frac{1}{4}$

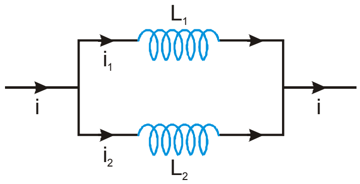
35. A uniform magnetic field of induction B is confined to a cylindrical region of radius R. The magnetic field is increasing at a constant rate of $\frac{dB}{dt}$ (Tesla/second). An electron of charge q, placed at the point P on the periphery of the field experiences an acceleration :



(A) $\frac{1}{2}\frac{eR}{m}\frac{dB}{dt}$ toward left (B) $\frac{1}{2}\frac{eR}{m}\frac{dB}{dt}$ toward right

(C) $\frac{eR}{m}\frac{dB}{dt}$ toward left (D) zero

36. 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



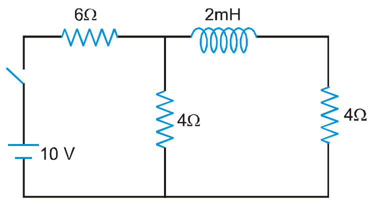
(A) L_1/L_2 **(B)** L_2/L_1

(C) $\frac{L_1^2}{(L_1+L_2)^2}$ **(D)** $\frac{L_2^2}{(L_1+L_2)^2}$

37. 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 same wire is wound on a solenoid of length $\frac{\ell}{2}$ and radius $\frac{r}{2}$, then the self inductance will be:

(A) 2 L **(B)** L **(C)** 4 L **(D)** 8 L

38. 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

39. 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) $\ln\left(\frac{10}{9}\right)$ **(B)** 2

(C) $\frac{2}{\ln\left(\frac{10}{9}\right)}$ **(D)** $2\ln\left(\frac{10}{9}\right)$

40. 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

41. 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

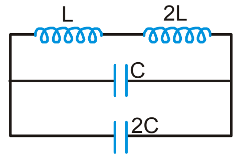
42. Two coils of self inductance 100 mH and 400 mH are placed very close to each other. Find the maximum mutual inductance between the two when 4 A current passes through them

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

43. 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

44. The frequency of oscillation of current in the inductor is:



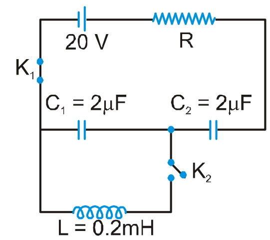
(A) $\frac{1}{3\sqrt{LC}}$ **(B)** $\frac{1}{6\pi\sqrt{LC}}$

(C) $\frac{1}{\sqrt{LC}}$ **(D)** $\frac{1}{2\pi\sqrt{LC}}$

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

(A) $\frac{\mu_0 R}{2}$ **(B)** $\frac{\mu_0 \pi R}{2}$ **(C)** $\frac{\mu_0}{2}$ **(D)** 0

46. 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 :

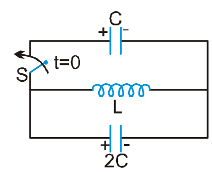


(A) 1 A **(B)** $\frac{1}{2}$ A

(C) 2 A **(D)** None of these

47. 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 2 Q/3 C L

(C) maximum energy in the inductor will be $3Q^2/2C$

(D) none of these

Part # II [Assertion & Reason Type Questions]

In each of the following questions, a Assertion of Statement -1 and Statement - 2 of Reason.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

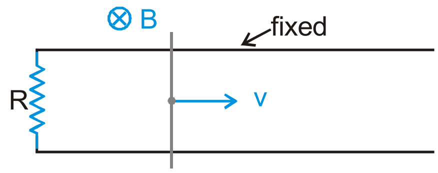
(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

1. **Statement-1 :** Two coaxial conducting rings of different radii are placed in space. The mutual inductance of both the rings is maximum if the rings are coplanar also.

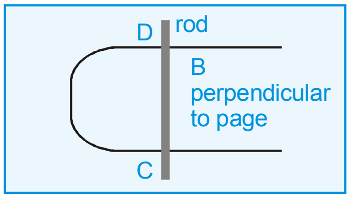
Statement-2 : For two coaxial conducting rings of different radii, the magnitude of magnetic flux in one ring due to current in other ring is maximum when both rings are coplanar.

2. **Statement-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. The total work done by magnetic field is negative.



Statement-2 : If force acts opposite to direction of velocity its work done is negative.

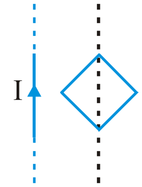
3. **Statement-1 :** Consider the arrangement shown below. A smooth conducting rod, CD, is lying on a smooth U-shaped conducting wire making good electrical contact with it. The U-shape conducting wire is fixed and lies in horizontal plane. There is a uniform and constant magnetic field B in vertical direction (perpendicular to plane of page in figure). If the magnetic field strength is decreased, the rod moves towards right.



Statement-2 : In the situation of statement-1, the direction in which the rod will slide is that which tends to maintain constant flux through the loop. Providing a larger loop area counteracts the decrease in magnetic flux. So the rod moves to the right independent of the fact that the direction of magnetic field is into the page or out of the page.

Exercise # 3 Part # I [Matrix Match Type Questions]

1. 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

(A) If the magnitude of current I is increased

(B) If the magnitude of current I is decreased

(C) If the loop is moved away from the wire

(D) If the loop is moved towards the wire

Column-II

(P) Current will induce in clockwise direction in the loop

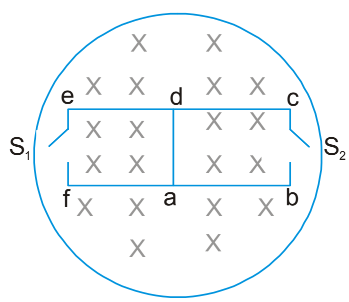
(Q) Current will induce in anticlockwise direction in the loop

(R) wire will attract the loop

(S) wire will repel the loop

(T) loop will rotate when current changes.

2. 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

(A) the switch S_1 is closed but S_2 is open

(B) S_1 is open but S_2 is closed

(C) both S_1 and S_2 are open

(D) both S_1 and S_2 are closed.

Column-II

(P) 5×10^{-7} A, d to a

(Q) 5×10^{-7} A, a to d

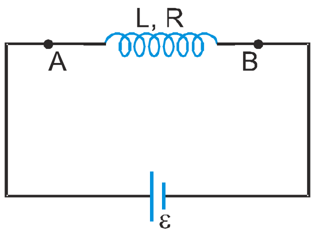
(R) 2.5×10^{-8} A, d to a

(S) 2.5×10^{-8} A, a to d

(T) No current flows

Part # II [Comprehension Type Questions]

Comprehension # 1



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 ($n > 1$).

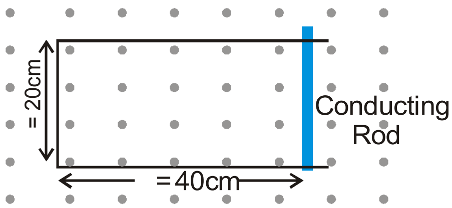
1. After insertion of rod which of the following quantities will change with time ?
(1) Potential difference across terminals A and B.
(2) Inductance.
(3) Rate of heat produced in coil
(A) only (1) **(B)** (1) & (3) **(C)** Only (3) **(D)** (1), (2) & (3)

2. 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

3. 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

Comprehension # 2

Figure shows a conducting rod of negligible resistance that can slide on smooth U-shaped rail made of wire of resistance 1Ω/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.



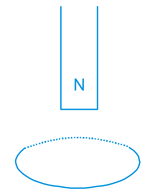
1. The current in the loop at t = 0 due to induced emf is
(A) 0.16 A, clockwise
(B) 0.08 A, clockwise
(C) 0.08 A, anticlockwise
(D) zero

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 to move the conducting rod at constant speed 5 cm/s at the same instant t = 2s, is equal to
(A) 0.16 N **(B)** 0.12 N **(C)** 0.08 N **(D)** 0.06 N

Exercise # 4 [Subjective Type Questions]

1. 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?

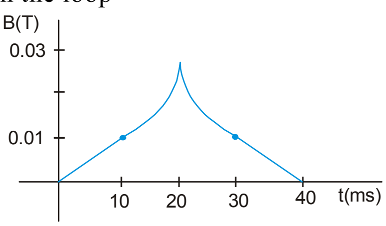


2. If flux in a coil changes by $\Delta\phi$, and the resistance of the coil is R , prove that the charge flown in the coil during the flux change is $\frac{\Delta\phi}{R}$. (Note : It is independent of the time taken for the change in flux)

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.

4. 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

5. **(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.

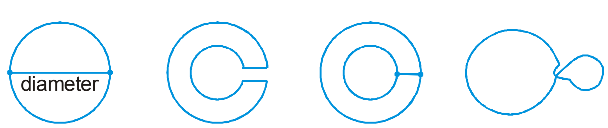


6. A heart pacing device consists of a coil of 50 turns & radius 1 mm just inside the body with a coil of 1000 turns & radius 2 cm placed concentrically and coaxially just outside the body. Calculate the average induced EMF in the internal coil, if a current of 1A in the external coil collapses in 10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

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.

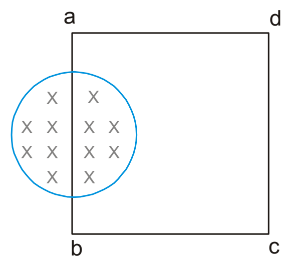
8. A metallic ring of area 25 cm^2 is placed perpendicular to a magnetic field of 0.2 T .It is removed from the field in 0.2 s. Find the average emf produced in the ring during this time .

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.

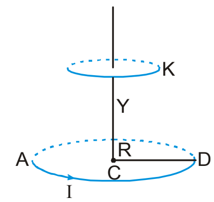


10. A closed circular loop of 200 turns of mean diameter 50 cm & having a total resistance of 10 Ω is placed with its plane at right angle to a magnetic field of strength 10^{-2} Tesla. Calculate the quantity of electric charge passed through it when the coil is turned through 180° about an axis in its plane.

11. A uniform magnetic field B exists in a cylindrical region or 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.

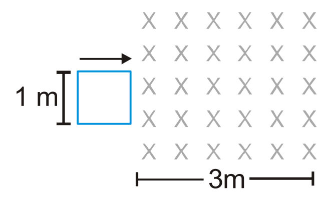


12. A coil ACD of N turns & radius R carries a current of I Amp & is placed on a horizontal table. K is a very small horizontal conducting ring of radius *r* placed at a distance Y_0 from the centre of the coil vertically above the coil ACD. Find an expression for the EMF established when the ring K is allowed to fall freely. Express the EMF in terms of instantaneous speed v & height Y.

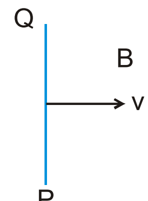


13. Find the total heat produced in the loop of the previous problem during the interval 0 to 5 s

14. 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)

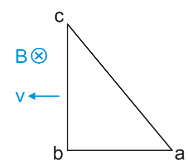


15. A metallic wire PQ of length 1 cm moves with a velocity of 2 m/s in a direction perpendicular to its length and perpendicular to a uniform magnetic field of magnitude 0.2 T. Find the emf induced between the ends of the wire. Which end will be positively charged.



16. 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.

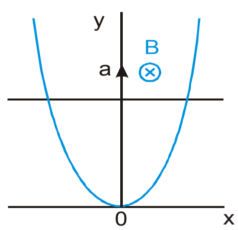
17. A right angled triangle abc, made of a metallic wire, moves at a uniform speed v in its plane as shown in the figure. A uniform magnetic field B exists in the perpendicular direction of plane of triangle. Find the emf induced **(a)** in the loop abc, **(b)** in the segment bc, **(c)** in the segment ac and **(d)** in the segment ab.



18. 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 30º .

19. A metallic metre stick translates in a direction making an angle of 60º 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.

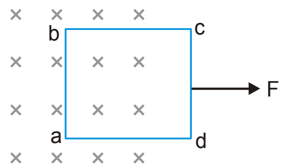
20. A wire bent as a parabola $y = kx^2$ is located in a uniform magnetic field of induction B, the vector B being perpendicular to the plane xy. At the moment t = 0 a connector starts sliding translation wise from the parabola apex with a constant acceleration a (figure). Find the emf of electromagnetic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



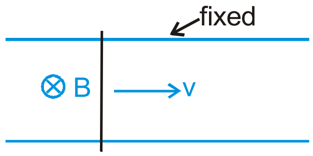
21. A circular conducting-ring of radius r translates in its plane with a constant velocity v. A uniform magnetic field B exists in the space in a direction perpendicular to the plane of the ring. Consider different pairs of diametrically opposite points on the ring. **(a)** Between which pair of points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

22. 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)

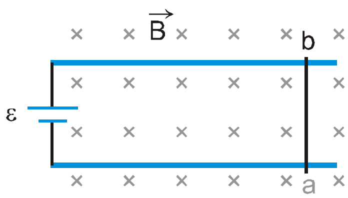
23. A square frame of wire abcd of side 1 m has a total resistance of 4 Ω. It is pulled out of a magnetic field B = 1 T by applying a force of 1 N (figure). It is found that the frame moves with constant speed. Find **(a)** this constant speed, **(b)** the emf induced in the loop, **(c)** the potential difference between the points a and b and **(d)** the potential difference between the points c and d.



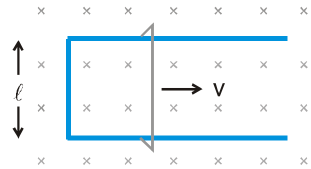
24. Figure shows a wire of resistance R sliding on two parallel, conducting fixed thick rails placed at a separation ℓ. A magnetic field B exists in a direction perpendicular to the plane of the rails. The wire is moving with a constant velocity v. Find current through the wire.



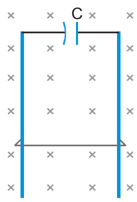
25. Figure shows a smooth pair of thick metallic rails connected across a battery of emf ε having a negligible internal resistance. A wire ab of length ℓ and resistance r can slide smoothly on the rails. The entire system lies in a horizontal plane and is immersed in a uniform vertical magnetic field 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.



26. 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.



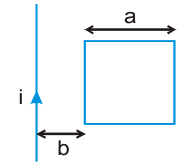
27. A wire of mass m and length ℓ can slide freely on a pair of fixed, smooth, vertical rails (figure). A magnetic field B exists in the region in the direction perpendicular to the plane of the rails. The rails are connected at the top end by an initially uncharged capacitor of capacitance C. Find the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



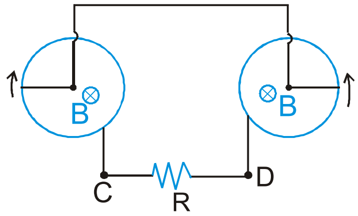
28. Consider the situation of the previous problem. **(a)** Calculate the force needed to keep the sliding wire moving with a constant velocity v. **(b)** If the force needed just after t = 0 is F_0, find the time at which the force needed will be $F_0/2$.

29. The magnetic field in a region is given by $\vec{B} = \frac{B_0}{L} x\hat{k}$, 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.

30. 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.



31. 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.



32. 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.

33. 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.

34. 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.

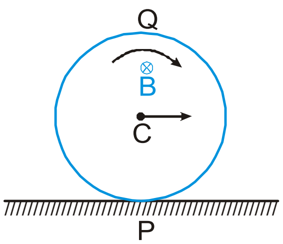
35. A bicycle is resting on its stand in the east-west direction and the rear wheel is rotated at an angular speed of 50 revolutions per minute. If the length of each spoke is 30.0 cm and the horizontal component of the earth's magnetic field is 4×10^{-5} T, find the emf induced between the axis and the outer end of a spoke. Neglect centripetal force acting on the free electrons of the spoke.

36. 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

37. 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

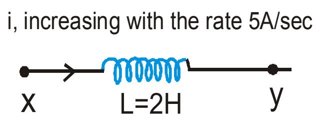
(C is centre, P&Q are opposite points on vertical diameter of the disc)



38. 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.

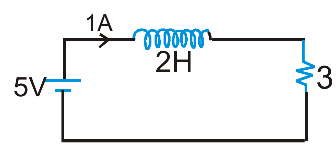
39. A circular loop of radius 1m is placed in a varying magnetic field given as B = 6t Tesla, where t is time in sec. **(a)** Find the emf induced in the coil if the plane of the coil is perpendicular to the magnetic field.

40. 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.

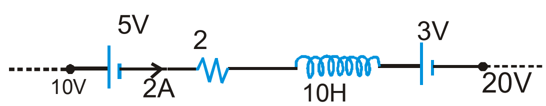


41. A uniform field of induction B is changing in magnitude at a constant rate dB/dt. You are given a mass *m* of copper which is to be drawn into a wire of radius *r* & formed into a circular loop of radius R. Show that the induced current in the loop does not depend on the size of the wire or of the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

42. 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.



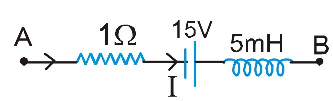
43. Figure shows a part of a circuit. Find the rate of change of the current, as shown.



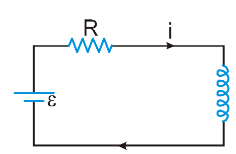
44. What is the magnetic energy density (in terms of standard constant & r) at the centre of a circulating electron in the hydrogen atom in first orbit. (Radius of the orbit is r)

45. Find the energy stored in the magnetic field inside a volume of 1.00 mm^3 at a distance of 10.0 cm from a long wire carrying a current of 4 A.

46. 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)?



47. Suppose the EMF of the battery, the circuit shown varies with time t so the current is given by $i(t) = 3 + 5t$, 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.



48. 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.

49. 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.

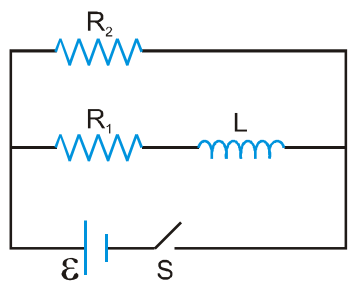
50. A coil of resistance 4 Ω is connected across a 0.4 V battery. The current in the coil is 63 mA . 1sec after the battery is connected. Find the inductance of the coil. [$e^{-1} \simeq 0.37$]

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

52. 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.

53. 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. ($e^{-0.4} = 0.67$)

54. 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.



55. 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.

56. 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.

57. 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 180°. Find the current in the loop after rotation.

58. 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.

59. 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?

60. 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?

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

Exercise # 5 Part # I [Previous Year Questions] [AIEEE/JEE-MAIN]

1. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon : **[AIEEE 2003]**

(1) the rates at which currents are changing in the two coils
(2) relative position and orientation of the two coils
(3) the materials of the wires of the coils
(4) the currents in the two coils

2. When the current changes from +2 A to –2 A in 0.05 second, an emf of 8 V is induced in a coil. The coefficient of self-induction of the coil is : **[AIEEE 2003]**

(1) 0.2 H (2) 0.4 H (3) 0.8 H (4) 0.1 H

3. In an oscillating LC circuit the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic field is : **[AIEEE 2003]**

(1) Q/2 (2) $Q/\sqrt{3}$ (3) $Q/\sqrt{2}$ (4) Q

4. A coil having n turns and resistance R Ω is connected with a galvanometer of resistance 4RΩ. This combination is moved in time t seconds from a magnetic field W_1 Weber to W_2 Weber. The induced current in the circuit is : **[AIEEE 2004]**

(1) $\frac{(W_2 - W_1)A}{5Rnt}$ (2) $-\frac{n(W_2 - W_1)A}{5Rt}$ (3) $-\frac{(W_2 - W_1)A}{Rnt}$ (4) $-\frac{n(W_2 - W_1)A}{Rt}$

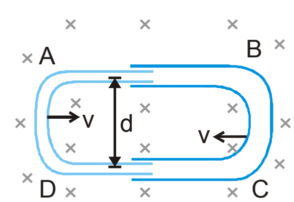
5. In a uniform magnetic field of induction B, a wire in the form of semicircle of radius r rotates about the diameter of the circle with angular frequency ω. If the total resistance of the circuit is R, the mean power generated per period of rotation is : **[AIEEE 2004]**

(1) $\frac{B\pi^2\omega}{2R}$ (2) $\frac{(B\pi r^2\omega)^2}{8R}$ (3) $\frac{(B\pi r\omega)^2}{2R}$ (4) $\frac{(B\pi r\omega^2)^2}{8R}$

6. A metal conductor of length 1 m rotates vertically about one of its ends at angular velocity 5 radians per second. If the horizontal component of earth's magnetic field is 0.2×10^{-4} T, then the emf developed between the two ends of the conductor is : **[AIEEE 2004]**

(1) 5 μV (2) 50 μV (3) 5 mV (4) 50 mV

7. One conducting u tube can slide inside another as shown in figure, maintaining electrical contacts between the tubes. The magnetic field B is perpendicular to the plane of the figure. If each tube moves towards the other at a constant speed v, then the emf induced in the circuit in terms of B, ℓ and v, where ℓ is the width of each tube, will be : **[AIEEE 2005, 4/300]**

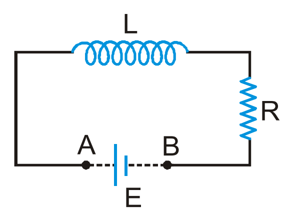


(1) $B\ell v$ (2) $-B\ell v$
(3) zero (4) $2B\ell v$

8. A coil of inductance 300 mH and resistance 2Ω is connected to a source of voltage 2V. The current reaches half of its steady state value in : **[AIEEE 2005]**

(1) 0.05 s (2) 0.1 s (3) 0.15 s (4) 0.3 s

9. An inductor (L = 100 mH), a resistor (R = 100 Ω) and a battery (E = 100 V) are initially connected in series as shown in the figure. After a long time the battery is disconnected after short circuiting the points A and B. The current in the circuit, 1 ms after the short circuit is : **[AIEEE 2006]**

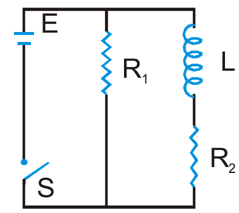


(1) 1 A (2) 1/e A (3) e A (4) 0.1 A

10. Two coaxial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area $A = 10cm^2$ and length = 20 cm. If one of the solenoids has 300 turns and the other 400 turns, their mutual inductance is $(\mu_0 = 4\pi \times 10^{-7}\ T\,m\,A^{-1})$: **[AIEEE 2008]**

(1) $4.8\pi \times 10^{-4}$ H **(2)** $4.8\pi \times 10^{-5}$ H **(3)** $2.4\pi \times 10^{-4}$ H **(4)** $2.4\pi \times 10^{-5}$ H

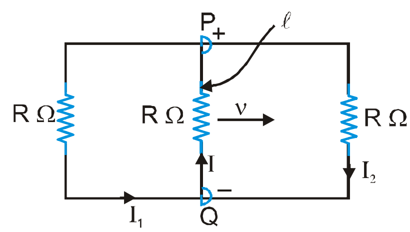
11. An inductor of inductance L = 400 mH and resistors of resistances $R_1 = 2\ \Omega$ and $R_2 = 2\ \Omega$ are connected to a battery of emf 12 V as shown in the figure. The internal resistance of the battery is negligible. The switch S is closed at t = 0. The potential drop across L as a function of time is : **[AIEEE 2009]**



(1) $\frac{12}{t}e^{-3t}$ V **(2)** $6\left(1 - e^{-t/0.2}\right)$ V

(3) $12\ e^{-5t}$ V **(4)** $6\ e^{-5t}$ V

12. 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]**



(1) $I_1 = -I_2 = \frac{B\ell v}{R}, I = \frac{2B\ell v}{R}$ **(2)** $I_1 = I_2 = \frac{B\ell v}{3R}, I = \frac{2B\ell v}{3R}$

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

13. 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) $\pi\sqrt{LC}$ **(2)** $\frac{\pi}{4}\sqrt{LC}$ **(3)** $2\pi\sqrt{LC}$ **(4)** $\sqrt{LC}$

14. A boat is moving due east in a region where the earth's magnetic field is $5.0 \times 10^{-5}\ NA^{-1}m^{-1}$ 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) 1 mV **(2)** 0.75 mV **(3)** 0.50 mV **(4)** 0.15 mV

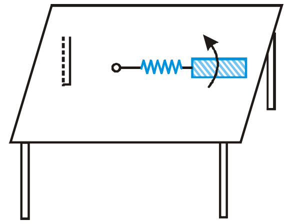
15. A horizontal straight wire 20 m long extending from to east to west falling with a speed of 5.0 m\s, at right angles to the horizontal component of the earth's magnetic field 0.30×10^{-4} Wb \ m². The instantaneous Value of the e.m. f. induced in the wire will be : **[AIEEE 2011]**

(1) 3 mV **(2)** 4.5 mV **(3)** 1.5 mV **(4)** 6.0mV

16. 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 :

(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.

17. 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-Mains 2013]**



(1) $\frac{2B\omega l^2}{2}$ **(2)** $\frac{3B\omega l^2}{2}$

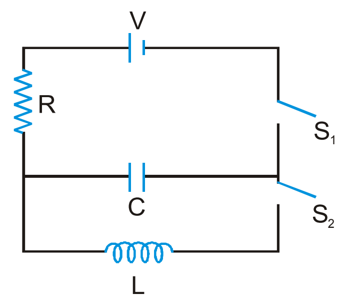
(3) $\frac{4B\omega l^2}{2}$ **(4)** $\frac{5B\omega l^2}{2}$

18. 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-Mains 2013]**

(1) 9.1×10^{-11} weber **(2)** 6×10^{-11} weber

(3) 3.3×10^{-11} weber **(4)** 6.6×10^{-9} weber

19. 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-Mains 2013]**



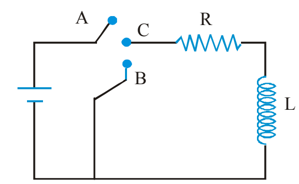
(1) Work done by the battery is half of the energy dissipated in the resistor

(2) At $t = \tau$, $q = CV/2$ $t = \tau$ $q = CV/2$

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

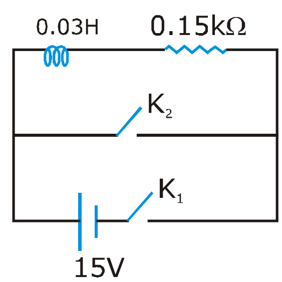
(4) At $t = \frac{\tau}{2}$, $q = CV(1 - e^{-1})$

20. 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-Mains 2014]**



(1) –1 **(2)** $\frac{1-e}{e}$ **(3)** $\frac{e}{1-e}$ **(4)** 1

21. 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 = 1 ms, the current in the circuit will be $(e^5 \cong 150)$ **[JEE-Mains 2015]**



(1) 6.7 mA **(2)** 0.67 mA **(3)** 100 mA **(4)** 67 mA

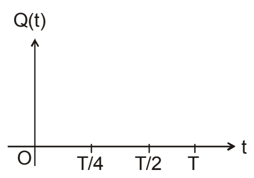
22. An arc lamp requires a direct current of 10 A at 80 V to function. If it is connected to a 220 V (rms), 50 Hz AC supply, the series inductor needed for it to work is close to **[JEE-Mains 2016]**

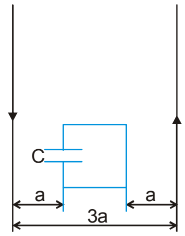
(1) 0.08 H **(2)** 0.044 H **(3)** 0.065 H **(4)** 80 H

Part # II [Previous Year Questions][IIT-JEE ADVANCED]

Marked Questions are having more than one correct option.

1. Two infinitely long parallel wires carrying currents $I = I_0 \sin \omega t$ in opposite directions are placed a distance 3a apart. A square loop of side a of negligible resistance with a capacitor of capacitance C is placed in the plane of wires as shown. Find the maximum current in the square loop. Also sketch the graph showing the variation of charge on the upper plate of the capacitor as a function of time for one complete cycle taking anticlockwise direction for the current in the loop as positive. **[JEE-2003 (Mains)]**





2. An infinitely long cylindrical conducting rod is kept along + Z direction. A constant magnetic field is also present in + Z direction. Then current induced will be **[JEE 2005 (Scr.)]**

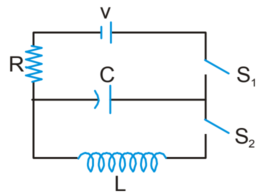
(A) 0 **(B)** along +z direction

(C) along clockwise as seen from + Z **(D)** along anticlockwise as seen from + Z

Comprehension Type

Comprehension # 1

The capacitor of capacitance C can be charged (with the help of a resistance R) by a voltage source V, by closing switch S_1 while keeping switch S_2 open. The capacitor can be connected in series with an inductor 'L' by closing switch S_2 and opening S_1. **[JEE 2006]**



3. Initially, the capacitor was uncharged. Now, switch S_1 is closed and S_2 is kept open. If time constant of this circuit is τ, then

(A) after time interval τ, charge on the capacitor is CV/2

(B) after time interval 2τ, charge on the capacitor is $CV(1 - e^{-2})$

(C) the work done by the voltage source will be half of the heat dissipated when the capacitor is fully charged

(D) after time interval 2τ, charge on the capacitor is $CV(1 - e^{-1})$

4. After the capacitor gets fully charged, S_1 is opened and S_2 is closed so that the inductor is connected in series with the capacitor. Then, **[JEE 2006]**

(A) at t = 0, energy stored in the circuit is purely in the form of magnetic energy

(B) at any time t > 0, current in the circuit is in the same direction

(C) at t > 0, there is no exchange of energy between the inductor and capacitor

(D) at any time t > 0, instantaneous current in the circuit will have maximum value $V\sqrt{\frac{C}{L}}$, where C is the capacitance and L is the inductance.

5. If the total charge stored in the LC circuit is Q_0, then for $t \geq 0$ **[JEE 2006]**

(A) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} + \frac{t}{\sqrt{LC}}\right)$

(B) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} - \frac{t}{\sqrt{LC}}\right)$

(C) the charge on the capacitor is $Q = -LC\,\frac{d^2Q}{dt^2}$

(D) the charge on the capacitor is $Q = -\frac{1}{\sqrt{LC}}\,\frac{d^2Q}{dt^2}$

Comprehension # 2

Modern trains are based on Maglev technology in which trains are magnetically elevated, which runs its EDS Maglev system.

There are coils on both sides of wheels. Due to motion of train current induces in the coil of track which elevate it. This is in accordance with Lenz's law. If trains lower down then due to Lenz's law a repulsive force increases due to which train gets uplifted and if it goes much high then there is a net downward force due to gravity.

The advantage of maglev train is that there is no friction between the train and the track, thereby reducing power consumption and enabling the train to attain very high speeds.

Disadvantage of maglev train is that as it slows down the electromagnetic forces decreases and it becomes difficult to keep it elevated and as it moves forward according to Lenz law there is an electromagnetic drag force.

6. What is the advantage of this system ? **[JEE 2006]**

(A) No friction hence no power consumption **(B)** Electric power is used

(C) Gravitation force is zero **(D)** Electrostatic force draws the train

7. What is the disadvantage of this system ? **[JEE 2006]**

(A) Train experiences upward force according to Lenz's law

(B) Friction force create a drag on the train

(C) Retardation

(D) By Lenz's law train experience a drag

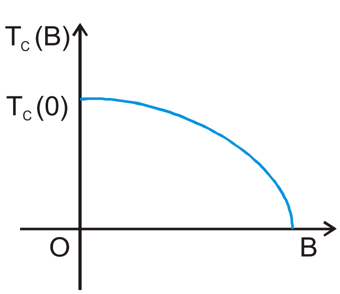
8. Which force causes the train to elevate up ? **[JEE 2006]**

(A) Electrostatic force **(B)** Time varying electric field

(C) Magnetic force **(D)** Induced electric field

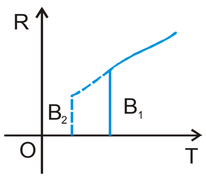
Comprehension # 3

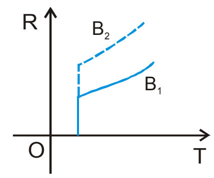
Electrical resistance of certain materials, known as superconductors, changes abruptly from a nonzero value to zero as their temperature is lowered below a critical temperature $T_C(0)$. An interesting property of superconductors is that their critical temperature becomes smaller than $T_C(0)$ if they 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.

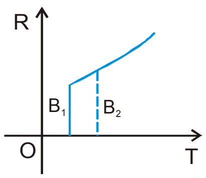


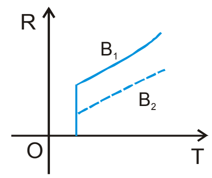
[JEE - 2010]

9. 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?

(A)


(B)


(C)


(D)


10. 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 :

(A) B = 5 Tesla, $T_C(B) = 80$ K
(B) B = 5 Tesla, $75\text{ K} < T_C(B) < 100$ K
(C) B = 10 Tesla, $75\text{ K} < T_C(B) < 100$ K
(D) B = 10 Tesla, $T_C(B) = 70$ K

Match the Column

11 . Column I gives certain situations in which a straight metallic wire of resistance R is used and Column II gives some resulting effect. Match the statements in Column I with the statements in Column II.

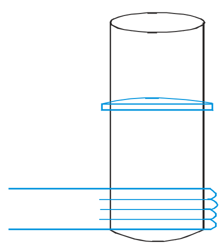
[IIT-JEE 2007]

Column I		Column II	
(A)	A charged capacitor is connected to the ends of the wire	**(P)**	A constant current flows through the wire
(B)	The wire is moved perpendicular to its length with a constant velocity in a uniform magnetic field perpendicular to the plane of motion.	**(Q)**	Thermal energy is generated in the wire
(C)	The wire is placed in a constant electric field that has a direction along the length of the wire.	**(R)**	A constant potential difference develops between the ends of the wire.
(D)	A battery of constant emf is connected to the ends of the wire.	**(S)**	Charges of constant magnitude appear at the ends of the wire.

12. **Statement -1**

A vertical iron rod has a coil of wire wound over it at the bottom end. An alternating current flows in the coil. The rod goes through a conducting ring as shown in the figure. The ring can float at a certain height above the coil.

[JEE 2007]



Statement - 2

In the above situation, a current is induced in the ring which interacts with the horizontal component of the magnetic field to produce an average force in the upward direction

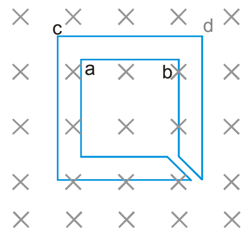
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True.

13. The figure shows certain wire segments joined together to form a coplanar loop. The loop is placed in a perpendicular magnetic field in the direction going into the plane of the figure. The magnitude of the field increases with time. I_1 and I_2 are the currents in the segments ab and cd. Then, **[JEE 2009]**



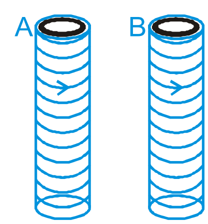
(A) $I_1 > I_2$

(B) $I_1 < I_2$

(C) I_1 is in the direction BA and I_2 is in the direction CD

(D) I_1 is in the direction AB and I_2 is in the direction DC

14. Two metallic rings A and B, identical in shape and size but having different resistivities ρ_A and ρ_B, are kept on top of two identical solenoids as shown in the figure. When current I is switched on in both the solenoids in identical manner, the rings A and B jump to heights h_A and h_B, respectively, with $h_A > h_B$. The possible relation(s) between their resistivities and their masses m_A and m_B is(are) **[JEE 2009]**



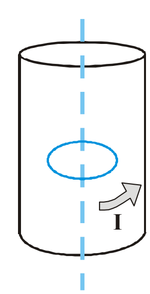
(A) $\rho_A > \rho_B$ and $m_A = m_B$

(B) $\rho_A < \rho_B$ and $m_A = m_B$

(C) $\rho_A > \rho_B$ and $m_A > m_B$

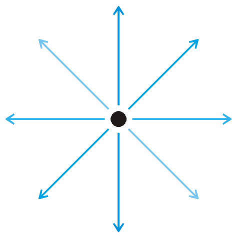
(D) $\rho_A < \rho_B$ and $m_A < m_B$

15. 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]**

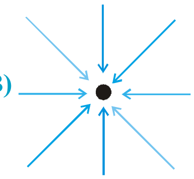


16. Which of the field patterns given below is valid for electric field as well as for magnetic field? **[JEE - 2011]**

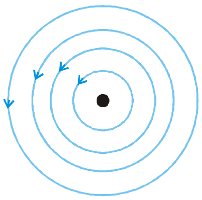
(A)



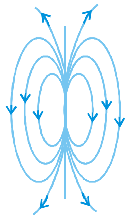
(B)



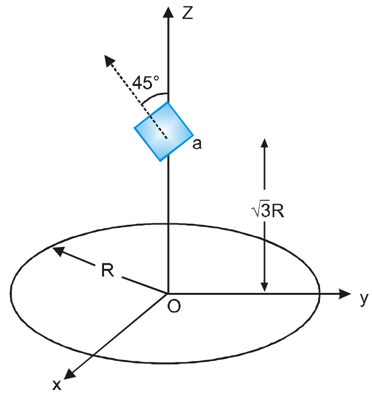
(C)



(D)



17. 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 $\frac{\mu_0 a^2}{2^{p/2} R}$, then the value of p is **[IIT-JEE-2012]**



18. 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]**

(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.

19. Two inductors L_1 (inductance 1 mH, internal resistance 3Ω) and L_2 (inductance 2 mH, internal resistance 4Ω), and a resistor R (resistance 12Ω) 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 **[IIT-JEE-2016]**

20. A conducting loop in the shape of a right angled isosceles triangle of height 10 cm is kept such that the 90° vertex is very close to an infinitely long conducting wire (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? **[IIT-JEE 2016]**

(A) The magnitude of induced emf in the wire is $\left(\frac{\mu_0}{\pi}\right)$ volt

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

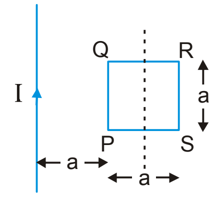
(C) The induced current in the wire is in opposite direction to the current along the hypotenuse

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

MOCK TEST

SECTION - I : STRAIGHT OBJECTIVE TYPE

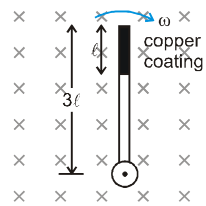
1. In the figure shown a square loop PQRS of side 'a' and resistance 'r' is placed near an infinitely long wire carrying a constant current I. The sides PQ and RS are parallel to the wire. The wire and the loop are in the same plane. The loop is rotated by 180º about an axis parallel to the long wire and passing through the mid points of the side QR and PS. The total amount of charge which passes through any point of the loop during rotation is :



(A) $\frac{\mu_0 Ia}{2\pi r}\ \ell n2$ (B) $\frac{\mu_0 Ia}{\pi r}\ \ell n2$

(C) $\frac{\mu_0 Ia^2}{2\pi r}$ (D) cannot be found because time of rotation not give.

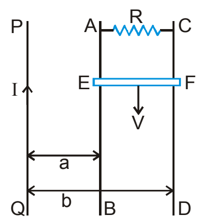
2. A wooden stick of length 3ℓ is rotated about an end with constant angular velocity ω in a uniform magnetic field B perpendicular to the plane of motion. If the upper one third of its length is coated with copper, the potential difference across the whole length of the stick is



(A) $\frac{9B\omega\ell^2}{2}$ (B) $\frac{4B\omega\ell^2}{2}$

(C) $\frac{5B\omega\ell^2}{2}$ (D) $\frac{B\omega\ell^2}{2}$

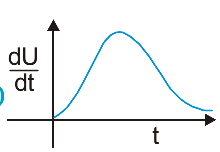
3. PQ is an infinite current carrying conductor. AB and CD are smooth conducting rods on which a conductor EF moves with constant velocity V as shown. The force needed to maintain constant speed of EF is.

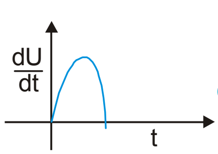


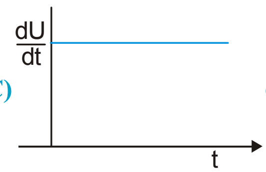
(A) $\frac{1}{VR}\left[\frac{\mu_0 IV}{2\pi}\ell n\left(\frac{b}{a}\right)\right]^2$ (B) $\left[\frac{\mu_0 IV}{2\pi}\ell n\left(\frac{b}{a}\right)\right]\frac{1}{R}$

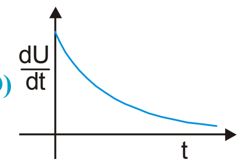
(C) $\left[\frac{\mu_0 IV}{2\pi}\ell n\left(\frac{b}{a}\right)\right]^2\frac{V}{R}$ (D) $\left[\frac{\mu_0 IV}{2\pi}\ell n\left(\frac{b}{a}\right)\right]$

4. 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) 

(B) 

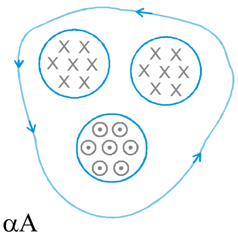
(C) 

(D) 

5. 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 same wire is wound on a solenoid of length $\frac{\ell}{2}$ and radius $\frac{r}{2}$, then the self inductance will be :

(A) 2 L (B) L (C) 4 L (D) 8 L

6. Figure shows three regions of magnetic field, each of area A, and in each region magnitude of magnetic field decreases at a constant rate α. If $\vec{E}$ is induced electric field then value of line integral $\oint \vec{E} \cdot d\vec{r}$ along the given loop is equal to



(A) αA **(B)** $-\alpha A$ **(C)** $3\alpha A$ **(D)** $-3\alpha A$

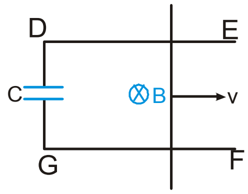
7. In an ideal transformer, the voltage and the current in the primary are 200 volt and 2 amp respectively. If the voltage in the secondary is 2000 volt. Then value of current in the secondary will be :

(A) 0.2 amp **(B)** 2 amp **(C)** 10 amp **(D)** 20 amp

8. 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 by 180º. The current in the loop after rotation is equal to

(A) zero **(B)** $\frac{B\pi R^2}{L}$ **(C)** $\frac{2B\pi R^2}{L}$ **(D)** $\frac{B\pi R^2}{2L}$

9. In the figure shown the section EDFG is fixed. A rod having resistance 'R' is moved with constant velocity in a uniform magnetic field B as shown in the figure. DE & FG are smooth and resistanceless. Initially capacitor is uncharged. The charge on the capacitor:



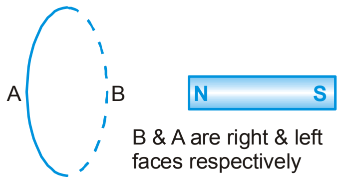
(A) remains constant **(B)** increases with time

(C) increases linearly with time **(D)** oscillates.

10. 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

11. In the figure shown, the magnet is pushed towards the fixed ring along the axis of the ring and it passes through the ring.



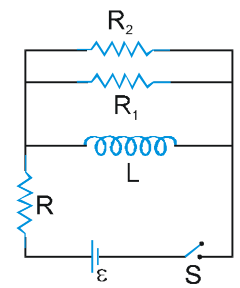
(A) when magnet goes towards the ring the face B becomes south pole and the face A becomes north pole

(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.

12. Switch S is closed for a long time at t = 0. It is opened, then :



(A) total heat produced in resistor R after opening the switch is $\frac{1}{2}\frac{L\varepsilon^2}{R^2}$

(B) total heat produced in resistor R_1 after opening the switch is $\frac{1}{2}\frac{L\varepsilon^2}{R^2}\left(\frac{R_1}{R_1+R_2}\right)$

(C) heat produced in resistor R_1 after opening the switch is $\frac{1}{2}\frac{R_2\,L\,\varepsilon^2}{(R_1+R_2)\,R^2}$

(D) no heat will be produced in R_1.

13. A rod of length ℓ having uniformly distributed charge Q is rotated about one end with constant frequency 'f'. Its magnetic moment is.

(A) πfQl^2 **(B)** $\frac{\pi fQ\ell^2}{3}$ **(C)** $\frac{2\pi fQ\ell^2}{3}$ **(D)** $2\pi fQl^2$

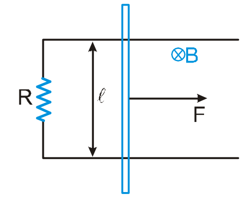
14. A vertical rod of length ℓ is moved with constant velocity v towards East. The vertical component of the earth's magnetic field is B and the angle of dip is θ. The induced e.m.f. in the rod is :

(A) $B\ell v\cot\theta$ **(B)** $B\ell v\sin\theta$ **(C)** $B\ell v\tan\theta$ **(D)** $B\ell v\cos\theta$

15. Two identical cycle wheels (geometrically) have different number of spokes connected from centre to rim. One is having 20 spokes and other having only 10 (the rim and the spokes are resistanceless). One resistance of value R is connected between centre and rim. The current in R will be :

(A) double in first wheel than in the second wheel
(B) four times in first wheel than in the second wheel
(C) will be double in second wheel than that of the first wheel
(D) will be equal in both these wheels.

16. 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 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.

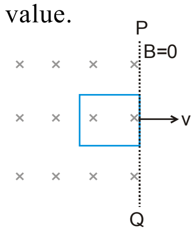
17. A uniform magnetic field exists in region given by $\vec{B} = 3\hat{i}+4\hat{j}+5\hat{k}$. A rod of length 5 m is placed along y−axis is moved along x−axis with constant speed 1 m/sec. Then induced e.m.f. in the rod will be:

(A) zero **(B)** 25 volt **(C)** 20 volt **(D)** 15 volt

18 In a L-R growth circuit, inductance and resistance used are 1 H and 20 Ω respectively. If at t = 50 millisecond, current in the circuit is 3.165 A then applied direct current emf is :

(A) 200 V **(B)** 100 V
(C) 50 V **(D)** Data is insufficient to find out the value.

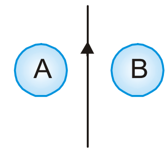
19. Figure shows a square loop of side 1 m and resistance 1 Ω. The magnetic field on left side of line PQ has a magnitude B = 1.0T. The work done in pulling the loop out of the field uniformly in 1 s is



(A) 1 J **(B)** 10 J
(C) 0.1 J **(D)** 100 J

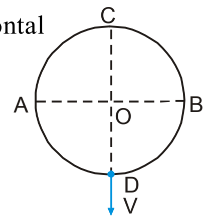
20. A and B are two metallic rings placed at opposite sides of an infinitely long straight conducting wire as shown. If current in the wire is slowly decreased, the direction of induced current will be :

(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

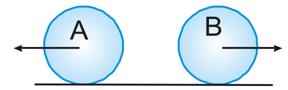


21. A vertical conducting ring of radius R falls vertically with a speed V in a horizontal uniform magnetic field B which is perpendicular to the plane of the ring :

(A) A and B are at same potential
(B) C and D are at same potential
(C) current flows in clockwise direction
(D) current flows in anticlockwise direction



22. 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 :

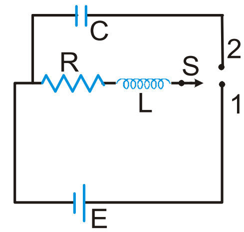


(A) zero **(B)** 2 Bvr
(C) 4Bvr **(D)** none of these

23. An inductor L and a resistor R are connected in series with a direct current source of emf E. The maximum rate at which energy is stored in the magnetic field is :

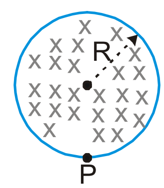
(A) $\frac{E^2}{4R}$ **(B)** $\frac{E^2}{R}$ **(C)** $\frac{4E^2}{R}$ **(D)** $\frac{2E^2}{R}$

24. In the circuit shown in figure, the switch S was initially at position 1. After sufficiently long time, the switch S was thrown from position 1 to position 2.
The voltage drop across the resistor at that instant is :



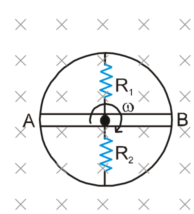
(A) zero **(B)** E
(C) $\frac{E}{R}$LC **(D)** none of these

25. 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 $\frac{dB}{dt}$ (tesla/second). An electron of charge q, placed at the point P on the periphery of the field experiences an acceleration :



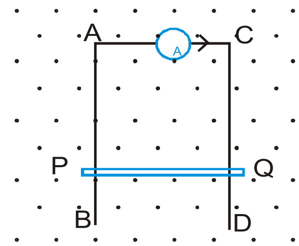
(A) $\frac{1}{2}\frac{eR}{m}\frac{dB}{dt}$ towards left **(B)** $\frac{1}{2}\frac{eR}{m}\frac{dB}{dt}$ towards right
(C) $\frac{eR}{m}\frac{dB}{dt}$ towards left **(D)** zero

26. AB is a resistanceless conducting rod which forms a diameter of a conducting ring of radius r rotating in a uniform magnetic field B as shown. The resistors R_1 and R_2 do not rotate. Then current through the resistor R_1 is :



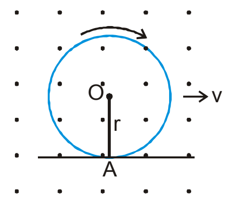
(A) $\frac{B\omega r^2}{2R_1}$ **(B)** $\frac{B\omega r^2}{2R_2}$ **(C)** $\frac{B\omega r^2}{2R_1R_2}(R_1+R_2)$ **(D)** $\frac{B\omega r^2}{2(R_1+R_2)}$

27. 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,



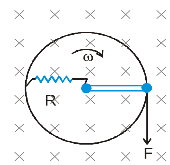
(A) The rod PQ will move downward with constant acceleration
(B) The rod PQ will move upward with constant acceleration
(C) The rod will move downward with decreasing acceleration and finally acquire a constant velocity
(D) either A or B.

28. A conducting ring of radius r with a conducting spoke is in pure rolling on a horizontal surface in a region having a uniform magnetic field B as shown, v being the velocity of the centre of the ring. Then the potential difference $V_0 - V_A$ is -



(A) $\frac{Bvr}{2}$ **(B)** $\frac{3Bvr}{2}$ **(C)** $\frac{-Bvr}{2}$ **(D)** $\frac{3Bvr}{2}$

29. A metallic ring of mass m and radius r with a uniform metallic spoke of same mass m and length r is rotated about its axis with angular velocity ω in a perpendicular uniform magnetic field B as shown. If the central end of the spoke is connected to the rim of the wheel through a resistor R as shown. The resistor does not rotate, its one end is always at the center of the ring and other end is always in contact with the ring. A force F as shown is needed to maintain constant angular velocity of the wheel. F is equal to (The ring and the spoke has zero resistance)

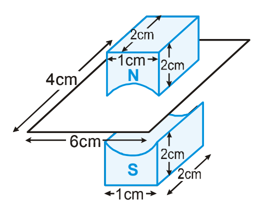


(A) $\frac{B^2\omega r^2}{8R}$ **(B)** $\frac{B^2\omega r^2}{2R}$ **(C)** $\frac{B^2\omega r^3}{2R}$ **(D)** $\frac{B^2\omega r^3}{4R}$

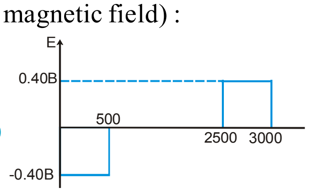
30. A closed circuit consists of a resistor R, inductor of inductance L and a source of emf E are connected in series. If the inductance of the coil is abruptly decreased to L/4 (by removing its magnetic core), the new current immediately after this moment is : (before decreasing the inductance the circuit is in steady state)

(A) zero **(B)** E/R **(C)** $4\frac{E}{R}$ **(D)** $\frac{E}{4R}$

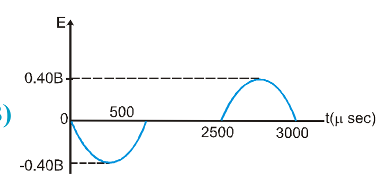
31. A magnetic field (B), uniform between two magnets can be determined measuring the induced voltage in the loop as it is pulled through the gap at uniform speed 20 m/sec. Size of magnet and coil is 2cm × 1cm × 2cm and 4cm × 6cm as shown in figure. The correct variation of induced emf with time is :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



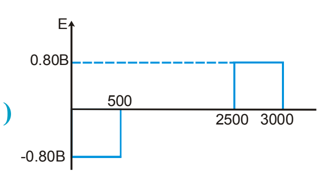
(A)



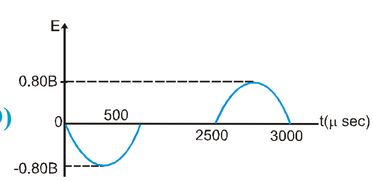
(B)



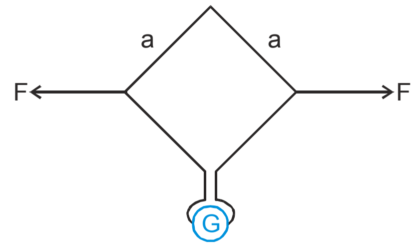
(C)



(D)

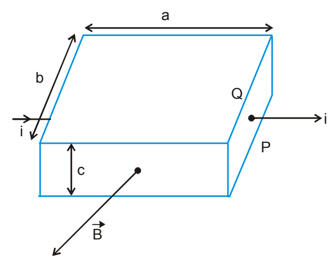


32. The plane of a square loop of wire with edge length a = 0.2 m is perpendicular to the earth's magnetic field B_E at a point where B_E = 15 μT. The total resistance of the loop and the wires connecting it to the galvanometer is 0.5 Ω. If the loop is suddenly collapsed(such that area of the loop becomes zero) by horizontal forces as shown, the total charge passing through the galvanometer is :



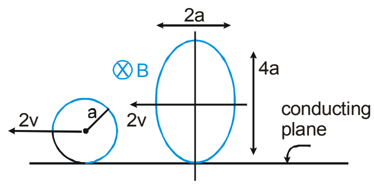
(A) 0.4 μC **(B)** 0.75 μC
(C) 0.9 μC **(D)** 1.2 μC

33. A current flows through a rectangular conductor in the presence of uniform magnetic field B pointing out of the page as shown. Then the potential difference $V_P - V_Q$ is equal to. (assume charge carriers in the conductor to be positively charged moving with a drift velocity of v)



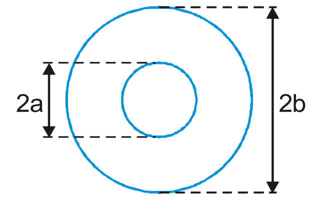
(A) Bvb **(B)** –Bvb
(C) Bvc **(D)** –Bvc

34. A conducting circular ring and a conducting elliptical ring both are moving pure translationally in a uniform magnetic field of strength B as shown in figure on a horizontal conducting plane then potential difference between top most points of circle and ellipse is :



(A) 12 va **(B)** 4 vBa
(C) 8 vBa **(D)** 2 vBa

35. A small circular wire loop of radius a is located at the centre of a much larger circular wire loop of radius b as shown above(b>>a). Both loops are coaxial and coplanar. The larger loop carries a time (t) varying current $I = I_0 \cos \omega t$, where I_0 and ω are constants. The magnetic field generated by the current in the large loop induces in the small loop an emf that is approximately equal to which of the following.



(A) $\frac{\pi\mu_0 I_0}{2}\frac{a^2}{b}\omega \cos\omega t$ **(B)** $\frac{\pi\mu_0 I_0}{2}\frac{a^2}{b}\omega \sin\omega t$

(C) $\frac{\pi\mu_0 I_0}{2}\frac{a}{b^2}\omega \sin\omega t$ **(D)** $\frac{\pi\mu_0 I_0}{2}\frac{a}{b^2}\omega \cos\omega t$

36. 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	
2	2N	A	
3	3N	3A	
4	2N	2A	

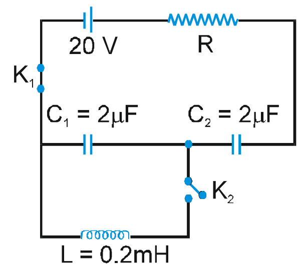
The solenoid with maximum self inductance is :

(A) 1 **(B)** 2 **(C)** 3 **(D)** 4

37. Assume Earth's surface is a 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) $\frac{1}{2}B\omega R_e^2$ **(B)** $B\omega R_e^2$ **(C)** $\frac{3}{2}B\omega R_e^2$ **(D)** zero

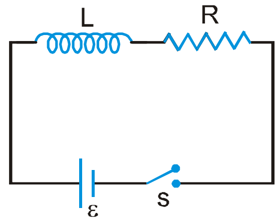
38. A circuit containing capacitors C_1 and C_2 as shown in the figure are in steady state with key K_1 closed. At the instant t = 0, if K_1 is opened and K_2 is closed then the maximum current in the circuit will be :



(A) 1 A **(B)** $\frac{1}{2}$ A

(C) 2 A **(D)** None of these

39. In the given circuit having an ideal inductor of inductance L, resistor of resistance R and an ideal cell of emf ε, the work done by the battery in one time constant after the switch is closed is

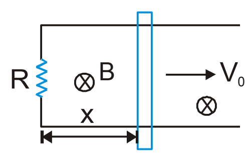


(A) $\frac{\varepsilon^2}{R}$ **(B)** $\frac{\varepsilon^2 L}{R^2}e$

(C) $\frac{\varepsilon^2 L}{R^2}$ **(D)** $\frac{\varepsilon^2 L}{eR^2}$

SECTION - II : MULTIPLE CORRECT ANSWER TYPE

40. 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.

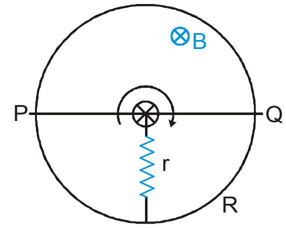
41. In the figure shown 'R' is a fixed conducting fixed ring of negligible resistance and radius 'a'. PQ is a uniform rod of resistance r. It is hinged at the centre of the ring and rotated about this point in clockwise direction with a uniform angular velocity ω. There is a uniform magnetic field of strength 'B' pointing inwards. 'r' is a stationary resistance

(A) Current through 'r' is zero.

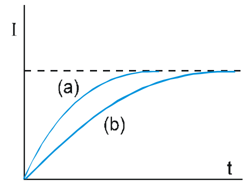
(B) Current through 'r' is $\frac{2B\omega a^2}{5r}$.

(C) Direction of current in external 'r' is from centre to circumference.

(D) Direction of current in external 'r' is from circumference to centre.

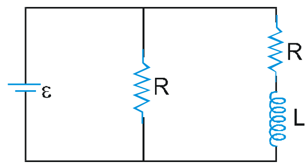


42. A circuit consisting of a constant e.m.f. 'E', a self induction 'L' and a resistance 'R' is closed at t = 0. The relation between the current I in the circuit and time t is as shown by curve 'a' in the figure. When one or more of parameters E, R & L are changed, the curve 'b' is obtained.The steady state current is same in both the cases. Then it is possible that:



(A) E & R are kept constant and L is increased.
(B) E & R are kept constant and L is decreased
(C) E & R are both halved and L is kept constant
(D) E & L are kept constant and R is decreased

43. In the circuit diagram shown



(A) time constant is L/R
(B) time constant is 2L/R
(C) steady state current in inductor is 2ε/R
(D) steady state current in inductor is ε/R

44 A conducting loop rotates with constant angular velocity about its fixed diameter in a uniform magnetic field. Whose direction is 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 π/2

45. An ideal inductor, (having initial current zero) a resistor and an ideal battery are connected in series at time t = 0. At any time t, the battery supplies energy at the rate P_B, the resistor dissipates energy at the rate P_R and the inductor stores energy at the rate P_L.
(A) $P_B = P_R + P_L$ for all times t.
(B) $P_R < P_L$ for all times t.
(C) $P_R < P_L$ only near the starting of the circuit.
(D) $P_R > P_L$ only near the starting of the circuit.

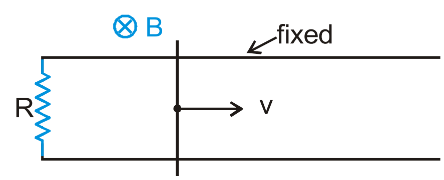
SECTION - III : ASSERTION AND REASON TYPE

46. **Statement-1 :** Two coaxial conducting rings of different radii are placed in space. The mutual inductance of both the rings is maximum if the rings are also coplanar.

Statement-2 : For two coaxial conducting rings of different radii, the magnitude of magnetic flux in one ring due to current in other ring is maximum when both rings are coplanar.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True.

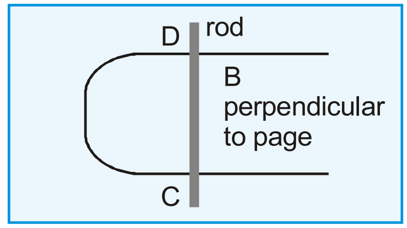
47 **Statement-1 :** A resistance R is connected between the two ends of the parallel smooth conducting rails. A conducting rod lies on these fixed horizontal rails and a uniform constant magnetic field B exists perpendicular to the plane of the rails as shown in the figure. If the rod is given a velocity v and released as shown in figure, it will stop after some time. The total work done by magnetic field is negative.



Statement-2 : If force acts opposite to direction of velocity its work done is negative.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

48. **STATEMENT–1 :** Consider the arrangement shown below. A smooth conducting rod, CD, is lying on a smooth U-shaped conducting wire making good electrical contact with it. The U-shape conducting wire is fixed and lies in horizontal plane. There is a uniform and constant magnetic field B in vertical direction (perpendicular to plane of page in figure). If the magnetic field strength is decreased, the rod moves towards right.



STATEMENT–2 : In the situation of statement-1, the direction in which the rod will slide is that which tends to maintain constant flux through the loop. Providing a larger loop area counteracts the decrease in magnetic flux. So the rod moves to the right independent of the fact that the direction of magnetic field is into the page or out of the page.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True.

49. **STATEMENT–1 :** No electric current will be present within a region having uniform and constant magnetic field.

STATEMENT–2 : Within a region of uniform and constant magnetic field $\vec{B}$, the path integral of magnetic field $\oint \vec{B} \cdot d\vec{\ell}$ along any closed path is zero. Hence from Ampere circuital law $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I$ (where the given terms have usual meaning), no current can be present within a region having uniform and constant magnetic field.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True.

50. **Statement-1 :** Electric field produced by changing magnetic field is nonconservative.

Statement-2: For the electric field $\vec{E}$ induced by a changing magnetic field which has closed lines of force,

$$\oint \vec{E} d\vec{\ell} = 0$$

(A) Statement -1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

SECTION - IV : COMPREHENSION TYPE

Comprehension # 1

A fan operates at 200 volt (DC) consuming 1000 W when running at full speed. It's internal wiring has resistance 1 Ω. When the fan runs at full speed, its speed becomes constant. This is because the torque due to magnetic field inside the fan is balanced by the torque due to air resistance on the blades of the fan and torque due to friction between the fixed part and the shaft of the fan. The electrical power going into the fan is spent (i) in the internal resistance as heat, call it P_1 (ii) in doing work against internal friction and air resistance producing heat, sound etc., call it P_2. When the coil of fan rotates, an emf is also induced in the coil. This opposes the external emf applied to send the current into the fan. This emf is called back-emf, call it 'e'.

Answer the following questions when the fan is running at full speed.

51. The current flowing into the fan and the value of back emf 'e' is :

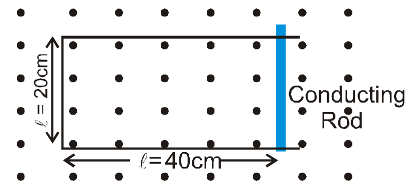
(A) 200 A, 5 volt **(B)** 5 A, 200 volt **(C)** 5 A, 195 volt **(D)** 1 A , 0 volt

52. The value of power 'P_1' is
(A) 1000 W **(B)** 975 W **(C)** 25 W **(D)** 200 W

53. The value of power 'P_2 is
(A) 10000 W **(B)** 975 W **(C)** 25 W **(D)** 200 W

Comprehension # 2

Figure shows a conducting rod of negligible resistance that can slide on smooth U-shaped rail made of wire of resistance 1Ω/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.



54. 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

55. 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 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

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

Comprehension # 3

A train of mass 100 tons (1 ton = 1000 kg) runs on a meter gauge track(distance between the two rails is 1 m.) The coefficient of friction between the rails and the train is 0.045. The train is powered by an electric engine of 90% efficiency. The train is moving with uniform speed of 72 Kmph at its highest speed limit. Horizontal and vertical component of earth's magnetic field are $B_H = 10^{-5}$T and $B_V = 2 \times 10^{-5}$ T. Assume the body of the train and rails to be perfectly conducting.

57. The electrical power consumed by the train is -
(A) 1.11 MW **(B)** 1 MW **(C)** 0.50 MW **(D)** 0.90 MW

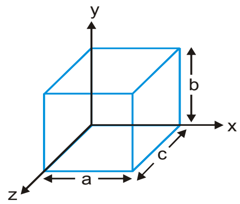
58. The potential difference between the two rails is -
(A) 100 μV **(B)** 200 μV **(C)** 400 μV **(D)** 800 μV

59. If now a resistor of 10^{-3} Ω is attached of between the two rails, the extra units of energy (electricity) consumed during a 324 km run of the train is (1 unit of power = 1 kW hour) (assume the speed of train to remain unchanged)
(A) 8×10^{-4} KW hour **(B)** 8×10^{-5} KW hour **(C)** 8×10^{-6} KW hour **(D)** 8×10^{-7} KW hour

SECTION - V : MATRIX - MATCH TYPE

60. The figure shows a metallic solid block, placed in a way so that its faces are parallel to the coordinate axes. Edge lengths along axis x, y and z are a, b and c respectively. The block is in a region of uniform magnetic field of magnitude 30mT. One of the edge length of the block is 25 cm. The block is moved at 4 m/s parallel to each axis and in turn, the resulting potential difference V that appears across the block is measured. When the motion is parallel to the y axis, V = 24 mV; with the motion parallel to the z axis, V = 36 mV; with the motion parallel to the x axis, V = 0. Using the given information, correctly match the dimensions of the block with the values given.

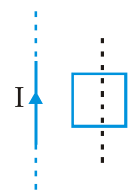
(A)	a	**(P)**	20 cm
(B)	b	**(Q)**	24 cm
(C)	c	**(R)**	25 cm
(D)	$\frac{bc}{a}$	**(S)**	30 cm
		(T)	26 cm



61. Column-I gives situations involving a charged particle which may be realised under the condition given in column-II. Match the situations in column-I with the condition in column-II.

Column I	**Column II**
(A) Increase in speed of a charged particle	**(P)** Electric field uniform in space and constant with time
(B) Exert a force on an electron initially at rest	**(Q)** Magnetic field uniform in space and constant with time.
(C) Move a charged particle in a circle with uniform speed	**(R)** Magnetic field uniform in space but varying with time.
(D) Accelerate a moving charged particle	**(S)** Magnetic field non-uniform in space but constant with time
	(T) Electric field non–uniform in space but constant with time.

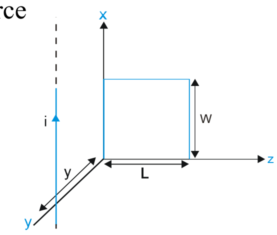
62. A square loop of conducting wire is placed near a long straight current carrying wire as shown. Match the statements in column-I with the corresponding results in column-II.



Column-I	**Column-II**
(A) If the magnitude of current I is increased	**(P)** Induced current in the loop will be clock wise
(B) If the magnitude of current I is decreased	**(Q)** Induced current in the loop will be anticlockwise
(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) Torque about centre of mass of loop is zero due to magnetie force

SECTION - VI : INTEGER TYPE

63. In the figure, a long thin wire carrying a varying current $i = i_0 \sin \omega t$ lies at a distance y above one edge of a rectangular wire loop of length L and width W lying in the x-z plane. What emf is induced in the loop.



64. The magnetic field of a cylindrical magnet that has a pole-face radius 2.8 cm can be varied sinusoidally between minimum value 16.8 T and maximum value 17.2 T at a frequency of $\frac{60}{\pi}$ Hz. Cross section of the magnetic field created by the magnet is shown. At a radial distance of 2cm from the axis find the amplitude of the electric field (in mN/C) induced by the magnetic field variation.

65. In the figure shown ABCDEFGH is a square conducting frame of side 2m and resistance 1 Ω/m. A uniform magnetic field B is applied perpendicular to the plane and pointing inwards . It increases with time at a constant rate of 10 T/s . Find the rate at which heat in watt is produced in the circuit , AB = BC = CD = BH .

66. A long coaxial cable consists of two thin walled conducting cylinders with inner radius 2cm and outer radius 8cm. The inner cylinder carries a steady current 1A, and the outer cylinder provides the return path for that current. The current produces a magnetic field between the two cylinders. Find the energy stored in the magnetic field for length 1 m of the cable. Express answer in nJ (use $\ell n2 = 0.7$).

ANSWER KEY

EXERCISE - 1

1. C	**2.** C	**3.** B	**4.** C	**5.** A	**6.** A	**7.** A	**8.** B	**9.** B
10. B	**11.** D	**12.** C	**13.** A	**14.** A	**15.** B	**16.** B	**17.** C	**18.** A
19. B	**20.** A,B,C,D	**21.** A,D	**22.** A,B,C,D	**23.** A,C	**24.** A,B,D	**25.** A,B,C	**26.** C, D	**27.** A,C

EXERCISE - 2 : PART # I

2. D	**1.** D	**3.** D	**4.** C	**5.** C	**8.** D	**7.** B,C	**6.** A	**9.** A
11. A	**12.** D	**10.** C	**14.** A	**13.** B	**16.** C	**15.** D	**17.** B	**19.** B
18. B	**21.** B	**20.** D	**23.** D	**22.** A	**25.** D	**24.** C	**26.** D	**28.** D
27. C	**30.** C	**29.** B	**32.** A	**33.** A	**31.** B	**35.** A	**34.** A,C,D	**37.** A
36. B	**39.** C	**38.** B	**41.** A	**40.** D	**43.** A	**42.** A	**45.** D	**44.** B
47. C	**46.** A							

PART # II

1. A **2.** D **3.** A

EXERCISE - 3 : PART # I

1. A → Q,S ; B → P,R ; C → P,R ; D → Q,S **2.** A → Q ; B → P ; C → T ; D → T

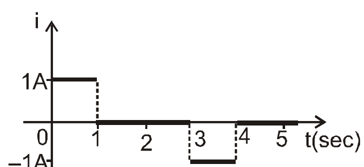
PART # II

Comp. #1 : **1.** C **2.** A **3.** C **Comp.#2 :** **1.** A **2.** B **3.** C

EXERCISE - 4

1. 1.0 V ,anticlockwise. **2.** $i = \frac{\varepsilon}{R} = \frac{\Delta\phi}{\Delta t} \times \frac{1}{R} \quad \frac{\Delta q}{\Delta t} = \frac{\Delta\phi}{\Delta t} \times \frac{1}{R} \quad \Delta q = \frac{\Delta\phi}{R}$ **3. (i)** 1.2 Volt **(ii)** 1.4 volt **(iii)** 17.5 C **(iv)** 3.5 A **(v)** 86/3 joule. **4.** zero **5. (a)** –1 mV, –2 mV, 2 mV, 1mV **(b)** 10 ms to 20 ms and 20 ms to 30 ms. **6.** 493 μV **7.** 1.6×10^{-5}A **8.** 2.5 mVa **9. (a)** In the round conductor the current flows clockwise, there is no current in the connector; **(b)** in the outside conductor clockwise; **(c)** in both round conductors, clockwise; no current in the connector, **(d)** in the left-hand side of the figure eight, clockwise. **10.** $25\pi \times 10^{-3}\,C = 0.078\,C$ **11.** $\frac{\pi}{8} \times 10^{-4}\,A$

12. $\frac{3}{2}\,\frac{\mu_0 \pi R^2 r^2 NI yv}{\left(R^2 + y^2\right)^{5/2}}$ **13.** $H = i^2R1 + 0 + i^2R1 = 1 + 0 + 1 = 2\,J$ **14.**



15. 4 mV, Q **16.** Opposite direction, Same direction. **17. (a)** zero **(b)** vB (bc), positive at b **(c)** vB(bc), positive at a **(d)** zero **18.** 1 mV **19.** $\sqrt{3} \times 10^{-2}\,V$

20. $V^2 = u^2 + 2ay = 0 + 2ay \Rightarrow V = \sqrt{2ay} \Rightarrow \varepsilon = BV(2x) = B\sqrt{2ay} \times 2\sqrt{\frac{y}{k}} \Rightarrow \varepsilon = 2By\sqrt{\frac{2a}{k}} = By\sqrt{\frac{8a}{k}}$.

21. **(a)** at the ends of the diameter perpendicular to the velocity, 2rvB
(b) at the ends of the diameter parallel to the velocity, zero.

22. **(a)** 0.1 mA **(b)** 0.2 mA **23.** **(a)** 4 m/s **(b)** 4 V **(c)** 3 V **(d)** 1 V. **24.** zero **25.** **(a)** $\frac{1}{r}(\varepsilon - vB\ell)$, from b to a

(b) $\frac{\ell B}{r}(\varepsilon - vB\ell)$ towards right **(c)** $\frac{\varepsilon}{B\ell}$. **26.** $i = \frac{Bv\ell}{2(\ell + vt)r}$ **27.** $\frac{mgt}{m + CB^2\ell^2}$ **28.** **(a)** $\frac{B^2\ell^2 v}{2r(\ell + vt)}$ **(b)** ℓ/v. **29.** $\frac{B_0 v_0 L}{2}$

30. **(a)** $\phi = \frac{\mu_0 ia}{2\pi}\ell n\left(\frac{a+b}{b}\right)$; **(b)** $\varepsilon = \frac{\mu_0 i_0 a}{T}\ell n\left(\frac{a+b}{b}\right)\sin\left(\frac{2\pi t}{T}\right)$ **(c)** heat $= \left(\frac{5\mu_0^2 i_0^2 a^2}{Tr}\right)\left[\ell n\left(\frac{a+b}{b}\right)\right]^2$ **31.** 67.5 mV

32. $(BV\sin\alpha)/r(1+\sin\alpha)$ **33.** $\frac{B\omega a^2}{R}$ from C to D **34.** $B\ell\sqrt{g\ell}\sin\frac{\theta}{2}$

35. $3\pi \times 10^{-6}$ V **36.** **(a)** 2.0×10^{-3} V **(b)** zero **(c)** 50 μC **(d)** $\pi \times 10^{-3}\sin(10\pi t)$ **(e)** π mV **(f)** $\frac{\pi^2}{2}\times 10^{-6}$ V

37. **(a)** 2BRv **(b)** $\frac{BRv}{2}$ **(c)** $\frac{3BRv}{2}$ **38.** **(a)** $16\pi^2 \times 10^{-10} = 1.6 \times 10^{-8}$ Weber **(b)** $4\pi \times 10^{-8}$ V/m **(c)** $18\pi \times 10^{-8} = 5.6 \times 10^{-7}$ V/m

39. 6π Volt **40.** 10V **42.** **(a)** 5 W **(b)** 3W **(c)** 2 W **43.** 2.2 A/s, decreasing **44.** $\frac{\mu_0 e^4}{128\pi^3\varepsilon_0 mR^5}$ **45.** 2.55×10^{-14} J

46. 15V **47.** 42 + 20 t volt **48.** (L/R) ln 2 = 1.109 s, 640 J **49.** **(a)** $\frac{1}{5}(1 - e^{-2}) \simeq 0.17$ A

(b) $\frac{1}{25}(1 - e^{-2})^2 \simeq 0.03$ J **50.** 4.0 H **51.** $t = (L/R)\,\ell n 2 = 3.47$ s **52.** $\frac{2}{e}$ A/s, $\frac{2}{e}$ V **53.** $2[1 - e^{-0.4}] = 0.66$ V

54. **(a)** $\frac{\varepsilon(R_1 + R_2)}{R_1 R_2}$ **(b)** $\frac{L}{R_1 + R_2}$ **(c)** $\frac{\varepsilon}{R_1 e}$ **55.** **(a)** -2.5×10^3 V/s **(b)** $-2.5 \times 10^3 \times e^{-5}$ V/s

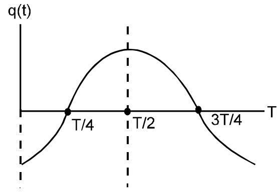
56. $\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} = \frac{1}{L} + \frac{1}{L} = \frac{2}{L}$ or $L_{eq} = \frac{L}{2}$ **57.** $\frac{2B\pi R^2}{L}$ **58.** 0.01 H

59. **(b)** Separation is large to neglect mutual inductance **60.** 2.5 V **61.** $M = \frac{2\sqrt{2}\mu_0\ell^2}{\pi L}$

EXERCISE - 5 : PART - I

1. 2 **2.** 4 **3.** 3 **4.** 2 **5.** 2 **6.** 2 **7.** 4 **8.** 2 **9.** 2 **10.** 3 **11.** 3 **12.** 2 **13.** 2
14. 1 **19.** 3 **20.** 1 **21.** 2 **22.** 3

PART - II

1. 

$I_{max} = \dfrac{a\mu_0 I_0 \omega^2 c \ell n\, 2}{\pi}$ **2.** A **3.** B **4.** D **5.** C **6.** A **7.** D **8.** C

9. A **10.** B **11 .** $A \to Q$; $B \to R,S$; $C \to S$; $D \to P, Q, R$ **12.** A **13.** D **14.** B,D **15.** N = 6 **16.** C **17.** 7

18. A,C **19.** 8 **20.** A, D

MOCK TEST

1. B **2.** C **3.** A **4.** A **5.** A **6.** B **7.** A **8.** C **9.** B **10.** A **11.** C **12.** C **13.** B
14. A **15.** D **16.** D **17.** B **18.** B **19.** A **20.** B **21.** B **22.** C **23.** A **24.** B **25.** A . **26.** A
27. D **28.** C **29.** D **30.** C **31.** A **32.** D **33.** C **34.** B **35.** B **36.** D **37.** A **38.** A **39.** D
40. A,B,D **41.** B,D **42.** A,C **43.** A,D **44.** A,B,C,D **45.** A,C **46.** A **47.** D **48.** A **49.** A
50. C **51.** C **52.** C **53.** B **54.** A **55.** B **56.** C **57.** B **58.** C **59.** D
60. $A \to R$; $B \to S$; $C \to P$; $D \to Q$ **61.** $A \to P, R, T$; $B \to P, R, T$; $C \to Q, S$; $D \to P, Q, R, S, T$

62. $A \to Q,S$; $B \to P,R \to$ $C \to P,R$; $D \to Q,S$ **63.** $\dfrac{\mu_0 \mathbf{i}_0 W \omega \cos \omega t}{4\pi} \ell n\left(\dfrac{L^2}{y^2}+1\right)$ **64.** $\omega = 240$ mN/C

65. 200 watt . **66.** U = 140 nJ