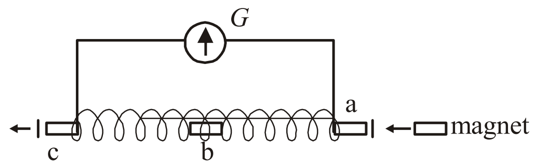
20 Electromagnetic Induction

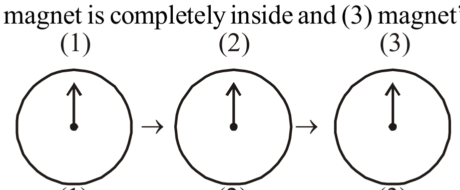
TOPIC 1 Magnetic Flux, Faraday's and Lenz's Law

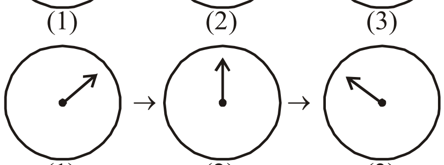
1. Two concentric circular coils, C_1 and C_2, are placed in the XY plane. C_1 has 500 turns, and a radius of 1 cm. C_2 has 200 turns and radius current 20 cm. C_2 carries a time dependent current $I(t) = (5t^2 - 2t + 3)$ A Where t is in s. The emf induced in C_1 (in mV), at the instant $t = 1$ s is $\frac{4}{x}$. The value of x is ______. **[NA Sep. 05, 2020 (I)]**

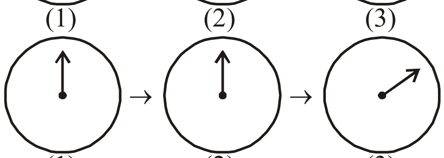
2. A small bar magnet is moved through a coil at constant speed from one end to the other. Which of the following series of observations will be seen on the galvanometer G attached across the coil ? **[Sep. 04, 2020 (I)]**

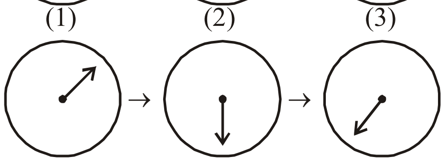


Three positions shown describe : (1) the magnet's entry (2) magnet is completely inside and (3) magnet's exit.

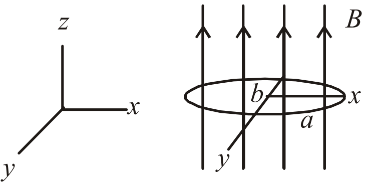
(a) 

(b) 

(c) 

(d) 

3. An elliptical loop having resistance R, of semi major axis a, and semi minor axis b is placed in a magnetic field as shown in the figure. If the loop is rotated about the x-axis with angular frequency ω, the average power loss in the loop due to Joule heating is : **[Sep. 03, 2020 (I)]**



(a) $\frac{\pi^2 a^2 b^2 B^2 \omega^2}{2R}$ (b) zero

(c) $\frac{\pi abB\omega}{R}$ (d) $\frac{\pi^2 a^2 b^2 B^2 \omega^2}{R}$

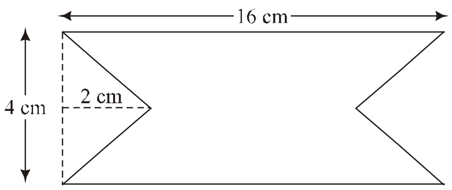
4. A uniform magnetic field B exists in a direction perpendicular to the plane of a square loop made of a metal wire. The wire has a diameter of 4 mm and a total length of 30 cm. The magnetic field changes with time at a steady rate $dB/dt = 0.032$ Ts^{-1}. The induced current in the loop is close to (Resistivity of the metal wire is $1.23 \times 10^{-8}\ \Omega$ m) **[Sep. 03, 2020 (II)]**

(a) 0.43 A (b) 0.61 A (c) 0.34 A (d) 0.53 A

5. A circular coil of radius 10 cm is placed in a uniform magnetic field of 3.0×10^{-5} T with its plane perpendicular to the field initially. It is rotated at constant angular speed about an axis along the diameter of coil and perpendicular to magnetic field so that it undergoes half of rotation in 0.2 s. The maximum value of EMF induced (in μV) in the coil will be close to the integer _____. **[NA Sep. 02, 2020 (I)]**

6. In a fluorescent lamp choke (a small transformer) 100 V of reverse voltage is produced when the choke current changes uniformly from 0.25 A to 0 in a duration of 0.025 ms. The self-inductance of the choke (in mH) is estimated to be ______. **[NA 9 Jan. 2020 I]**

7. At time $t = 0$ magnetic field of 1000 Gauss is passing perpendicularly through the area defined by the closed loop shown in the figure. If the magnetic field reduces linearly to 500 Gauss, in the next 5 s, then induced EMF in the loop is: **[NA 8 Jan. 2020 I]**



(a) 56μV (b) 28μV (c) 48μV (d) 36μV

8. Consider a circular coil of wire carrying constant current I, forming a magnetic dipole. The magnetic flux through an infinite plane that contains the circular coil and excluding the circular coil area is given by ϕ_i. The magnetic flux through the area of the circular coil area is given by ϕ_0. Which of the following option is correct? **[7 Jan. 2020 I]**

(a) $\phi_i = \phi_0$ (b) $\phi_i > \phi_0$ (c) $\phi_i < \phi_0$ (d) $\phi_i = -\phi_0$

9. A long solenoid of radius R carries a time (t) - dependent current $I(t) = I_0 t(1-t)$. A ring of radius $2R$ is placed coaxially near its middle. During the time interval $0 \le t \le 1$, the induced current (I_R) and the induced $EMF(V_R)$ in the ring change as: **[7 Jan. 2020 I]**

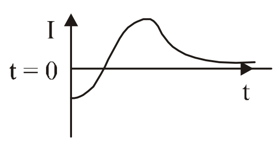
(a) Direction of I_R remains unchanged and V_R is maximum at $t = 0.5$
(b) At $t = 0.25$ direction of I_R reverses and V_R is maximum
(c) Direction of I_R remains unchanged and V_R is zero at $t = 0.25$
(d) At $t = 0.5$ direction of I_R reverses and V_R is zero

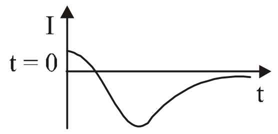
10. A loop ABCDEFA of straight edges has six corner points $A(0, 0, 0)$, $B\{5, 0, 0)$, $C(5, 5, 0)$, $D(0, 5, 0)$, $E(0, 5, 5)$ and $F(0, 0, 5)$. The magnetic field in this region is $\vec{B} = (3\hat{i} + 4\hat{k})$T. The quantity of flux through the loop $ABCDEFA$ (in Wb) is _________. **[NA 7 Jan. 2020 I]**

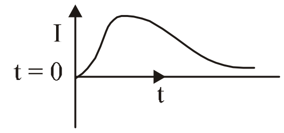
11. A planar loop of wire rotates in a uniform magnetic field. Initially, at $t = 0$, the plane of the loop is perpendicular to the magnetic field. If it rotates with a period of 10 s about an axis in its plane then the magnitude of induced emf will be maximum and minimum, respectively at: **[7 Jan. 2020 II]**

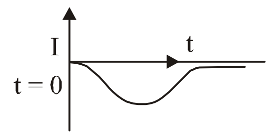
(a) 2.5 s and 7.5 s (b) 2.5 s and 5.0 s
(c) 5.0 s and 7.5 s (d) 5.0 s and 10.0 s

12. A very long solenoid of radius R is carrying current $I(t) = kte^{-\alpha t}$ ($k > 0$), as a function of time ($t \geq 0$). Counter clockwise current is taken to be positive. A circular conducting coil of radius 2R is placed in the equatorial plane of the solenoid and concentric with the solenoid. The current induced in the outer coil is correctly depicted, as a function of time, by: **[9 Apr. 2019 II]**

(a)


(b)


(c)


(d)


13. Two coils 'P' and 'Q' are separated by some distance. When a current of 3A flows through coil 'P', a magnetic flux of 10^{-3} Wb passes through 'Q'. No current is passed through 'Q'. When no current passes through 'P' and a current of 2A passes through 'Q', the flux through 'P' is: **[9 Apr. 2019 II]**

(a) 6.67×10^{-4} Wb (b) 3.67×10^{-3} Wb
(c) 6.67×10^{-3} Wb (d) 3.67×10^{-4} Wb

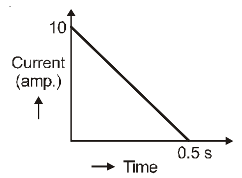
14. The self induced emf of a coil is 25 volts. When the current in it is changed at uniiform rate from 10 A to 25 A in 1s, the change in the energy of the inductance is: **[9 Jan. 2019 II]**

(a) 740 J (b) 437.5 J
(c) 540 J (d) 637.5 J

15. A conducting circular loop made of a thin wire, has area 3.5×10^{-3} m^2 and resistance 10Ω. It is placed perpendicular to a time dependent magnetic field B (t) = (0.4T) sin (50πt). The the net charge flowing through the loop during t = 0 s and t = 10 ms is close to: **[9 Jan. 2019 I]**

(a) 14mC (b) 7mC (c) 21mC (d) 6mC

16. In a coil of resistance 100 Ω, a current is induced by changing the magnetic flux through it as shown in the figure. The magnitude of change in flux through the coil is **[2017]**



(a) 250 Wb
(b) 275 Wb
(c) 200 Wb
(d) 225 Wb

17. A conducting metal circular–wire–loop of radius r is placed perpendicular to a magnetic field which varies with time as $B = B_0 e^{-t/\tau}$, where B_0 and τ are constants, at time t = 0. If the resistance of the loop is R then the heat generated in the loop after a long time ($t \to \infty$) is ; **[Online April 10, 2016]**

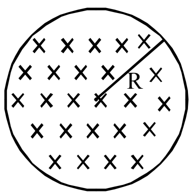
(a) $\dfrac{\pi^2 r^4 B_0^4}{2\tau R}$ (b) $\dfrac{\pi^2 r^4 B_0^2}{2\tau R}$

(c) $\dfrac{\pi^2 r^4 B_0^2 R}{\tau}$ (d) $\dfrac{\pi^2 r^4 B_0^2}{\tau R}$

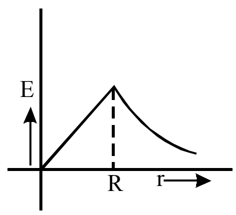
18. When current in a coil changes from 5 A to 2 A in 0.1 s, average voltage of 50 V is produced. The self - inductance of the coil is : **[Online April 10, 2015]**

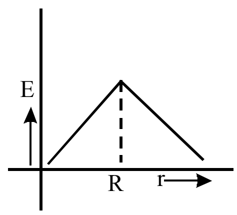
(a) 6 H (b) 0.67 H
(c) 3 H (d) 1.67 H

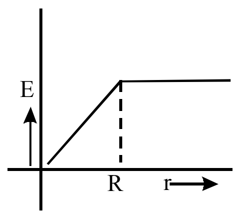
19. Figure shows a circular area of radius R where a uniform magnetic field $\vec{B}$ is going into the plane of paper and increasing in magnitude at a constant rate.

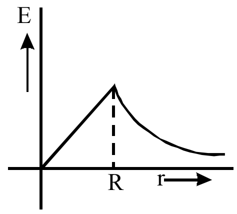


In that case, which of the following graphs, drawn schematically, correctly shows the variation of the induced electric field E(r)? **[Online April 19, 2014]**

(a)


(b)


(c)


(d)


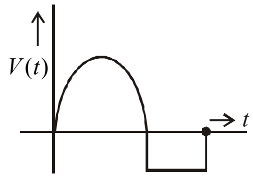
20. A coil of circular cross-section having 1000 turns and 4 cm^2 face area is placed with its axis parallel to a magnetic field which decreases by 10^{-2} Wb m^{-2} in 0.01 s. The e.m.f. induced in the coil is: **[Online April 11, 2014]**

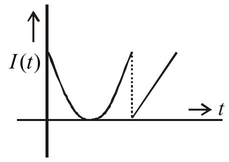
(a) 400mV (b) 200mV
(c) 4mV (d) 0.4mV

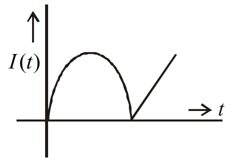
21. A circular loop of radius 0.3 cm lies parallel to amuch bigger circular loop of radius 20 cm. The centre of the small loop is on the axis of the bigger loop. The distance between their centres is 15 cm. If a current of 2.0 A flows through the smaller loop, then the flux linked with bigger loop is **[2013]**

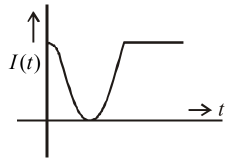
(a) 9.1×10^{-11} weber (b) 6×10^{-11} weber
(c) 3.3×10^{-11} weber (d) 6.6×10^{-9} weber

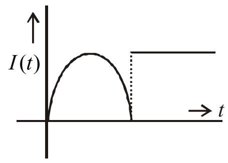
22. Two coils, X and Y, are kept in close vicinity of each other. When a varying current, $I(t)$, flows through coil X, the induced emf ($V(t)$) in coil Y, varies in the manner shown here. The variation of $I(t)$, with time, can then be represented by the graph labelled as graph : **[Online April 9, 2013]**



(A)


(B)


(C)


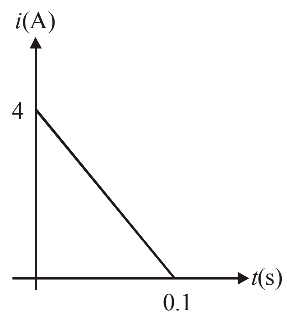
(D)


(a) A (b) C
(c) B (d) D

23. A coil is suspended in a uniform magnetic field, with the plane of the coil parallel to the magnetic lines of force. When a current is passed through the coil it starts oscillating; It is very difficult to stop. But if an aluminium plate is placed near to the coil, it stops. This is due to : **[2012]**

(a) developement of air current when the plate is placed
(b) induction of electrical charge on the plate
(c) shielding of magnetic lines of force as aluminium is a paramagnetic material.
(d) electromagnetic induction in the aluminium plate giving rise to electromagnetic damping.

24. Magnetic flux through a coil of resistance 10 Ω is changed by $\Delta\phi$ in 0.1 s. The resulting current in the coil varies with time as shown in the figure. Then $|\Delta\phi|$ is equal to (in weber) **[Online May 12, 2012]**



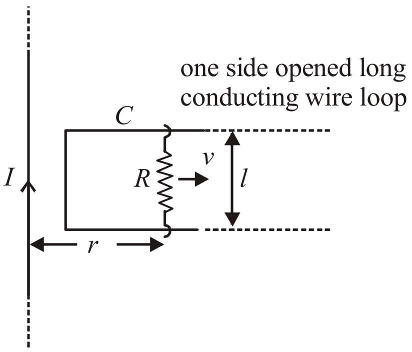
(a) 6 (b) 4
(c) 2 (d) 8

25. The flux linked with a coil at any instant 't' is given by $\phi = 10t^2 - 50t + 250$. The induced emf at $t = 3s$ is **[2006]**

(a) –190 V (b) –10 V
(c) 10 V (d) 190 V

TOPIC 2 Motional and Static EMI and Application of EMI

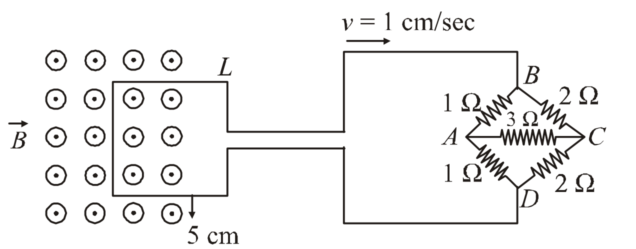
26. An infinitely long straight wire carrying current I, one side opened rectangular loop and a conductor C with a sliding connector are located in the same plane, as shown in the figure. The connector has length l and resistance R. It slides to the right with a velocity v. The resistance of the conductor and the self inductance of the loop are negligible. The induced current in the loop, as a function of separation r, between the connector and the straight wire is : **[Sep. 05, 2020 (II)]**



(a) $\frac{\mu_0}{4\pi}\frac{Ivl}{Rr}$ (b) $\frac{\mu_0}{\pi}\frac{Ivl}{Rr}$

(c) $\frac{2\mu_0}{\pi}\frac{Ivl}{Rr}$ (d) $\frac{\mu_0}{2\pi}\frac{Ivl}{Rr}$

27. The figure shows a square loop L of side 5 cm which is connected to a network of resistances. The whole setup is moving towards right with a constant speed of 1 cm s^{-1}. At some instant, a part of L is in a uniform magnetic field of 1 T, perpendicular to the plane of the loop. If the resistance of L is 1.7 &!, the current in the loop at that instant will be close to : **[12 Apr. 2019 I]**

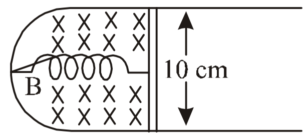


(a) 60μA (b) 170 μA
(c) 150 μA (d) 115 μA

28. The total number of turns and cross-section area in a solenoid is fixed. However, its length L is varied by adjusting the separation between windings. The inductance of solenoid will be proportional to: **[9 April 2019 I]**

(a) L (b) L^2 (c) 1/ L^2 (d) 1/L

29. A thin strip 10 cm long is on a U shaped wire of negligible resistance and it is connected to a spring of spring constant 0.5 Nm^{-1} (see figure). The assembly is kept in a uniform magnetic field of 0.1 T. If the strip is pulled from its equilibrium position and released, the number of oscillations it performs before its amplitude decreases by a factor of e is N. If the mass of strip is 50 grams, its resistance 10Ω and air drag negligible, N will be close to : **[8 April 2019 I]**



(a) 1000 (b) 50000 (c) 5000 (d) 10000

30. A 10 m long horizontal wire extends from North East to South West. It is falling with a speed of 5.0 ms^{-1}, at right angles to the horizontal component of the earth's magnetic field, of 0.3×10^{-4} Wb/m^2. The value of the induced emf in wire is : **[12 Jan. 2019 II]**

(a) 1.5×10^{-3} V (b) 1.1×10^{-3} V
(c) 2.5×10^{-3}V (d) 0.3×10^{-3} V

31. There are two long co-axial solenoids of same length l. The inner and outer coils have radii r_1 and r_2 and number of turns per unit length n_1 and n_2, respectively. The ratio of mutual inductance to the self-inductance of the inner-coil is : **[11 Jan. 2019 I]**

(a) $\frac{n_1}{n_2}$ (b) $\frac{n_2}{n_1}\cdot\frac{r_1}{r_2}$

(c) $\frac{n_2}{n_1}\cdot\frac{r_2^2}{r_1^2}$ (d) $\frac{n_2}{n_1}$

32. A copper wire is wound on a wooden frame, whose shape is that of an equilateral triangle. If the linear dimension of each side of the frame is increased by a factor of 3, keeping the number of turns of the coil per unit length of the frame the same, then the self inductance of the coil: **[11 Jan. 2019 II]**

(a) decreases by a factor of 9
(b) increases by a factor of 27
(c) increases by a factor of 3
(d) decreases by a factor of $9\sqrt{3}$

33. A solid metal cube of edge length 2 cm is moving in a positive y-direction at a constant speed of 6 m/s. There is a uniform magnetic field of 0.1 T in the positive z-direction. The potential difference between the two faces of the cube perpendicular to the x-axis, is: **[10 Jan. 2019 I]**

(a) 12 mV (b) 6 mV
(c) 1 mV (d) 2 mV

34. An insulating thin rod of length l has a linear charge density $\rho(x) = \rho_0 \frac{x}{l}$ on it. The rod is rotated about an axis passing through the origin ($x = 0$) and perpendicular to the rod. If the rod makes n rotations per second, then the time averaged magnetic moment of the rod is: **[10 Jan. 2019 I]**

(a) $\pi n \rho l^3$ (b) $\frac{\pi}{3} n \rho l^3$

(c) $\frac{\pi}{4} n \rho l^3$ (d) $n \rho l^3$

35. A coil of cross-sectional area A having n turns is placed in a uniform magnetic field B. When it is rotated with an angular velocity ω, the maximum e.m.f. induced in the coil will be **[Online April 16, 2018]**

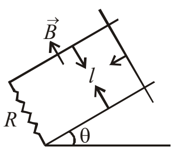
(a) nBAω (b) $\frac{3}{2}$nBAω

(c) 3nBAω (d) $\frac{1}{2}$nBAω

36. An ideal capacitor of capacitance 0.2 μF is charged to a potential difference of 10V. The charging battery is then disconnected. The capacitor is then connected to an ideal inductor of self inductance 0.5mH. The current at a time when the potential difference across the capacitor is 5V, is: **[Online April 15, 2018]**

(a) 0.17A (b) 0.15A (c) 0.34A (d) 0.25A

37. A copper rod of mass m slides under gravity on two smooth parallel rails, with separation 1 and set at an angle of θ with the horizontal. At the bottom, rails are joined by a resistance R. There is a uniform magnetic field B normal to the plane of the rails, as shown in the figure. The terminal speed of the copper rod is: **[Online April 15, 2018]**



(a) $\frac{mgR\cos\theta}{B^2l^2}$ (b) $\frac{mgR\sin\theta}{B^2l^2}$

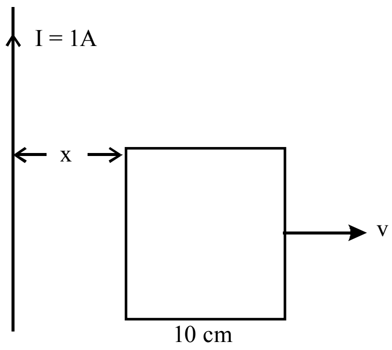
(c) $\frac{mgR\tan\theta}{B^2l^2}$ (d) $\frac{mgR\cot\theta}{B^2l^2}$

38. At the centre of a fixed large circular coil of radius R, a much smaller circular coil of radius r is placed. The two coils are concentric and are in the same plane. The larger coil carries a current I. The smaller coil is set to rotate with a constant angular velocity ω about an axis along their common diameter. Calculate the emf induced in the smaller coil after a time t of its start of rotation. **[Online April 15, 2018]**

(a) $\frac{\mu_0 I}{2R}\omega r^2 \sin\omega t$ (b) $\frac{\mu_0 I}{4R}\omega\pi r^2 \sin\omega t$

(c) $\frac{\mu_0 I}{2R}\omega\pi r^2 \sin\omega t$ (d) $\frac{\mu_0 I}{4R}\omega r^2 \sin\omega t$

39. A square frame of side 10 cm and a long straight wire carrying current 1 A are in the plate of the paper. Starting from close to the wire, the frame moves towards the right with a constant speed of 10 ms^{-1} (see figure).

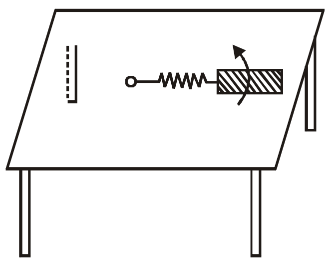


The e.m.f induced at the time the left arm of the frame is at x = 10 cm from the wire is: **[Online April 19, 2014]**

(a) 2 μV (b) 1 μV

(c) 0.75 μV (d) 0.5 μV

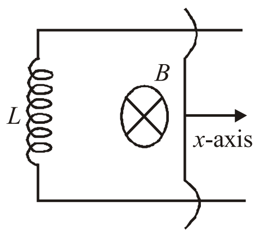
40. A metallic rod of length 'ℓ' is tied to a string of length 2ℓ and made to rotate with angular speed ω on a horizontal table with one end of the string fixed. If there is a vertical magnetic field 'B' in the region, the e.m.f. induced across the ends of the rod is **[2013]**

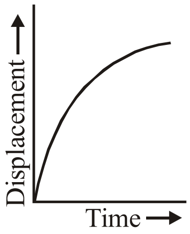


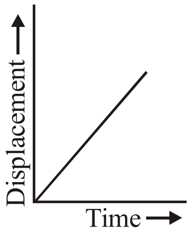
(a) $\frac{2B\omega\ell^2}{2}$ (b) $\frac{3B\omega\ell^2}{2}$

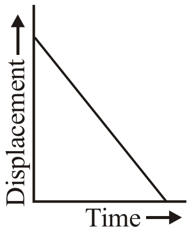
(c) $\frac{4B\omega\ell^2}{2}$ (d) $\frac{5B\omega\ell^2}{2}$

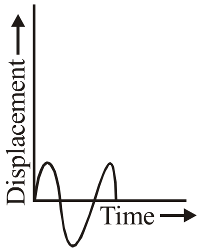
41. A coil of self inductance L is connected at one end of two rails as shown in figure. A connector of length l, mass m can slide freely over the two parallel rails. The entire set up is placed in a magnetic field of induction B going into the page. At an instant $t = 0$ an initial velocity v_0 is imparted to it and as a result of that it starts moving along x-axis. The displacement of the connector is represented by the figure. **[Online May 19, 2012]**



(a) 

(b) 

(c) 

(d) 

42. This question has Statement 1 and Statement 2. Of the four choices given after the Statements, choose the one that best describes the two Statements.

Statement 1: Self inductance of a long solenoid of length L, total number of turns N and radius r is less than $\frac{\pi\mu_0 N^2 r^2}{L}$.

Statement 2: The magnetic induction in the solenoid in Statement 1 carrying current I is $\frac{\mu_0 NI}{L}$ in the middle of the solenoid but becomes less as we move towards its ends. **[Online May 19, 2012]**

(a) Statement 1 is true, Statement 2 is false.
(b) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1.
(c) Statement 1 is false, Statement 2 is true.
(d) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1.

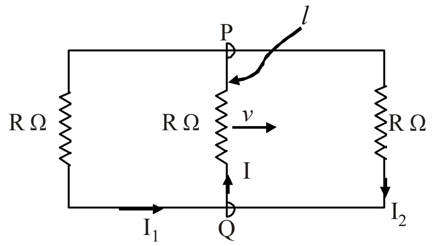
43. A boat is moving due east in a region where the earth's magnetic field is 5.0×10^{-5} NA^{-1} m^{-1} due north and horizontal. The boat carries a vertical aerial 2 m long. If the speed of the boat is 1.50 ms^{-1}, the magnitude of the induced emf in the wire of aerial is: **[2011]**

(a) 0.75 mV (b) 0.50 mV
(c) 0.15 mV (d) 1 mV

44. A horizontal straight wire 20 m long extending from east to west falling with a speed of 5.0 m/s, at right angles to the horizontal component of the earth's magnetic field 0.30×10^{-4} Wb/m^2. The instantaneous value of the e.m.f. induced in the wire will be **[2011 RS]**

(a) 3 mV (b) 4.5 mV (c) 1.5 mV (d) 6.0 mV

45. A rectangular loop has a sliding connector PQ of length l and resistance R Ω and it is moving with a speed v as shown. The set-up is placed in a uniform magnetic field going into the plane of the paper. The three currents I_1, I_2 and I are **[2010]**



(a) $I_1 = -I_2 = \frac{Blv}{6R},\ I = \frac{2Blv}{6R}$

(b) $I_1 = I_2 = \frac{Blv}{3R}, I = \frac{2Blv}{3R}$

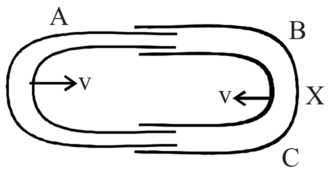
(c) $I_1 = I_2 = I = \frac{Blv}{R}$

(d) $I_1 = I_2 = \frac{Blv}{6R},\ I = \frac{Blv}{3R}$

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

(a) $2.4\pi \times 10^{-5}$ H (b) $4.8\pi \times 10^{-4}$ H
(c) $4.8\pi \times 10^{-5}$ H (d) $2.4\pi \times 10^{-4}$ H

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



(a) $-Blv$ (b) Blv
(c) 2 Blv (d) zero

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

(a) 5 mV (b) 50 μV
(c) 5 μV (d) 50 mV

49. A coil having n turns and resistance $R\Omega$ is connected with a galvanometer of resistance $4R\Omega$. This combination is moved in time t seconds from a magnetic field W_1 weber to W_2 weber. The induced current in the circuit is **[2004]**

(a) $-\frac{(W_2 - W_1)}{Rnt}$ (b) $-\frac{n(W_2 - W_1)}{5\ Rt}$

(c) $-\frac{(W_2 - W_1)}{5\ Rnt}$ (d) $-\frac{n(W_2 - W_1)}{Rt}$

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

(a) the rates at which currents are changing in the two coils

(b) relative position and orientation of the two coils

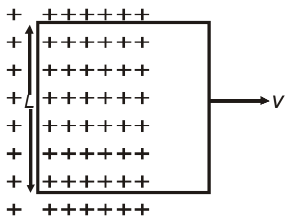
(c) the materials of the wires of the coils

(d) the currents in the two coils

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

(a) 0.2 H (b) 0.4 H (c) 0.8 H (d) 0.1 H

52. A conducting square loop of side L and resistance R moves in its plane with a uniform velocity v perpendicular to one of its sides. A magnetic induction B constant in time and space, pointing perpendicular and into the plane at the loop exists everywhere with half the loop outside the field, as shown in figure. The induced emf is **[2002]**



(a) zero (b) RvB (c) vBL/R (d) vBL

Hints & Solutions

1. **(5)**
For coil C_1, No. of turns $N_1 = 500$ and radius, $r = 1$ cm.
For coil C_2, No. of turns $N_2 = 200$ and radius, $R = 20$ cm

$$I = (5t^2 - 2t + 3) \Rightarrow \frac{dI}{dt} = (10t - 2)$$

$$\phi_{\text{small}} = BA = \left(\frac{\mu_0 I N_2}{2R}\right)(\pi r^2)$$

Induced emf in small coil,

$$e = \frac{d\phi}{dt} = \left(\frac{\mu_0 N_2}{2r}\right)\pi r^2 N_1 \frac{di}{dt} = \left(\frac{\mu_0 N_1 N_2 \pi r^2}{2R}\right)(10t - 2)$$

At $t = 1$ s

$$e = \left(\frac{\mu_0 N_1 N_2 \pi r^2}{2R}\right)8 = 4\frac{\mu_0 N_1 N_2 \pi r^2}{R}$$

$$= \frac{4(4\pi)10^{-7} \times 200}{20} \times 500 \times \frac{10^{-4}}{10^{-2}}\pi$$

$$= 80 \times \pi^2 \times 10^{-7} \times 10 \times 10^2 \times 10^{-2}$$

$$= 8 \times 10^{-4} \text{ volt} = 0.8 \text{ mV} = \frac{4}{x} \Rightarrow x = 5.$$

2. **(b) Case (a) :** When bar magnet is entering with constant speed, flux (ϕ) will change and an e.m.f. is induced, so galvanometer will deflect in positive direction.
Case (b) : When magnet is completely inside, flux (ϕ) will not change, so galvanometer will show null deflection.
Case (c) : When bar magnet is making on exit, again flux (ϕ) will change and an e.m.f. is induced in opposite direction so galvanometer will deflect in negative direction i.e. reverse direction.

3. **(a)** As we know, emf $\varepsilon = NAB\omega\cos\omega t$, Here $N = 1$
Average power,

$$<P> = <\frac{\varepsilon^2}{R}> = <\frac{A^2B^2\omega^2\cos^2\omega t}{R}> = \frac{A^2B^2\omega^2}{R}\left(\frac{1}{2}\right)$$

Therefore average power loss in the loop due to Joule heating

$$<P> = \frac{\pi^2 a^2 b^2 B^2}{2R}(\omega^2)$$

4. **(b)** Given,
Length of wire, $l = 30$ cm
Radius of wire, $r = 2$ mm $= 2 \times 10^{-3}$ m
Resistivity of metal wire, $\rho = 1.23 \times 10^{-8}\,\Omega$m

Emf generated, $|e| = \frac{d\phi}{dt} = \frac{dB}{dt}(A)$ $\quad (\because \phi = \text{B.A.})$

Current, $i = \frac{e}{R}$

But, resistance of wire, $R = \rho\frac{l}{A}$

$$\therefore i = \left|\frac{dB}{dt}\right|\frac{(A)^2}{\rho l} = \frac{0.032 \times \{\pi \times 2 \times 10^{-3}\}^2}{1.23 \times 10^{-8} \times 0.3} = 0.61 \text{ A}.$$

5. **(15)**
Here, $B = 3.0 \times 10^{-5}$ T, $R = 10$ cm $= 0.1$ m

$$\omega = \frac{2\pi}{2T} = \frac{\pi}{0.2}$$

Flux as a function of time $\phi = \vec{B} \cdot \vec{A} = AB\cos(\omega t)$

Emf induced, $e = \frac{-d\phi}{dt} = AB\omega\sin(\omega t)$

Max. value of Emf $= AB\omega = \pi R^2 B\omega$

$$= 3.14 \times 0.1 \times 0.1 \times 3 \times 10^{-5} \times \frac{\pi}{0.2}$$

$$= 15 \times 10^{-6} \text{ V} = 15\ \mu\text{V}$$

6. **(10)** Given $dI = 0.25 - 0 = 0.25$ A
$dt = 0.025$ ms
Induced voltage
$E_{ind} = 100$ v
Self-inductance, L = ?

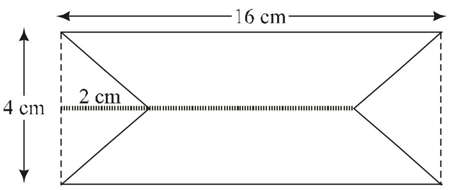
Using, $E_{\text{ind}} = \frac{\Delta\phi}{\Delta t} \Rightarrow 100 = \frac{L(0.25 - 0)}{.025 \times 10^{-3}}$

$\Rightarrow$ L $= 10^{-3}$ H $= 10$ mH

7. **(a)** According to question, $dB = 1000 - 500 = 500$ gauss $= 500 \times 10^{-4}T$
Time $dt = 5$ s
Using faraday law

Induced EMF, $e = \left|-\frac{d\phi}{dt}\right| = \left|A\frac{dB}{dt}\right|$

$$\frac{dB}{dt} = \frac{1000 - 500}{5} \times 10^{-4} = 10^{-2} \text{ T/sec}$$



Area, A = ar of ▭ -2 ar of $\Delta = (16 \times 4 - 2 \times \text{Area of triangle})\text{cm}^2$

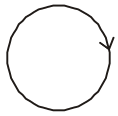
$$= \left(64 - 2 \times \frac{1}{2} \times 2 \times 4\right)\text{cm}^2$$

$= 56 \times 10^{-4}$ m^2

$\therefore \varepsilon_{induced} = \left|A\frac{dB}{dt}\right| = 56\times10^{-4}\times10^{-2} = 56\times10^{-6}V = 56\mu V$

8. (d) As magnetic field lines form close loop, hence every magnetic field line creating magnetic flux through the inner region (ϕ_i) must be passing through the outer region. Since flux in two regions are in opposite region.

$\therefore \quad \phi_i = -\phi_0$



9. (d) According to question,

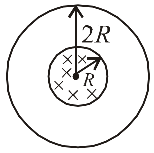
$I(t) = I_0 t(1-t)$

$\therefore I = I_0 t - I_0 t^2$

$\phi = B.A$

$\phi = (\mu_0 nI)\times(\pi R^2)$

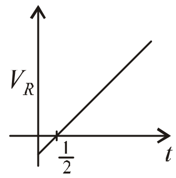
$(\because B = \mu_0 nI \text{ and } A = \pi R^2)$



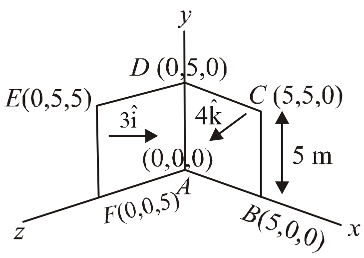
$V_R = \frac{-d\phi}{dt}$

$V_R = \mu_0 n\pi R^2(I_0 - 2I_0 t)$

$\Rightarrow V_R = 0$ at $t = \frac{1}{2}s$



10. (175.00)



Flux through the loop ABCDEFA,

$\phi = \vec{B}.\vec{A} = (3\hat{i}+4\hat{k}).(25\hat{i}+25\hat{k})$

$\Rightarrow \phi = (3\times25)+(4\times25) = 175$ weber

11. (b) We have given, time period, $T = 10$s

$\therefore$ Angular velocity, $\omega = \frac{2\pi}{10} = \frac{\pi}{5}$

Magnetic flux, $\phi(t) = BA\cos\omega t$

Emf induced, $E = \frac{-d\phi}{dt} = BA\omega\sin\omega t = BA\omega\sin(\omega t)$

Induced emf, $|\varepsilon|$ is maximum when $\omega t = \frac{\pi}{2}$

$\Rightarrow t = \frac{\frac{\pi}{2}}{\frac{\pi}{5}} = 2.5$ s

For induced emf to be minimum i.e zero

$\omega t = \pi \quad \Rightarrow \quad t = \frac{\pi}{\frac{\pi}{5}} = 5\ s$

$\therefore$ Induced emf is zero at t = 5 s

12. (a) $Q = BA$

$= (\mu_0 n_i)A$

$= \mu_0 n(kt e^{-\alpha t})A$

$e = -\frac{dQ}{dt} = -\mu_0 nAk\frac{d}{dt}(te^{-\alpha t})$

$= -\mu_0 nAk[t(-1)e^{-\alpha t} + e^{-\alpha t}\times1]$

$= -\mu_0 nAk[e^{-\alpha t}(1-t)]$

$i = \frac{e}{R} = \frac{-\mu_0 nAk}{R}[e^{-\alpha t}(1-t)]$

At $t = 0$, $i \Rightarrow -$ve

13. (a) $Q_{coil} = (NQ) \propto i$

So, $\frac{Q_1}{Q_2} = \frac{i_1}{i_2} = \frac{3}{2}$

or $Q_2 = \frac{2}{3}Q_1 = \frac{2}{3}\times10^{-3} = 6.67\times10^{-4}$ Wb

14. (b) According to faraday's law of electromagnetic induction, $e = \frac{-d\phi}{dt}$

$L\times\frac{di}{dt} = 25 \Rightarrow L\times\frac{15}{1} = 25$ or $L = \frac{5}{3}H$

Change in the energy of the inductance,

$\Delta E = \frac{1}{2}L(i_1^2 - i_2^2) = \frac{1}{2}\times\frac{5}{3}\times(25^2 - 10^2)$

$= \frac{5}{6}\times525 = 437.5J$

15. [Bonus]

Net charge $Q = \frac{\Delta\phi}{R} = \frac{1}{10}A(B_f - B_i) = \frac{1}{10}\times3.5\times10^{-3}$

$\left(0.4\sin\frac{\pi}{2} - 0\right)$

$= \frac{1}{10}(3.5\times10^{-3})(0.4-0)$

$= 1.4\times10^{-4}$

No option matches, So it should be a bonus.

16. (a) According to Faraday's law of electromagnetic induction, $\varepsilon = \frac{d\phi}{dt}$

Also, $\varepsilon = iR$

$\therefore \quad iR = \frac{d\phi}{dt} \quad \Rightarrow \quad \int d\phi = R\int i\,dt$

Magnitude of change in flux ($d\phi$) = R × area under current vs time graph

or, $d\phi = 100 \times \frac{1}{2} \times \frac{1}{2} \times 10 = 250$ Wb

17. **(b)** Electric flux is given by
$\phi = B.A$

$$\phi = B_0 \pi r^2 e^{-t/\tau} \qquad \left(\because B = B_0 e^{-t/\tau}\right)$$

Induced E.m.f. $\varepsilon = \frac{d\phi}{dt} = \frac{B_0 \pi r^2}{\tau^2} e^{-t/\tau}$

Heat $= \int_0^{\infty} \frac{\varepsilon^2}{R} = \frac{\pi^2 r^4 B_0^2}{2\tau R}$

18. **(d)** According to Faraday's law of electromagnetic induction,

Induced emf, $e = \frac{Ldi}{dt}$

$$50 = L\left(\frac{5-2}{0.1\text{sec}}\right)$$

$$\Rightarrow \quad L = \frac{50 \times 0.1}{3} = \frac{5}{3} = 1.67 \text{ H}$$

19. **(a)** Inside the sphere field varies linearly i.e., $E \propto r$ with distance and outside varies according to $E \propto \frac{1}{r^2}$

Hence the variation is shown by curve (a)

20. **(a)** **Given:** No. of turns $N = 1000$
Face area, $A = 4 \text{ cm}^2 = 4 \times 10^{-4} \text{ m}^2$
Change in magnetic field,
$\Delta B = 10^{-2}$ wbm^{-2}
Time taken, $t = 0.01\text{s} = 10^{-2}$ sec
Emf induced in the coil $e = ?$
Applying formula,

Induced emf, $e = \frac{-d\phi}{dt} = N\left(\frac{\Delta B}{\Delta t}\right) A\cos\theta$

$$= \frac{1000 \times 10^{-2} \times 4 \times 10^{-4}}{10^{-2}} = 400 \text{ mV}$$

21. **(a)** As we know, Magnetic flux, $\phi = B.A$

$$\frac{\mu_0(2)(20 \times 10^{-2})^2}{2[(0.2)^2 + (0.15)^2]} \times \pi(0.3 \times 10^{-2})^2$$

On solving
$= 9.216 \times 10^{-11} = 9.2 \times 10^{-11}$ weber

22. **(a)** Induced emf

$$\varepsilon \propto \frac{-di}{dt}$$

23. **(d)** Because of the Lenz's law of conservation of energy. Length of straignt wire, $\ell = 20$m Earth's Magneti field, $B = 0.30 \times 10^{-4}$ Wb/m^2.

24. **(c)** As $e = \frac{\Delta\phi}{\Delta t}$ or $Ri = \frac{\Delta\phi}{\Delta t}$ $\quad (\because e = Ri)$

$\Rightarrow \Delta\phi = R(i.\Delta t)$
$= R$ × area under $i - t$ graph
$= 10 \times \frac{1}{2} \times 4 \times 0.1 = 2$ weber

25. **(b)** Electric flux, $\phi = 10t^2 - 50t + 250$

Induced emf, $e = -\frac{d\phi}{dt} = -(20t - 50)$
$e_{t=3} = -10\ V$

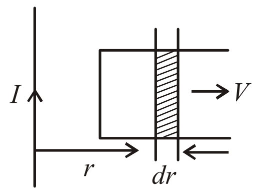
26. **(d)** Magnetic field at a distance r from the wire

$$B = \frac{\mu_0 I}{2\pi r}$$

Magnetic flux for small displacement dr,

$\phi = B \cdot A = Bldr \qquad [\because A = l\,dr$ and $B.A = BA\cos 0°]$

$$\Rightarrow \phi = \frac{\mu_0 I}{2\pi r} l\,dr$$



Emf, $e = \frac{d\phi}{dt} = \frac{\mu_0 Il}{2\pi r} \cdot \frac{dr}{dt} \Rightarrow e = \frac{\mu_0}{2\pi} \cdot \frac{Ivl}{r}$

Induce current in the loop, $i = \frac{e}{R} = \frac{\mu_0}{2\pi} \cdot \frac{Ivl}{Rr}$

27. **(b)** Induced emf,
$e = Bv\ell = 1 \times 10^{-2} \times 0.05 = 5 \times 10^{-4}$ V
Equivalent resistance,

$$R = \frac{4 \times 2}{4 + 2} + 1.7 = \frac{4}{3} + 1.7 \simeq 3\,\Omega$$

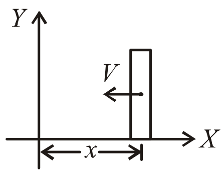
Current, $i = \frac{e}{R} = \frac{5 \times 10^{-4}}{3} \simeq 170\ \mu$A

28. **(d)** Inductance $= \frac{\mu_0 N^2 A}{L}$

29. **(c)** Force on the strip when it is at stretched position x from mean position is

$$F = -kx - iIB = -kx - \frac{BIv}{R} \times IB$$

$$F = -kx - \frac{B^2 I^2}{R} \times v$$



Above expression shows that it is case of damped oscillation, so its amplitude can be given by

$$\Rightarrow A = A_0 e^{-\frac{bt}{2m}}$$

$$\Rightarrow \frac{A_0}{e} = A_0 e^{-\frac{bt}{2m}} \quad \text{[as per question } A = \frac{A_0}{e}\text{]}$$

$$\Rightarrow t = \frac{2m}{\left(\frac{B^2 I^2}{R}\right)} = \frac{2 \times 50 \times 10^{-3} \times 10}{0.01 \times 0.01}$$

Given, $m = 50 \times 10^{-3}$ kg
$B = 0.1$ T
$l = 0.1$ m
$R = 10\ \Omega$
$k = 0.5$ N

Time period, $T = 2\pi\sqrt{\frac{m}{k}} \simeq 2$ s

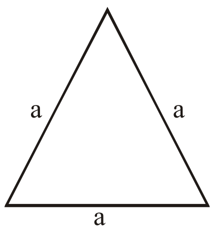
so, required number of oscillations,

$$N = \frac{10000}{2} = 5000$$

30. (a) Induced emf, $\varepsilon = Bv\ell$
$= 0.3 \times 10^{-4} \times 5 \times 10$
$= 1.5 \times 10^{-3}$ V

31. (d) The rate of mutual inductance is given by
$M = \mu_0 n_1 n_2 \pi r_1^2$ ...(i)
The rate of self inductance is given by
$L = \mu_0 n_1^2 \pi r_1^2$ ...(ii)
Dividing (i) by (ii) $\Rightarrow \frac{M}{L} = \frac{n_2}{n_1}$

32. (c) As total length L of the wire will remain constant
$L = (3a) N$ (N = total turns)
and length of winding = (d) N



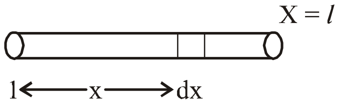
(d = diameter of wire)
self inductance = $\mu_0 n^2 A\ell$

$$= \mu_0 n^2 \left(\frac{\sqrt{3}a^2}{4}\right) dN$$

$\propto a^2 N \propto a$ [as $N = L/3a \Rightarrow N \propto \frac{1}{a}$]
Now 'a' increased to '3a'
So self inductance will become 3 times

33. (a) Potential difference between two faces perpendicular to x-axis
$= lV.B = 2 \times 10^{-2}(6 \times 0.1) = 12$ mV

34. (c)



Magnetic moment, M = NIA
$dQ = \rho\, dx$

$$dI = \frac{dQ}{2\pi}.\omega$$

$dM = dI \times A$

$$= \frac{\omega}{2\pi}.\frac{\rho_0}{\ell}.x\pi x^2\, dx \Rightarrow M = \frac{\rho_0}{\ell} n\pi \int_0^{\ell} x^3\, dx$$

$$= \frac{\pi}{4}.n\rho\ell^3$$

35. (a) Induced emf in a coil, $e = -\frac{d\phi}{dt} = NBA \sin \omega t$
Also, $e = e_0 \sin \omega t$
$\therefore$ Maximum emf induced, $e_0 = nBA\omega$

36. (a) Given: Capacitance, $C = 0.2\ \mu F = 0.2 \times 10^{-6}$ F
Inductance $L = 0.5$ mH $= 0.5 \times 10^{-3}$ H
Current I = ?
Using energy conservation

$$\frac{1}{2}CV^2 = \frac{1}{2}CV_1^2 + \frac{1}{2}LI^2$$

$$\frac{1}{2} \times 0.2 \times 10^{-6} \times 10^2 + 0$$

$$= \frac{1}{2} \times 0.2 \times 10^{-6} \times 5^2 + \frac{1}{2} \times 0.5 \times 10^{-3} I^2$$

$\therefore I = \sqrt{3} \times 10^{-1}$ A $= 0.17$ A

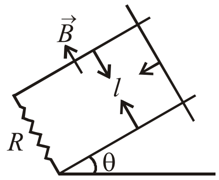
37. (b) From Faraday's law of electomagnetic induction,

$$e = \frac{d\phi}{dt} = \frac{d(BA)}{lt} = \frac{d(Bll)}{dt}$$

$$= \frac{Bdl \times l}{dt} = BVl$$

Also, $F = ilB = \left(\frac{BV}{R}\right)(l^2 B) = \frac{B^2 l^2 V}{R}$

At equilibrium



$$mg \sin\theta = \frac{B^2 lV}{R} \Rightarrow V = \frac{mgR\sin\theta}{B^2 l^2}$$

38. **(c)** According to Faraday's law of electromagnetic induction,

$$e=-\frac{d\phi}{dt} \text{ and } \phi=BA\cos\omega t=B\pi r^2\cos\omega t$$

$$\Rightarrow \quad e=-\frac{d}{dt}(\pi r^2 B\cos\omega t)=\pi r^2 B\sin\omega t(\omega)$$

$$\therefore \quad e=\frac{\mu_0 I}{2R}\pi\omega r^2\sin\omega t \quad \left(\because B=\frac{\mu_0 I}{2R}\right)$$

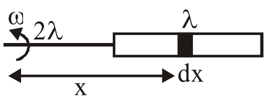
39. **(b)** In the given question,
Current flowing through the wire, I = 1A
Speed of the frame, v = 10 ms^{-1}
Side of square loop, l = 10 cm
Distance of square frame from current carrying wires x = 10 cm.
We have to find, e.m.f induced e = ?
According to Biot-Savart's law

$$B=\frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{x^2}$$

$$=\frac{4\pi\times10^{-7}}{4\pi}\times\frac{1\times10^{-1}}{\left(10^{-1}\right)^2}$$

$= 10^{-6}$
Induced e.m.f. e = Blv
$= 10^{-6}\times10^{-1}\times10 = 1\ \mu v$

40. **(d)** Here, induced e.m.f.



$$e=\int_{2\ell}^{3\ell}(\omega x)Bdx=B\omega\frac{[(3\ell)^2-(2\ell)^2]}{2}$$

$$=\frac{5B\ell^2\omega}{2}$$

41. **(d)**

42. **(b)** Self inductance of a long solenoid is given by

$$L=\frac{\mu_0 N^2 A}{l}$$

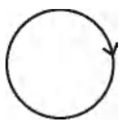
Magnetic field at the centre of solenoid

$$B=\frac{\mu_0 NI}{l}$$

So both the statements are correct and statement 2 is correct explanation of statement 1

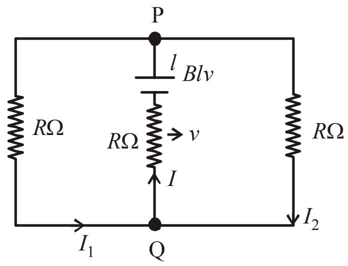
43. **(d)** As magnetic field lines form close loop, hence every magnetic field line creating magnetic flux through the inner region (ϕ_i) must be passing through the outer region. Since flux in two regions are in opposite region.

$\therefore\ \phi_i=-\phi_0$



44. **(a)** Induced, emF, $\varepsilon = Bv\ell$
$= 0.3\times10^{-4}\times5\times20$
$= 3\times10^{-3}$ V = 3 mV.

45. **(b)** Due to the movement of resistor R, an emf equal to Blv will be induced in it as shown in figure clearly,



$I=I_1+I_2$ Also, $I_1=I_2$
Solving the circuit,

we get $I_1=I_2=\dfrac{Blv}{3R}$

and $I=2I_1=\dfrac{2Blv}{3R}$

46. **(d)** Given, Area of cross-section of pipe,
A = 10 cm^2
Length of pipe, ℓ = 20 cm

$$M=\frac{\mu_0 N_1 N_2 A}{\ell}$$

$$=\frac{4\pi\times10^{-7}\times300\times400\times100\times10^{-4}}{0.2}$$

$$M=\frac{\mu_0 N_1 N_2 A}{\ell}$$

$= 2.4\pi\times10^{-4}$ H

47. **(c)** Relative velocity of the tube of width l,
$= v-(-v)\ v=2v$
$\therefore$ Induced emf. $= B.l\,(2v)$

48. **(b)** Given, length of conductor ℓ = 1m,
Angular speed, ω = 5 rad/s,
Magnetic field, $B = 0.2\times10^{-4}\ T$
EmF generated between two ends of conductor

$$\varepsilon=\frac{B\omega l^2}{2}=\frac{0.2\times10^{-4}\times5\times1}{2}=50\mu V$$

49. **(b)** $\dfrac{\Delta\phi}{\Delta t}=\dfrac{(W_2-W_1)}{t}$

$$R_{tot}=(R+4R)\Omega=5R\Omega$$

$$i=\frac{nd\phi}{R_{tot}dt}=\frac{-n(W_2-W_1)}{5Rt}$$

($\because W_2$ & W_1 are magnetic flux)

50. **(b)** Mutual inductance depends on the relative position and orientation of the two coils.

51. **(d)** Induced emf,

$$e = -\frac{\Delta\phi}{\Delta t} = \frac{-\Delta(LI)}{\Delta t} = -L\frac{\Delta I}{\Delta t}$$

$$\therefore\ |e| = L\frac{\Delta I}{\Delta t}$$

$$\Rightarrow\ 8 = L \times \frac{[2-(-2)]}{0.05}$$

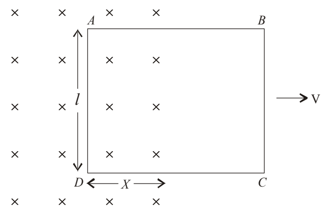
$$\Rightarrow\ L = \frac{8 \times 0.05}{4} = 0.1\text{H}$$

52. **(d)** As the side BC is outside the field, no emf is induced across BC. Further, sides AB and CD are not cutting any flux. So, they will not centribute in flux.

Only side AD is cutting the flux 50 emf will be induced due to AD only.

The induced emf is

$$e = \frac{-d\phi}{dt} = -\frac{d(\vec{B}\cdot\vec{A})}{dt} = \frac{-d(BA\cos 0^{o})}{dt}$$



$$\therefore\ e = -B\frac{dA}{dt} = -B\frac{d(\ell \times x)}{dt}$$

$$\therefore\ e = -B\ell\frac{dx}{dt} = -B\ell v$$