ELECTROMAGNETIC INDUCTION

IMPORTANT FORMULAE

1. **Magnetic flux** $\phi_B = \vec{B}.\vec{A} = BA\cos\theta$

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

2. **Induced emf in a coil** $\varepsilon = -N\dfrac{\Delta\phi}{\Delta t}$

3. **EMF induced in a moving conductor,** $\varepsilon = Bvl$

   where B, v, l are mutually perpendicular

4. **Magnetic flux** $\phi = LI$

   where L is the coefficient of self-induction.

5. **If L is self inductance, emf induced** $\varepsilon = -L\dfrac{\Delta I}{\Delta t}$

6. **Self inductance of a solenoid**

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

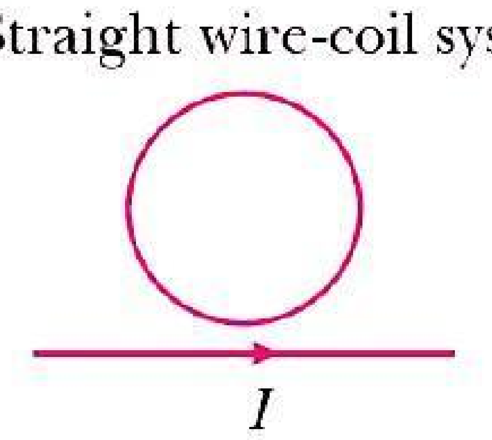
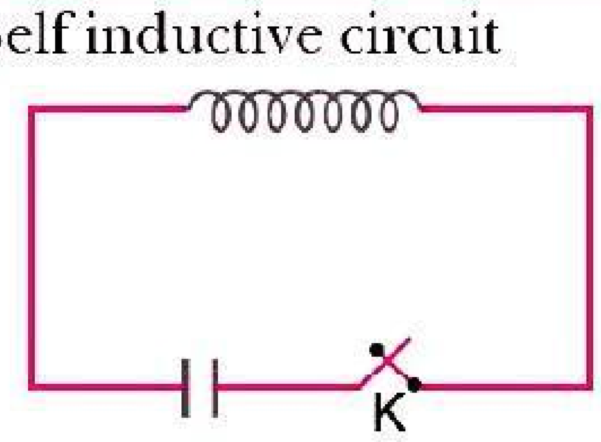
7. **Mutual Inductance** $E_2 = -M\dfrac{\Delta I}{\Delta t}$

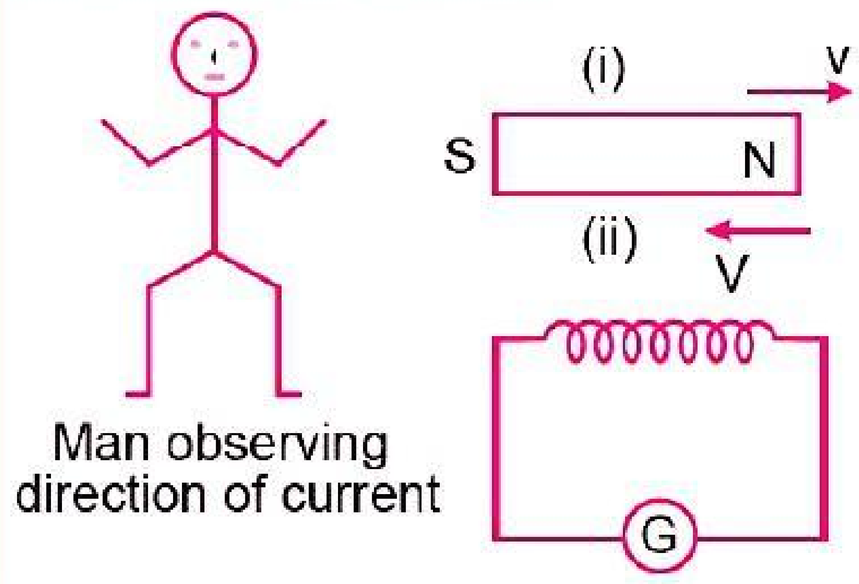
8. **Mutual inductance of solenoid coil system** $M = \dfrac{\mu_0 N_1 N_2 A}{l}$

   where N_1 = number of turns/metre in solenoid, N_2 = number of turns in coil.

9. **Energy stored in inductance** $U_m = \dfrac{1}{2}LI^2 = \dfrac{1}{2}\phi I$

Direction of Current Induced in Some Cases

	System	Primary Current	Induced Current
1.	Straight wire-coil system 	(*i*) Current increasing (*ii*) Current decreasing	Clockwise current Anticlockwise current
2.	Self inductive circuit 	(*i*) Key is pressed (*ii*) Key is released	Opposite to direction of main currents In the direction of main current

3.	Magnetic-coil system 	(*ii*) North pole approaching coil (*ii*) North pole receding coil	Anticlockwise current Clockwise current

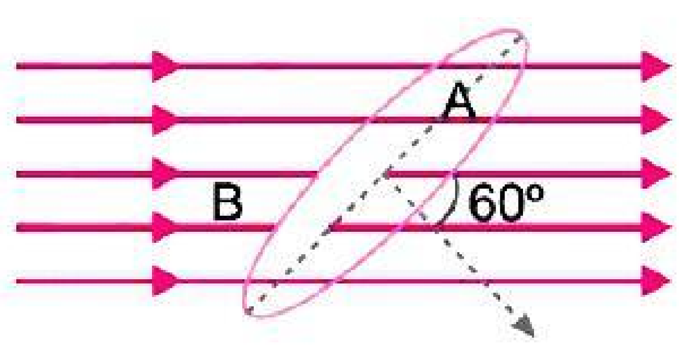
MULTIPLE CHOICE QUESTIONS

Choose and write the correct option in the following questions.

1. **Whenever the flux linked with a circuit changes, there is an induced emf in the circuit. This emf in the circuit lasts**
   (*a*) for a very short duration
   (*b*) for a long duration
   (*c*) forever
   (*d*) as long as the magnetic flux in the circuit changes.

2. **The area of a square shaped coil is 10^{-2} m^2. Its plane is perpendicular to a magnetic field of strength 10^{-3} T. The magnetic flux linked with the coil is**
   (*a*) 10 Wb (*b*) 10^{-5} Wb (*c*) 10^5 Wb (*d*) 100 Wb

3. **An area A = 0.5 m^2 shown in the figure is situated in a uniform magnetic field B = 4.0 Wb/m^2 and its normal makes an angle of 60° with the field. The magnetic flux passing through the area A would be equal to**



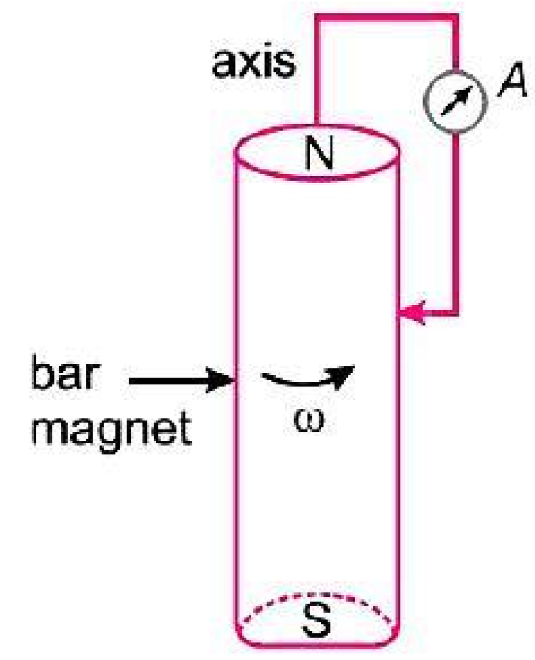
   (*a*) 2.0 weber (*b*) 1.0 weber (*c*) $\sqrt{3}$ weber (*d*) 0.5 weber

4. **A square of side L meters lies in the *X-Y* plane in a region, where the magnetic field is given by $B = B_o(2\hat{i} + 3\hat{j} + 4\hat{k})\,T$, where B_o is constant. The magnitude of flux passing through the square is** [*NCERT Exemplar*]
   (*a*) $2\,B_o L^2$ Wb (*b*) $3\,B_o L^2$ Wb
   (*c*) $4\,B_o L^2$ Wb (*d*) $\sqrt{29}\,B_o L^2$ Wb

5. **A loop, made of straight edges has six corners at $A(0, 0, 0)$, $B(L, O, 0)$, $C(L, L, 0)$, $D(0, L, 0)$ $E(0, L, L)$ and $F(0, 0, L)$. A magnetic field $B = B_o(\hat{i} + \hat{k})\,T$ is present in the region. The flux passing through the loop *ABCDEFA* (in that order) is** [*NCERT Exemplar*]
   (*a*) $B_o L^2$ Wb (*b*) $2\,B_o L^2$ Wb
   (*c*) $\sqrt{2}\,B_o L^2$ Wb (*d*) $4\,B_o L^2$ Wb

6. **An emf is produced in a coil, which is not connected to an external voltage source. This can be due to** [*NCERT Exemplar*]
   (*a*) the coil being in a time varying magnetic field.
   (*b*) the coil moving in a time varying magnetic field.
   (*c*) the coil moving in a constant magnetic field.
   (*d*) all of the above.

7. A cylindrical bar magnet is rotated about its axis (Figure given alongside). A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then *[NCERT Exemplar]*



(*a*) a direct current flows in the ammeter A.

(*b*) no current flows through the ammeter A.

(*c*) an alternating sinusoidal current flows through the ammeter A with a time period $T = 2\pi/\omega$.

(*d*) a time varying non-sinusoidal current flows through the ammeter A.

8. A copper ring is held horizontally and a magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet is

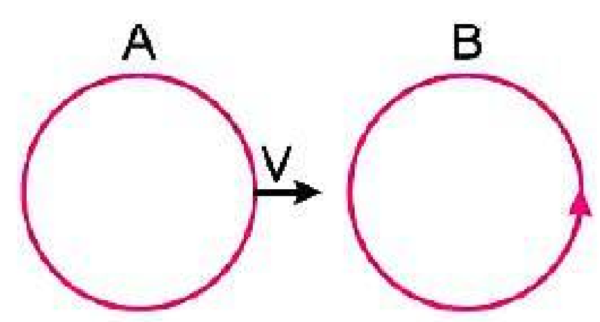
(*a*) equal to that due to gravity

(*b*) less than that due to gravity

(*c*) more than that due to gravity

(*d*) depends on the diameter of the ring and the length of the magnet

9. There are two coils *A* and *B* as shown in the figure. A current starts flowing in *B* as shown, when *A* is moved towards *B* and stops when *A* stops moving. The current in *A* is counter clockwise. *B* is kept stationary when A moves. We can infer that *[NCERT Exemplar]*



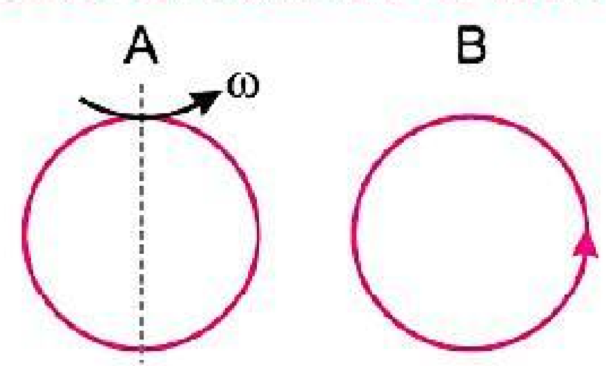
(*a*) there is a constant current in the clockwise direction in A.

(*b*) there is a varying current in A.

(*c*) there is no current in A.

(*d*) there is a constant current in the counterclockwise direction in A.

10. Same as the above problem except the coil A is made to rotate about a vertical axis refer to the figure. No current flows in B if A is at rest. The current in coil A, when the current in B (at $t = 0$) is counterclockwise and the coil A is as shown at this instant, $t = 0$, is *[NCERT Exemplar]*



(*a*) constant current clockwise.

(*b*) varying current clockwise.

(*c*) varying current counterclockwise.

(*d*) constant current counterclockwise.

11. Lenz's law is essential for

(*a*) conservation of energy

(*b*) conservation of mass

(*c*) conservation of momentum

(*d*) conservation of charge

12. The self inductance *L* of a solenoid of length *l* and area of crosssection *A*, with a fixed number of turns *N* increases as *[NCERT Exemplar]*

(*a*) l and A increase.

(*b*) l decreases and A increases.

(*c*) l increases and A decreases.

(*d*) both l and A decrease.

13. A thin circular ring of area *A* is held perpendicular to a uniform magnetic field of induction *B*. A small cut is made in the ring and a galvanometer is connected across its ends in such a way that the total resistance of the circuit is *R*. When the ring is suddenly squeezed to zero area, the charge flowing through the galvanometer is

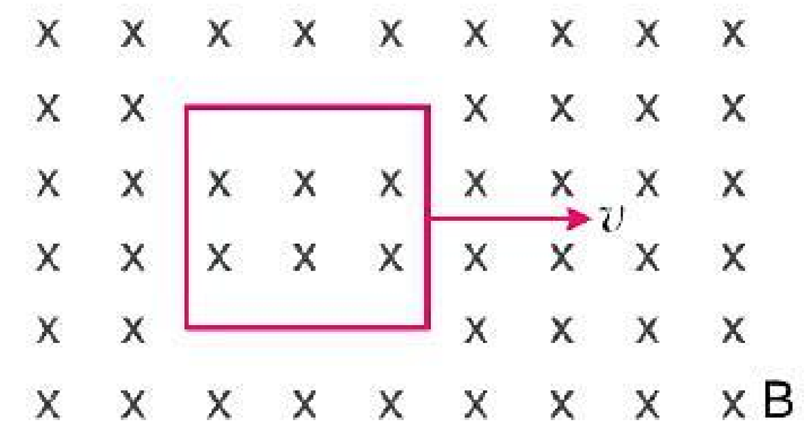
(*a*) $\frac{BR}{A}$

(*b*) $\frac{AB}{R}$

(*c*) ABR

(*d*) $\frac{B^2A}{R^2}$

14. 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 of the loop exists everywhere as in given figure. The current induced in the loop is



(a) Blv/R clockwise
(b) Blv/R anticlockwise
(c) $2Blv/R$ anticlockwise
(d) zero.

15. Inductance plays the role of

(a) inertia
(b) friction
(c) source of emf
(d) force

16. A circular coil expands radially in a region of magnetic field and no electromotive force is produced in the coil. This can be because *[NCERT Exemplar]*

(a) the magnetic field is constant.
(b) the magnetic field is in the same plane as the circular coil and it may or may not vary.
(c) the magnetic field has a perpendicular (to the plane of the coil) component whose magnitude is decreasing suitably.
(d) both (b) and (c)

17. When the current in a coil changes from 8 A to 2 A in 3×10^{-2} second, the emf induced in the coil is 2 volt. The self-inductance of the coil, in millihenry, is

(a) 1
(b) 5
(c) 20
(d) 10

18. The mutual inductance of two coils depends upon

(a) medium between coils
(b) separation between coils
(c) both on (a) and (b)
(d) none of (a) and (b)

19. Due to relative motion of a magnet with respect to a coil, an emf is induced in the coil. Identify the principle involved.

(a) Gauss's law
(b) Biot-Savart law
(c) Ampere's circuital law
(d) Faraday's law

20. In Faraday's experiment of electromagnetic induction, more deflection will be shown by galvanometer, when

(a) magnet is in uniform motion towards the coil
(b) magnet is in accelerated motion towards the coil
(c) magnet is in uniform motion away from the coil
(d) magnet is at rest near the coil

21. If both the number of turns and core length of an inductor is doubled keeping other factors constant, then its self-inductance will be

(a) halved
(b) quadrupled
(c) unaffected
(d) doubled

22. Oscillating metallic pendulum in a uniform magnetic field directed perpendicular to the plane of oscillation

(a) remains unaffected
(b) oscillates with changing frequency
(c) slows down
(d) becomes faster

23. A metallic cylinder is held vertically and then a small magnet is dropped along its axis. It will fall with

(a) acceleration $a = g$
(b) constant velocity $a = 0$
(c) acceleration $a > g$
(d) acceleration $a < g$

24. **An emf of 200 V is induced in a circuit when current in the circuit falls from 5 A to 0 A in 0.1 second. The self-inductance of the circuit is**

(*a*) 3.5 H (*b*) 3.9 H (*c*) 4 H (*d*) 4.2 H

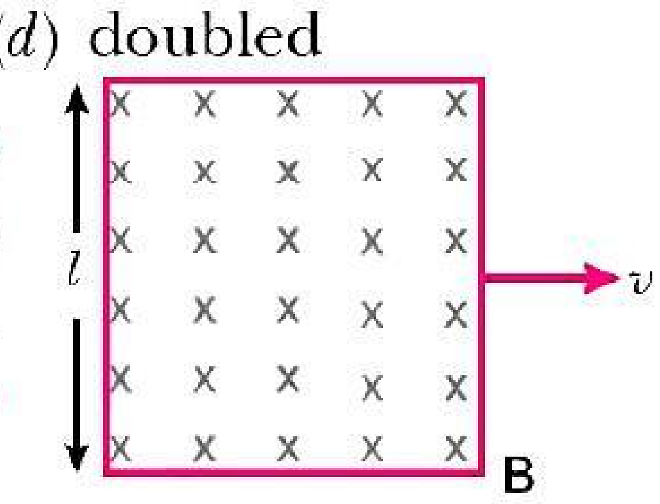
25. **A small piece of metal wire is dragged across the gap between the poles of a magnet in 0.4 s. If change in magnetic flux in the wire is 8×10^{-4} Wb, then emf induced in the wire is**

(*a*) 8×10^{-3} V (*b*) 6×10^{-3} V (*c*) 4×10^{-3} V (*d*) 2×10^{-3} V

26. **If the number of turns per unit length of the coil of a solenoid is doubled keeping other dimensions same, then its self-inductance will be**

(*a*) four times (*b*) eight times (*c*) halved (*d*) doubled

27. **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**



(*a*) zero (*b*) RvB (*c*) vBl/R (*d*) vBl

28. **A wheel with ten metallic spokes each 0.50 m long is rotated with a speed of 120 rev/min in a plane normal to the earth's magnetic field at the place. If the magnitude of the field is 0.4 G the induced emf between the axle and the rim of the wheel is equal to**

(*a*) 1.256×10^{-3} V (*b*) 6.28×10^{-4} V (*c*) 1.256×10^{-4} V (*d*) 6.28×10^{-5} V

29. **In a circuit with a coil of resistance 2 ohms, the magnetic flux changes from 2.0 Wb to 10.0 Wb in 0.2 second. The charge that flows in the coil during this time is**

(*a*) 5.0 coulomb (*b*) 0.8 coulomb (*c*) 1.0 coulomb (*d*) 4.0 coulomb

30. **The direction of induced current is such that it opposes the very cause that has produced it. This is the law of**

(*a*) Lenz (*b*) Faraday (*c*) Kirchhoff (*d*) Fleming

31. **The magnetic flux through a circuit of resistance *R* changes by an amount $\Delta\phi$ in time Δt, then the total quantity of electric charge *Q*, passing during this time through any point of the circuit is given by**

(*a*) $\Delta Q = \frac{\Delta\phi}{\Delta t}$ (*b*) $\Delta Q = \frac{\Delta\phi}{\Delta t} \times R$

(*c*) $\Delta Q = -\frac{\Delta\phi}{\Delta t} + R$ (*d*) $\Delta Q = \frac{\Delta\phi}{R}$

32. **The dimension of magnetic flux is**

(*a*) $M^1L^2T^{-2}A^{-1}$ (*b*) $M^2L^3T^{-3}A^1$ (*c*) $M^1L^2T^{-3}A^{-1}$ (*d*) $M^1L^3T^{-3}A^1$

33. **Lenz's law is a consequence of the law of conservation of**

(*a*) mass (*b*) charge (*c*) momentum (*d*) energy

34. **The physical quantity expressed in henry is**

(*a*) magnetic flux (*b*) self-inductance

(*c*) magnetic permeability (*d*) magnetic induction

35. **When current in a circuit drops from 10 A to 2 A in 2 seconds, the induced emf developed in the circuit is 16 volts. The self inductance of the circuit is**

(*a*) 16 henry (*b*) 8 henry (*c*) 6 henry (*d*) 4 henry

36. **The current passing through a choke coil of self-inductance 5 henry is decreasing at the rate of 2 A/s. The induced emf developed across the coil is**

(*a*) 10 volt (*b*) –10 volt (*c*) 2.5 volt (*d*) –2.5 volt

37. Magnetic flux through a coil changes from 0.7 Wb to 0.2 Wb in 0.1 second. The induced emf developed in the coil is

(*a*) 7 V (*b*) 5 V (*c*) 20 V (*d*) 2 V

38. The magnetic potential energy stored in a certain inductor is 25 mJ, when the current in the inductor is 60 mA. This inductor is of inductance

(*a*) 0.138 H (*b*) 138.88 H (*c*) 1.389 H (*d*) 13.89 H

39. The magnitude of induced emf in a coil depend on

(*a*) the amount of magnetic flux linked by the coil.

(*b*) the amount of electric flux linked by the coil.

(*c*) the rate of change of magnetic flux linked by the coil.

(*d*) the rate of change of electric flux linked by the coil.

40. Weber per second is equal to

(*a*) ampere (*b*) volt (*c*) ohm (*d*) henry

41. Self inductance of a coil delays

(*a*) the growth of current through it.

(*b*) the decay of current through it.

(*c*) both the growth and decay of current through it.

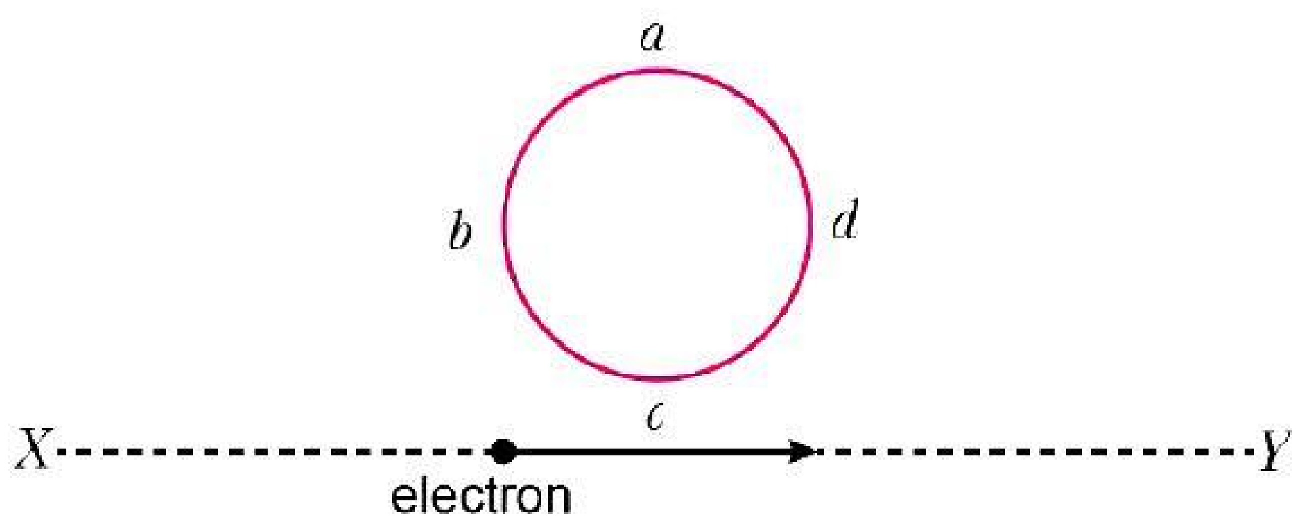
(*d*) neither the growth nor the decay of current through it.

42. Self inductance of a coil is the mechanical analogue of

(*a*) energy (*b*) momentum

(*c*) inertia (*d*) power

43. An electron moves on a straight line path *XY* as shown. The *abcd* is a coil adjacent to the path of electron. What will be the direction of current, if any, induced in the coil?



(*a*) The current will reverse its direction as the electron goes past the coil.

(*b*) No current induced

(*c*) *abcd*

(*d*) *adcb*

44. If the number of turns in a coil is doubled, then its self-inductance becomes

(*a*) double (*b*) half

(*c*) four times (*d*) unchanged

45. Whenever the flux linked with a circuit changes, there is an induced emf in the circuit. This emf in the circuit lasts

(*a*) for a very short duration

(*b*) for a long duration

(*c*) forever

(*d*) as long as the magnetic flux in the circuit changes.

46. Two coils of self inductances 2 mH and 8 mH are placed to close to each other that the flux linkage is complete between the coils. The mutual inductance between these coils is:

(*a*) 4 mH (*b*) 6 mH

(*c*) 10 mH (*d*) 16 mH

47. A copper ring is held horizontally and a magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet is:

(*a*) equal to that due to gravity

(*b*) less than that due to gravity

(*c*) more than that due to gravity

(*d*) depends on the diameter of the ring and the length of the magnet

48. The mutual inductance of two coils depends upon

(*a*) medium between coils (*b*) separation between coils

(*c*) both on (*a*) and (*b*) (*d*) none of (*a*) and (*b*)

49. The core used in transformers and other electromagnetic equipments is laminated because it

(*a*) prevents rusting of core

(*b*) increases the magnetic saturation level of the core

(*c*) decreases the residual magnetism of the core

(*d*) minimises eddy-current loss in the core

50. If L and R represent inductance and resistance respectively then the dimensions of L/R will be:

(*a*) $M^0L^0T^{-1}$ (*b*) $M^0L^0T^{-2}$

(*c*) M^0L^0T (*d*) cannot be expressed in terms of M, L and T.

51. When the current through a solenoid increases at a constant rate, the induced current:

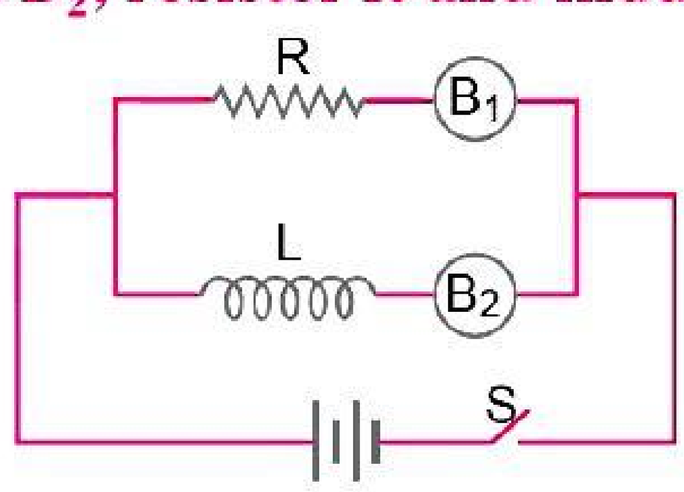
(*a*) is a constant and is in the direction of the inducing current

(*b*) is a constant and is opposite to the direction of the inducing current

(*c*) increases with time and is opposite to the direction of the inducing current

(*d*) zero

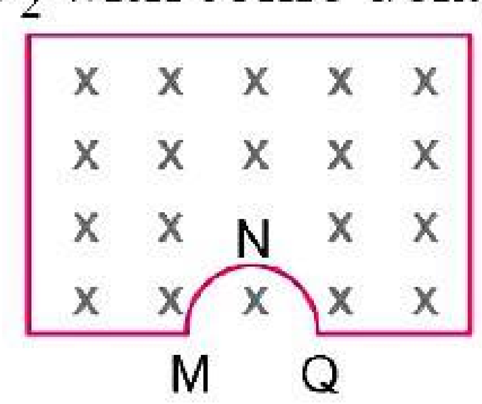
52. Figure shows two bulbs $B1$ and B_2, resistor R and inductor L. When the switch S is turned off



(*a*) both B_1 and B_2 dies out promptly (*b*) both B_1 and B_2 die out with some delay

(*c*) B_2 dies out promptly, but B_1 with some delay (*d*) B_1 dies out promptly, but B_2 with some delay

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



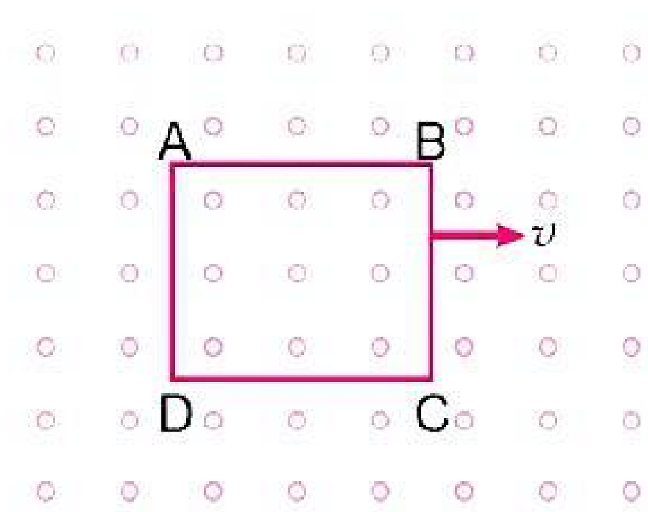
(*a*) zero

(*b*) $\frac{Bv\pi R^2}{2}$ and M at higher potential

(*c*) πRBv and Q at higher potential

(*d*) $2RBv$ and M at higher potential

54. A metallic square loop $ABCD$ is moving in its own plane with a velocity v in a uniform magnetic field perpendicular to plane as shown in fig. An electric field is induced



(*a*) in AD but not in BC

(*b*) in BC but not in AD

(*c*) neither in AD nor in BC

(*d*) in both AD and BC

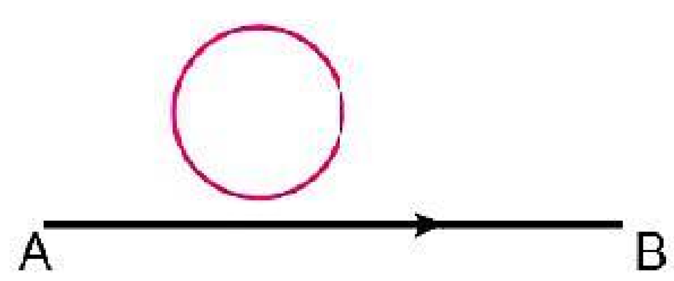
55. **Two identical circular loops *A* and *B* of metal wire are lying on a table without touching each other. Loop *A* carries a current which increases with time. In response the loop *B***
(*a*) remains stationary
(*b*) is attracted by loop A
(*c*) is repelled by loop A
(*d*) rotates about its centre of mass with centre of mass fixed

56. **Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon:**
(*a*) the materials of wires of the coils
(*b*) the currents in the two coils
(*c*) the rates at which currents are changing in the two coils
(*d*) relative position and orientation of the two coils

57. **Two coils have inductances $L_1 = 4$ mH and $L_2 = 1$ mH respectively. The currents in the two coils are increased at the same rate. At a certain instant of time, both coils are given the same power. If I_1 and I_2 are the currents in the two coils at that instant of time respectively, then the value of ratio $\frac{I_1}{I_2}$ is:**
(*a*) $\frac{1}{8}$ (*b*) $\frac{1}{4}$ (*c*) $\frac{1}{2}$ (*d*) 1

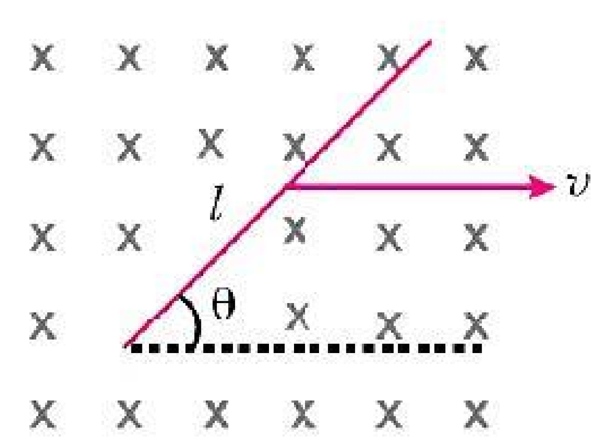
58. **An infinitely long cylindrical conducting rod is kept along + *z*-direction. A constant magnetic field is also present in + *z*-direction. Then the current induced will be:**
(*a*) 0
(*b*) along +*z*-direction
(*c*) along clockwise as seen from + *z* direction
(*d*) along anticlockwise as seen from + *z* direction

59. **The current in a wire *AB* is increasing in magnitude. The direction of induced current in the loop (if any) will be:**



(*a*) clockwise (*b*) anticlockwise
(*c*) arbitrary (*d*) no current is induced

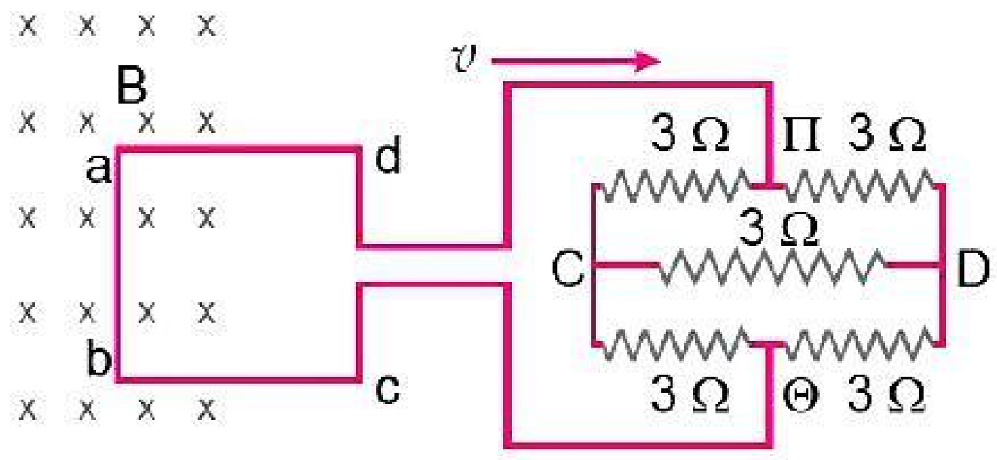
60. **A circular loop of radius *R* carrying current *I* lies in *x*-*y* plane with the centre at origin. The total magnetic flux through *xy* plane is:**



(*a*) directly proportional to *I* (*b*) directly proportional to *R*
(*c*) directly proportional to R^2 (*d*) zero

61. **The equivalent inductance of two inductors is 2.4 H when connected in parallel and 10 H when connected in series. What is the value of inductances of the individual inductors?**
(*a*) 2 H, 8 H (*b*) 4 H, 6 H
(*c*) 3 H, 7 H (*d*) 5 H, 5 H

62. A square loop of side 20 cm and resistance 2 Ω is moved towards right with speed 2v as shown. The left arm of the loop is in a uniform magnetic field of 0.5 T. The field is perpendicular to plane of paper, pointing downward. The loop is connected to a network of 5 resistors as shown in fig. With what speed should the loop be moved so that a steady current of 1 mA flows through the loop?

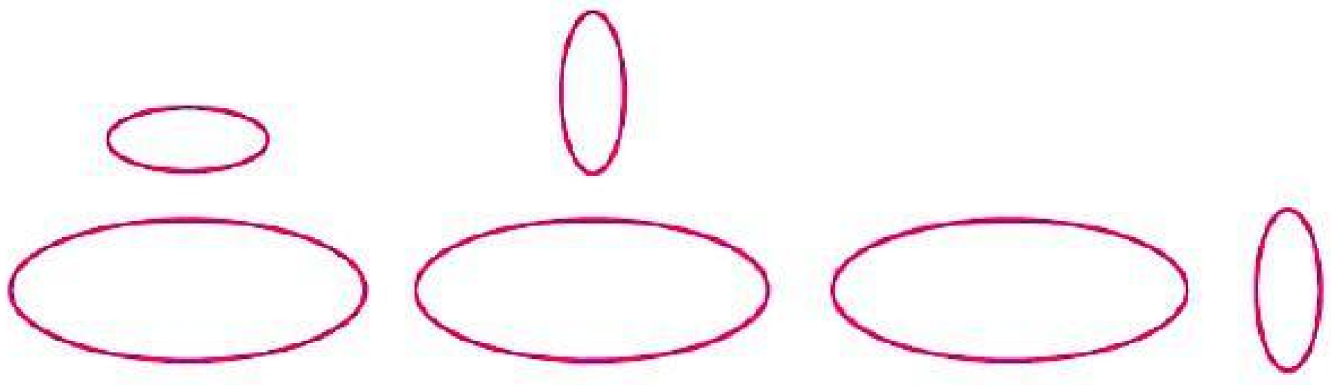


(*a*) 2 cm/s (*b*) 2·5 cm/s (*c*) 5 cm/s (*d*) 25 cm/s

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

(*a*) $\frac{l}{L}$ (*b*) $\frac{l^2}{L}$ (*c*) $\frac{L}{l}$ (*d*) $\frac{L^2}{l}$

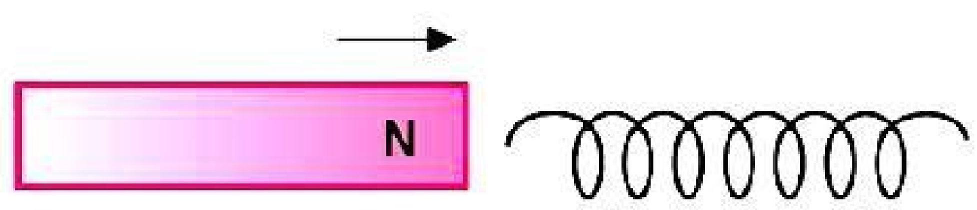
64. Two circular coils can be arranged in any of the three situations as shown in fig. Their mutual inductance will be:



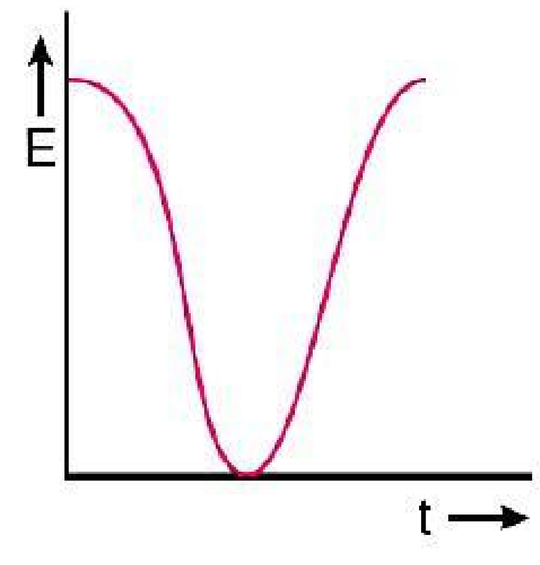
(*i*) (*ii*) (*iii*)

(*a*) maximum in situation (*i*) (*b*) maximum in situation (*ii*)
(*c*) maximum in situation (*iii*) (*d*) same in all situations

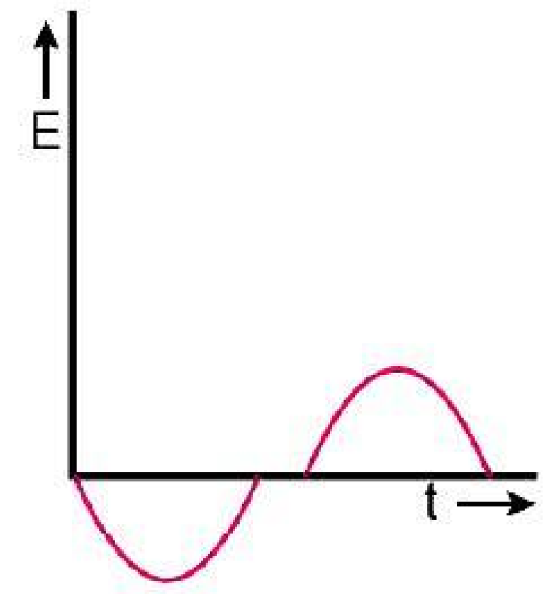
65. The variation of induced emf (E) with time t in a coil if a short bar magnet is moved along its axis with a constant velocity is best represented as:



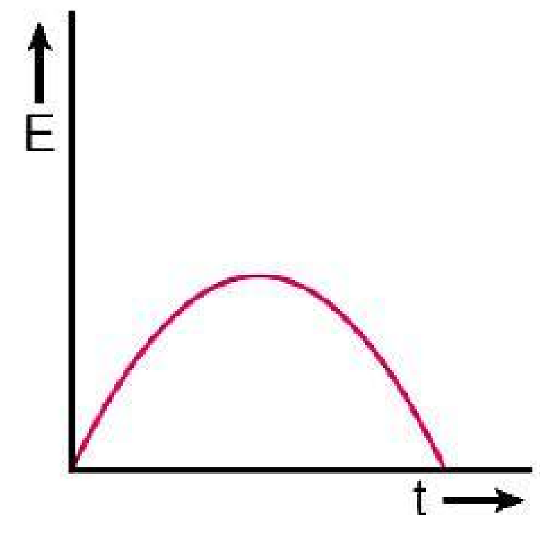
(*a*)



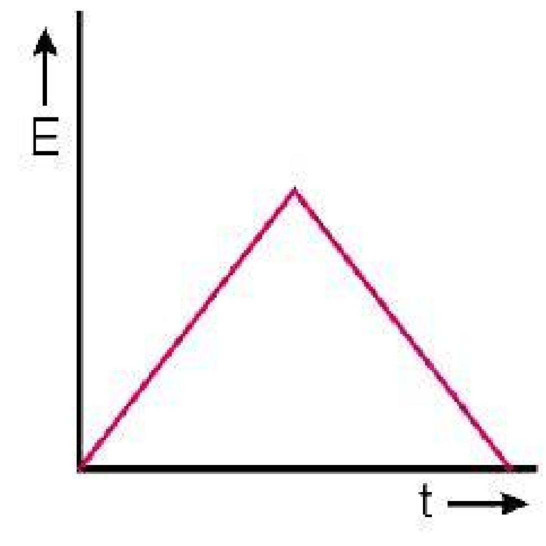
(*b*)



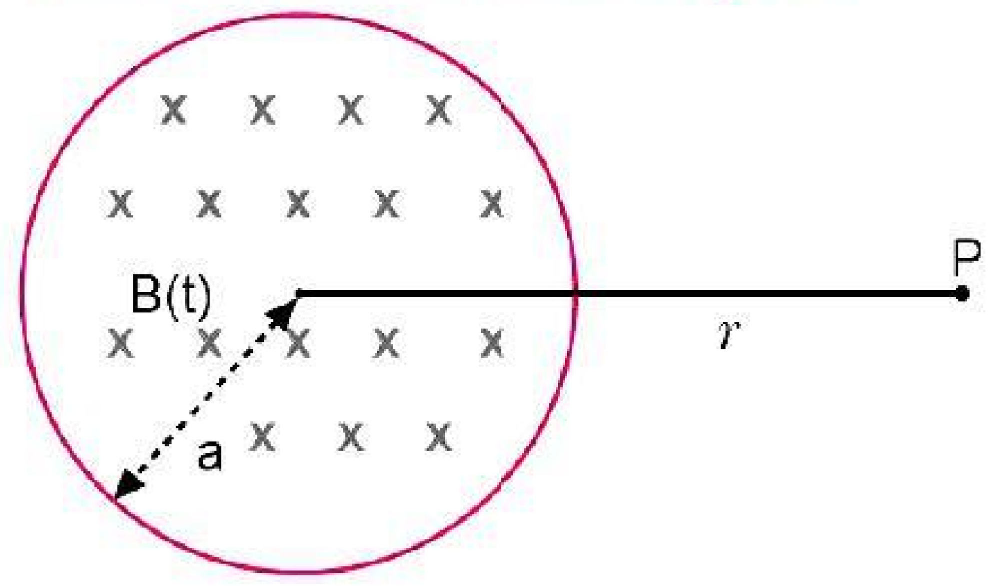
(*c*)



(*d*)



66. A uniform but time varying magnetic field $B(t)$ exists in a circular region of radius 'a' and is directed into the plane of paper as shown. The magnitude of the induced electric field at point P at a distance r from the centre of the circular region:

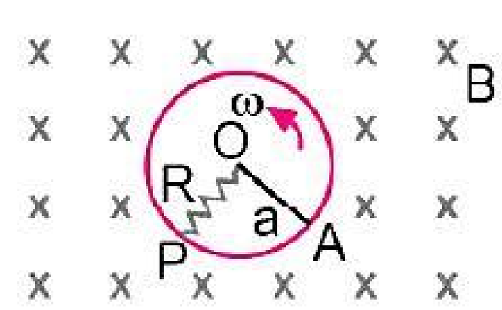


(*a*) is zero (*b*) decreases as $1/r$ (*c*) increases as r (*d*) decreases as $1/r^2$

67. A short circuited coil is placed in a time varying magnetic field. Electric power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled and the wire radius halved, the electrical power dissipated would be:

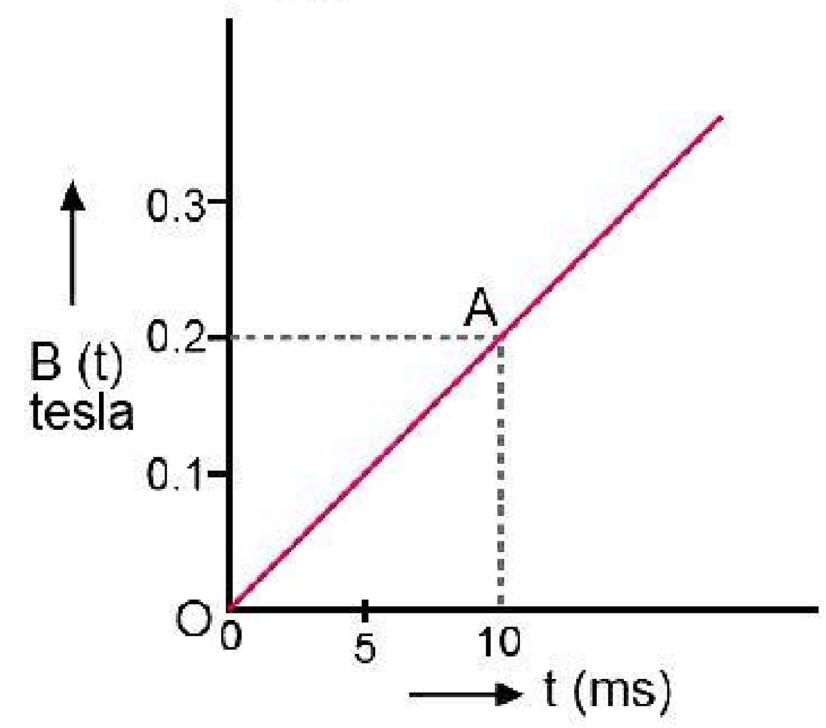
(*a*) halved (*b*) the same (*c*) doubled (*d*) quadrupled

68. Figure shows a conducting circular loop of radius 'a' placed in a uniform, perpendicular magnetic field B. A metal rod OA is pivoted at the centre O of the loop. The other end A of the rod touches the loop. The rod OA and the loop are resistanceless but a tungsten wire of resistance R is connected between O and a fixed point P on the loop. The rod OA is made to rotate anticlockwise with a uniform angular velocity ω by an external source. The current induced in the tungsten wire is:



(*a*) zero (*b*) $\frac{B\omega a^2}{R}$ (*c*) $\frac{B\omega a^2}{2R}$ (*d*) $\frac{B\omega a^2}{8R}$

69. A coil of area 5.0×10^{-3} m^2 is placed perpendicular to a time varying magnetic field shown in figure. The value of induced emf in coil in 10 ms is:



(*a*) 0·1 V

(*b*) 0·1 mV

(*c*) 0·5 V

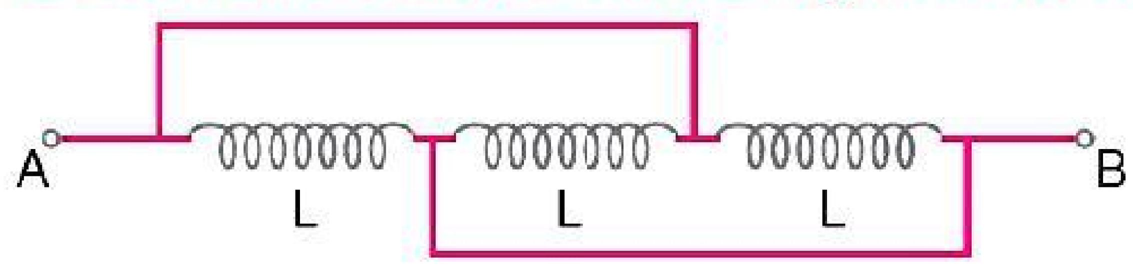
(*d*) 0·5 mV

70. When the current changes from + 2 A to –2 A in 0.05 s, an emf of 8 V is induced in a coil. The coefficient of self-inductance of the coil is:

(*a*) 0·1 H (*b*) 0·2 H

(*c*) 0·4 H (*d*) 0·8 H

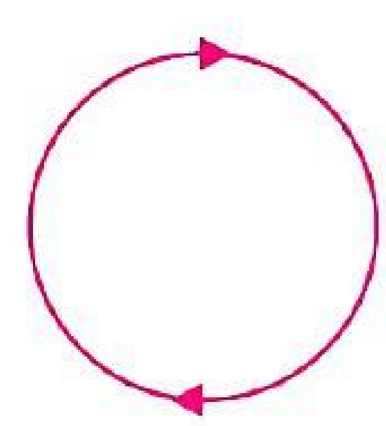
71. The effective inductance between A and B in the fig. shown if L = 3 H is:



(*a*) 1 H (*b*) 9 H

(*c*) 0·67 H (*d*) 1·5H

72. In the given diagram, a line of force of a particular force field is shown. Out of the following options, it can never represent:



(*a*) an electrostatic field (*b*) a magnetostatic field

(*c*) a gravitational field of a mass at rest (*d*) an induced electric field

73. **Which of the following units denotes the dimensions $\frac{ML^2}{Q^2}$, where Q denotes the electric charge?**

(a) Wb/m^2 (b) henry (H) (c) H/m^2 (d) weber (Wb)

74. **A circular loop of radius r, carrying a current I lies in y-z plane with its centre at the origin. The net magnetic flux through the loop is:** *[CBSE 2020 (55/4/1)]*

(a) directly proportional to r (b) zero
(c) inversely proportional to r (d) directly proportional to I

75. **A rectangular, a square, a circular and an elliptical loop, all in the x-y plane are moving out of the uniform magnetic field with a constant velocity $\vec{v} = v\hat{i}$. The magnetic field is directed along the negative z-direction. The induced emf during the passage of these loops, out of the field region will not remain constant for:**

(a) the circular and the elliptical loops (b) only the elliptical loop
(c) any of the four loops (d) the rectangular, circular and elliptical loops

76. **A conducting circular loop is placed in a uniform magnetic field 0·04 T with its plane perpendicular to the magnetic field. The radius of the loop starts shrinking at 2 mm/s. The induced emf in the loop when the radius is 2 cm is:**

(a) $4{\cdot}8\,\pi\,\mu V$ (b) $0{\cdot}8\,\pi\,\mu V$ (c) $1{\cdot}6\,\pi\,\mu V$ (d) $3{\cdot}2\,\pi\,\mu V$

77. **A long solenoid has 500 turns. When a current of 2 A is passed through it, the resulting magnetic flux linked with each turn of the solenoid is 4×10^{-3} Wb. The self inductance of the solenoid is :**

(a) 2·5 H (b) 2·0 H (c) 1·0 H (d) 40 H

78. **An emf of 100 mV is induced in a coil when current in neighbouring coil becomes 10 A from 0 in 0·1 second. The coefficients of mutual inductance between the two coils will be:**

(a) 1 mH (b) 10 mH (c) 100 mH (d) 1000 mH

79. **The magnetic flux linked with a coil at any instant 'E' is given by**

$$\phi = 10t^2 - 50t + 250 \text{ Wb}$$

The induced emf at $t = 3$ s is:

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

80. **Two co-axial solenoids are made by winding insulated wire over a pipe of cross-sectional area $A = 10\ cm^2$ and length $l = 10$ cm. If one solenoid has 300 turns and the other 400 turns, their mutual inductance is :**

(a) $4{\cdot}8\,\pi \times 10^{-5}$ H (b) $2{\cdot}4\,\pi \times 10^{-4}$ H (c) $2{\cdot}4\,\pi \times 10^{-5}$ H (d) $4{\cdot}8\,\pi \times 10^{-4}$ H

Answers

1. (d)	2. (b)	3. (b)	4. (c)	5. (b)	6. (d)	7. (b)	8. (b)
9. (d)	10. (a)	11. (a)	12. (b)	13. (b)	14. (d)	15. (a)	16. (d)
17. (d)	18. (c)	19. (d)	20. (b)	21. (d)	22. (c)	23. (d)	24. (c)
25. (d)	26. (a)	27. (d)	28. (d)	29. (d)	30. (a)	31. (d)	32. (a)
33. (d)	34. (b)	35. (d)	36. (a)	37. (b)	38. (d)	39. (c)	40. (b)
41. (c)	42. (c)	43. (a)	44. (c)	45. (d)	46. (a)	47. (b)	48. (c)
49. (d)	50. (c)	51. (b)	52. (d)	53. (d)	54. (d)	55. (c)	56. (b)
57. (b)	58. (a)	59. (a)	60. (d)	61. (b)	62. (c)	63. (b)	64. (a)
65. (b)	66. (b)	67. (d)	68. (c)	69. (a)	70. (a)	71. (a)	72. (a)
73. (b)	74. (b)	75. (a)	76. (d)	77. (c)	78. (a)	79. (b)	80. (d)

CASE-BASED QUESTIONS

Attempt any 4 sub-parts from each question. Each question carries 1 mark.

1. MIGRATION OF BIRDS:

The migratory birds pattern is one of the mysteries in the field of science. For example, every winter birds from Siberia fly unerringly to water spots in the Indian sub-continent. There has been a suggestion that electromagnetic induction may provide a clue to the migratory patterns. The earth's magnetic field has existed throughout evolutionary history. It would be of great benefit to migratory birds to use this field to determine the direction. As far as we know birds contains no ferromagnetic material. So, electromagnetic induction seems to be the only reasonable mechanism to determine the direction. Consider the optimal case where the magnetic field B, the velocity of the bird v and two relevant points of its anatomy separated by a distance l, all three are mutually perpendicular. From the formula for motional emf

i.e., $$\varepsilon = Blv$$

Certain kinds of fishes are able to detect small potential differences. However, in these fishes, special cells have been identified which detect small voltage differences. In birds no such cells have been identified. Thus, the migration patterns of birds continues to remains a mystery.

(*i*) Am emf is produced in a coil, which is not connected to an external voltage source. This can be due to

(*a*) the coil being in a time varying magnetic field
(*b*) the coil moving in a time varying magnetic field
(*c*) the coil moving out of a constant magnetic field
(*d*) all of the above

(*ii*) A circular coil expands radially in a region of magnetic field and no electromotive force is produced in the coil. This can be because

(*a*) the magnetic field is in the same plane as the circular coil and it may or may not vary.
(*b*) the magnetic field has a perpendicular (to the plane of the coil) component whose magnitude is decreasing suitably.
(*c*) there is constant magnetic field in the perpendicular (to the plane of the coil) direction.
(*d*) Both (*a*) and (*b*)

(*iii*) A migratory Siberian bird is flying in the sky with a velocity of 10 m/s and the distance between two feathers is 2 cm. The earth's magnetic field B perpendicular to the feathers is 4×10^{-5} T. Then emf generated between the two feathers is

(*a*) 4 μV (*b*) 6 μV
(*c*) 8 μV (*d*) 10 μV

(*iv*) An aeroplane having a wing span of 35 m flies due north with a speed of 90 m/s, given $B = 4 \times 10^{-5}$ T. The potential difference between the tips of the wings will be

(*a*) 0.126 V (*b*) 1.26 V
(*c*) 12.6 V (*d*) 0.013 V

(*v*) A moving conductor's coil produces an induced emf. This is in accordance with

(*a*) Lenz's law (*b*) Coulomb's law
(*c*) Faraday's law (*d*) Ampere's law

Answers

1. (*i*) (*d*); Emf is produced in coil if the magnetic flux linked with it changes. When a coil moves into or out of a uniform magnetic field, the area associated with it changes which in turn changes the magnetic flux linked with the coil and an emf is induced.

(*ii*) (*d*); When coil expands in constant magnetic field, the magnetic flux inside the coil (along area vector) increases and induced current is produced. As the component of magnetic field along the area vector is zero, so $\phi = BA$ becomes zero. So, no induced current flows in the coil.

(*iii*) (*c*); $\varepsilon = Blv$, taking, $B = 4 \times 10^{-5}$ T, $l = 2$ cm $= 2 \times 10^{-2}$m, $v = 10$ m/s

$\varepsilon = 4 \times 10^{-5} \times 2 \times 10^{-2} \times 10 = 8 \times 10^{-6}$ V

$\varepsilon = 8\,\mu$V

(*iv*) (*a*); $\varepsilon = Blv$, taking, $B = 4 \times 10^{-5}$ T, $l = 35$ m, $v = 90$ m/s

$\varepsilon = 4 \times 10^{-5} \times 35 \times 90 = 126 \times 10^{-3}$ V

$\varepsilon = 0.126$ V

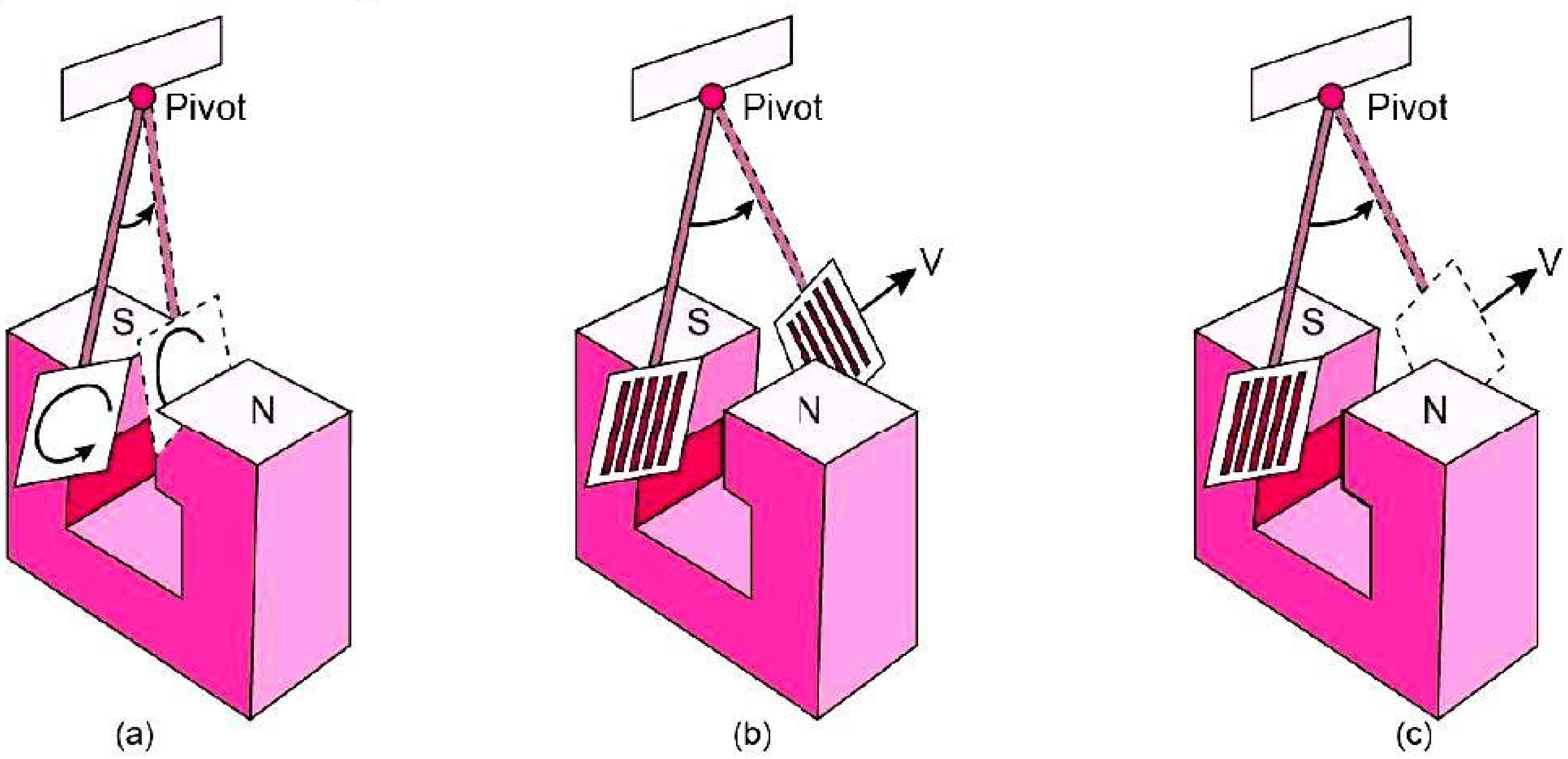
(*v*) (*c*); According to Faraday's law,

i.e., $$\varepsilon = -\frac{d\phi}{dt}$$

or $$|\varepsilon| = \frac{d\phi}{dt}$$

2. **MAGNETIC DAMPING:**

When a conductor oscillates inside a magnetic field, eddy currents are produced in it. The flow of electrons in the conductor immediately creates an opposing magnetic field which results in damping of the magnet and produces heat inside the conductor similar to heat build-up inside of a power cord during use.



By Lenz's law the circulating currents create their own magnetic field that opposes the field of the magnet. Thus, the moving conductor experiences a drag force that opposes its motion. A damping force is generated when these eddy current and magnetic field interact with each other. It is a damping technique where electromagnetically induced current slow down the motion of an object without any actual contact. As the distance between magnet and conductor decreases the damping force increases. The electromagnetic damping force is proportional to the induced eddy current, strength of the magnetic field and the speed of the object which implies that faster the object moves, greater will be the damping and slower the motion of object, lower will be damping which will result in the smooth stopping of the object.

(*i*) **Foucault's current are also known as**

(*a*) direct current (*b*) induced current

(*c*) eddy current (*d*) both eddy current and induced current

(ii) **Eddy current have negative effect because they produce**

(a) heating only (b) damping only

(c) heating and damping (d) harmful radiation

(iii) **The electromagnetic damping force is proportional to**

(a) the induced eddy current (b) the strength of magnetic field

(c) the speed of object (d) all of the above

(iv) **In electromagnetic induction, line integral of induced field E around a closed path is ______________ and induced electric field is ______________.**

(a) zero, non conservative (b) non zero, conservative

(c) zero, conservative (d) non zero, non conservative

(v) **A circular coil of area 200 cm^2 and 25 turns rotates about its vertical diameter with a angular speed of 20 m/s in a uniform horizontal magnetic field of magnitude 0.05 T. The maximum voltage induced in the coil is**

(a) 0.5 V (b) 1.5 V (c) 2.5 V (d) 2.0 V

Answers

2. (i) (c); Eddy current are the current which are induced in a conductor whenever the amount of linked magnetic flux with the conductor changes. These were discovered by Foucault in 1895. So, it is also called Foucault's current.

(ii) (c); When a conductive material is subjected to a time-varying magnetic flux, eddy current are generated in the conductor. Due to the internal resistance of conductor, the eddy current dissipated, heat and also energy removed from the system produce damping effect.

(iii) (d); The electromagnetic damping form is proportional to the induced eddy current (I), the strength of magnetic induction (B) and the speed of the object (v).

(iv) (d); In electromagnetic induction, line integral of induced field E around a close path is not zero, and induced electric field is non-conservative (*i.e.*, work done due to its path is not equal to zero).

(v) (a); It is induced emf of periodic EMI, so formula is $E = NBA\omega$. Here, ω is angular speed. So, $E = 25 \times 0.05 \times 200 \times 10^{-4} \times 20 = 0.5$ V.

ASSERTION-REASON QUESTIONS

In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.

(a) ***Both A and R are true and R is the correct explanation of A.***

(b) ***Both A and R are true but R is not the correct explanation of A.***

(c) ***A is true but R is false.***

(d) ***A is false and R is also false.***

1. Assertion (A) : An emf is induced in a closed loop where magnetic flux is varied. The induced field $\vec{E}$ is not a conservative field. *[AIIMS 2006]*

Reason (R) : The line integral $\oint \vec{E}.\vec{dl}$ around a closed path is non-zero.

2. Assertion (A) : Faraday established induced emf experimentally.

Reason (R) : Magnetic flux can produce an induced emf.

3. Assertion (A) : The direction of induced emf is always such as to oppose the changes that causes it.

Reason (R) : The direction of induced emf is given by Lenz's law.

4. **Assertion (A)** : Acceleration of a vertically falling magnet through a horizontal metallic ring is less than g.

Reason (R) : Current induced in the ring opposes the fall of magnet.

5. **Assertion (A)** : If we use a battery across the primary of a step up transformer, then voltage is also obtained across secondary.

Reason (R) : Battery gives a time varying current, so there is a change in magnetic flux through the secondary of transformer and hence, emf is induced across secondary.

6. **Assertion (A)** : When a rod moves in a transverse magnetic field, an emf is induced in the rod; the end becomes magnetic with end A positive.

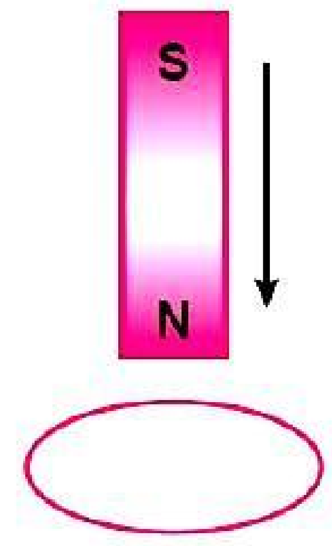
Reason (R) : A Lorentz force evB acts on free electrons, so electrons move from B to A, thus by making end A positive and end B negative.

7. **Assertion (A)** : In the phenomenon of mutual induction, self-induction of each of the coils persists

Reason (R) : Self-induction arises when strength of current in same coil changes. In mutual induction, current is changed in both individual coils.

8. **Assertion (A)** : The bar magnet falling vertically along the axis of the horizontal coil will be having acceleration less than g. *[AIIMS 2015]*

Reason (R) : Clockwise current is induced in the coil.



9. **Assertion (A)** : If current is flowing through a machine of iron, eddy currents are produced. *[AIIMS 1997]*

Reason (R) : Change in magnetic flux through an area causes eddy current.

10. **Assertion (A)** : The presence of large magnetic flux through a coil maintains a current in the coil, if the circuit is continuous. *[AIIMS 2018]*

Reason (R) : Only a change in magnetic flux will maintain an induced current in the coil.

Answers

1. (*a*)	**2.** (*c*)	**3.** (*b*)	**4.** (*a*)	**5.** (*d*)	**6.** (*d*)	**7.** (*a*)	**8.** (*c*)
9. (*a*)	**10.** (*d*)						

HINTS/SOLUTIONS OF SELECTED MCQs

1. (*d*) According to Faraday's law, emf is induced whenever the flur linked with circuit change.
2. (*b*) $\phi = BA = 10^{-3} \times 10^{-2} = 10^{-5}$ Wb
3. (*b*) $\phi = BA\cos\theta = 4 \times 0.5 \times \cos 60° = 1$ Wb
4. (*c*) $\phi = \vec{B}.\vec{A} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k}) \cdot L^2\hat{k} = 4\,B_0L^2$ Wb
5. (*b*) $\phi = \vec{B}.\vec{A} = B_0(\hat{i} + \hat{k}) \cdot (L^2\hat{k} + L^2\hat{i}) = 2B_0L^2$ Wb
6. (*d*) Magnetic flux linked with the isolated coil change the coil being in a time varying magnetic field, the coil moving in a constant magnetic field or in time varying magnetic field.
7. (*b*) When cylindrical bar magnet is rotated about its axis, no change in flux linked, so no emf induced.
8. (*b*) According to Lenz's law, due to opposes its cause of change, same polarity of magnet is developed in ring which opposes the motion of ring.
9. (*d*) When the A stops moving the current in B becomes zero, it possible only if the current in A is constant. If the current in A would be variable, these must be an induced emf in B even if the A stops moving.
10. (*a*) When the current in B (at $t = 0$) is anticlock wise and due to Lenz's law, when coil A start rotating at $t = 0$, the current in A is constant along clockwise direction.

11. (*a*) Lenz's law is consequence of conservation of energy.

12. (*b*) $L = \mu_r\mu_0 n^2 Al$, where $n = N/l$

Then, L is increases, when l decreases and A increases.

13. (*b*) Charge, $q = \frac{\Delta\phi}{R} = \frac{BA - O}{R} = \frac{AB}{R}$

14. (*d*) No flux change is taking place because magnetic field exists everywhere and is constant in time and space.

15. (*a*) Inertia because h is similar to inertial behaviour where body tend to opposes any change.

16. (*d*) When circular coil expands radially in a region of magnetic field such that the magnetic field is in the same plane as the circular coil or the magnetic field has a perpendicular (to the plane of the coil) component whose magnitude is decreasing suitably in such a away that the cross product of magnetic field and surface of plane of coil remain constant at every instant.

17. (*d*) $E = -L\frac{\Delta i}{\Delta t} \Rightarrow L = \frac{-E}{\Delta i/\Delta t} = \frac{-2}{(2-8)/3\times10^{-2}} = 10^{-2}\text{ H} = 10\text{ mH}$

18. (*c*) M depends on permeability of core, the number of their turns and cross-section area of the common core. It also depends on their separation as well as relative orientation.

21. (*d*) Doubled as $L = \mu_0\frac{N^2}{l}A$

22. (*c*) Slows down due to Eddy current.

23. (*d*) Due to lenz law, falling magnet will increase the magnetic flux which is opposed by metallic cylinder.

24. (*c*) $L = \frac{e}{\left(\frac{\Delta I}{\Delta t}\right)} = \frac{200}{\left(\frac{5}{0.1}\right)} = 4\text{ H}$

25. (*d*) $|e| = \frac{\Delta\phi}{\Delta t} = \frac{8\times10^{-4}}{0.4} = 2\times10^{-3}\text{ V}$

26. (*a*) $L = \mu_0 n^2 lA = L \propto n^2$

27. (*d*) $e = \frac{-d\phi}{dt} = \frac{-d}{dt}(-Bl\times(t)) = Bl.\frac{dx(t)}{dt} = Blv$

28. (*d*) $e = \frac{1}{2}Bl^2w = Bl^2\pi\nu = 0.4\times10^{-4}\times(0.5)^2\times(3.14)\times\frac{120}{60} = 6.28\times10^{-5}\text{ V}$

29. (*d*) $\Delta Q = \frac{\Delta\phi}{R} = \frac{(10-2)}{2} = 4\text{ C}$

31. (*d*) We know that $e = \left|\frac{d\phi}{dt}\right|$

But $e = iR$ and $i = \frac{dq}{dt} \Rightarrow e = \frac{dq}{dt}R \Rightarrow \frac{d\phi}{dt} = \frac{dqR}{dt} \Rightarrow \frac{d\phi}{R} = dq \Rightarrow \Delta q = \frac{\Delta\phi}{R}$

35. (*d*) As $e = \frac{-d}{dt}(N\,\phi\,B) = -\frac{LdI}{dt} \Rightarrow L = \frac{-edt}{dI} = \frac{-16\times2}{-8} = 4\text{ H}$

38. (*a*) Magnetic potential energy stored in an inductor in given by $= \frac{1}{2}LI^2$

$\rightarrow L = \frac{2E}{I^2} = \frac{2\times25\times10^{-3}}{(60\times10^{-3})^2} = \frac{500}{36} = 13.89\text{ H}$

43. (*a*) According to Lenz's law, the current induced in coil will opposes the increasing magnetic field when electron pass the coil from X to Y.

44. (*c*) $L = N^2\mu_0 A \Rightarrow L \propto N^2$

46. (*a*) $M = \sqrt{L_1 L_2} = \sqrt{2\times8} = 4\text{ mH}$

48. (*c*) Medium between coils and separation between them

50. (*c*) Time constant, $\tau = L/R$

52. (*d*) When switch S is turned off, the current in resistor branch becomes zero immediately, while current in inductor branch takes some time to become zero.

53. (*d*) For induced p.d., we have to take the component of length normal to both magnetic field and velocity, so induced emf $Bvl = Bv.2R$. By Fleming's left hand rule, the direction of induced current is from M to Q; so M is at higher potential.

54. (*d*) When loop moves in uniform magnetic field, equal and opposite emf's are induced in side AD and BC.

55. (*c*) Opposite currents are induced in loops, so loops repel each other.

57. (*b*) $\frac{I_1}{I_2} = \frac{L_2}{L_1} = \frac{1}{4}$

58. (*a*) As the magnetic field is constant, the rate of change of magnetic flux will be zero and thus current induced will also be zero.

59. (*a*) According to Lenz's law, the current induced in coil will oppose the increased magnetic field due to increase of current, so current induced will be *clockwise*.

60. (*d*) Magnetic flux through the coil,

$$\phi = \vec{B} \cdot \vec{A} = B\hat{k} \cdot (A_x \hat{i} + A_y \hat{j}) = 0$$

61. (*b*) $\frac{L_1 L_2}{L_1 + L_2} = 2.4, \qquad L_1 + L_2 = 10$

$$\frac{L_1 L_2}{10} = 2.4 \Rightarrow L_1 L_2 = 24 \Rightarrow L_1 = \frac{24}{L_2}$$

$$\frac{24}{L_2} + L_2 = 10 \Rightarrow L_2 = 4\text{ H}, L_1 = 6\text{ H}$$

62. (*c*) The network is a balanced Wheatstone bridge. Its equivalent resistance between C and D is total resistance of circuit

$$I = \frac{E}{R} = \frac{Bvl}{R}$$

$$\Rightarrow \quad v = \frac{IR}{Bl_{ab}} = 5 \times 10^{-2}\text{ m/s} = 5\text{ cm/s}$$

63. (*b*) Magnetic field at centre produced due to current I_1 in larger loop,

$$B = 4 \times \frac{\mu_0 I_1}{4\pi\left(\frac{L}{2}\right)}(\sin 45° + \sin 45°) = \frac{2\sqrt{2}\mu_0 I_1}{\pi L}$$

Magnetic flux linked with smaller loop,

$$\phi_2 = B_1 A_2 = \frac{2\sqrt{2}\mu_0 I_1}{\pi L} l^2$$

Mutual Inductance $M = \frac{\phi_2}{I_1} = \frac{2\sqrt{2}\mu_0}{\pi}\frac{l^2}{L} \propto \frac{l^2}{L}$.

64. (*a*) The magnetic field is along the axis of a circular coil. The maximum flux linkage between the coils is in situation (i).

65. (*b*) Induced emf,

$$E = -\frac{d\phi}{dt} = -\frac{d}{dt}(BA) = -A\frac{dB}{dt} = -A\frac{dB}{dx}\frac{dx}{dt} = -Av\frac{dB}{dx}$$

The magnetic flux linked with coil initially increases, so induced emf is initially negative, then magnetic flux linked becomes constant; so $\frac{dB}{dx} = 0$ and then magnetic flux begins to decrease, so $\frac{dB}{dx}$ is negative and induced emf is positive. The change of sign is only shown in (*b*).

66. (*d*) If E is electric field induced at distance r, then

$$E\, 2\pi r = \frac{d}{dt}\{AB(t)\} = \pi a^2 \frac{dB}{dt}(t)$$

$$\Rightarrow \quad E = \frac{a^2}{2r}\frac{dB}{dt}(t) \propto \frac{1}{r}$$

67. (*d*) $P = \frac{E^2}{R}$

Induced emf $E = -N\frac{d\phi}{dt} = -NA\frac{dB}{dt}$

Resistance $R = \frac{\rho l}{\pi r^2} \propto \frac{1}{r^2}$

$$P \propto \frac{N^2 r^2}{l}$$

$$\frac{P_2}{P_1} = \left(\frac{N_2}{N_1}\right)^2 \times \left(\frac{r_2}{r_1}\right)^2 = (4)^2 \times \left(\frac{1}{2}\right)^2 = 4$$

68. (*c*) EMF induced between point O and A,

$$E = \frac{1}{2}B\omega l^2$$

Potential difference across OP, $= \frac{1}{2}B\omega a^2$

Current in R, $I = \frac{V}{R} = \frac{B\omega a^2}{2R}$

69. (*a*) $E = \left|-\frac{d\phi}{dt}\right| = \left|A\frac{dB}{dt}\right| = A \times \text{slope of line OA}$

$$= 5\cdot0\times10^{-3} \times \frac{0\cdot2}{10\times10^{-3}} = 0\cdot1\text{ V}$$

71. (*a*) Given three inductors are connected in parallel, so

$$\frac{1}{L_{eff}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1,\ \mathbf{L_{eff}} = 1\text{ H}$$

72. (*a*) In electrostatic field and gravitational field, the field lines cannot originate and terminate at the same point.

74. (*b*) Magnetic flux $= \sum_i \vec{B_i}.\vec{A_i}$

Where B_i is the magnetic field passing through the area A_i.

Since $B = 0$

Hence net magnetic flux is zero.

76. (*d*) $\phi = BA = B.\pi r^2$

emf, $e = \frac{-d\phi}{dt} = -2B\pi r\frac{dr}{dt}$

$e = -2\times0.04\pi\times0.02\times0.002 = 3.2\,\pi\,\mu\text{V}$

77. (*c*) $\phi_{net} = \text{LI} \quad \Rightarrow \quad \phi_{net} = 500\times4\times10^{-3} = 2\text{ Wb} \quad$ So $L = \frac{\phi_{net}}{I} = \frac{2}{2} = 1\text{ H}$

78. (*a*) $|e| = M\frac{dI}{dt}$

$$M = \frac{e}{\left(\frac{dI}{dt}\right)} = \frac{100\times10^{-3}}{\left(\frac{10-0}{0.1}\right)}$$

$$= \frac{100\times10^{-3}\times0.1}{10} = 10^{-3}\text{ H} = 1\text{ mH}$$

79. (*b*) $\phi = 10t^2 - 50t + 250$

$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(10t^2 - 50t + 250) = -20t + 50$

At $t = 3$ s

$e = -20(3) + 50 = -10$ V

80. (*d*) Mutual inductance of two solenoid system,

$$M = \mu_0\left(\frac{N_1}{l}\right)N_2A = 4\pi\times10^{-7}\left(\frac{300}{0\cdot10}\right)\times400\times10\times10^{-4}\text{ H}$$

$$= 4.8\,\pi\times10^{-4}\text{ H}$$