CHAPTER

6

Electromagnetic Induction

A Quick Recapitulation of the Chapter

1. **Magnetic flux** linked with any surface is equal to total number of magnetic lines of force passing normally through it. It is a scalar quantity. Suppose, we consider small area dA in field B, then

$$\phi = \int \mathbf{B} \cdot d\mathbf{A}$$

Magnetic flux is a scalar quantity having SI unit Wb/m^2 (Tesla) and its dimensional formula is $[ML^2T^{-2}A^{-1}]$.

2. The phenomenon of generation of current or emf by changing the magnetic flux is known as **Electromagnetic Induction** (EMI).

3. **Faraday's Law of Electromagnetic Induction**

First Law Whenever magnetic flux linked with the closed loop or circuit changes, an emf is induced in the loop or circuit which lasts so long as change in flux continuous.

Second Law The induced emf in a closed loop or circuit is directly proportional to the rate of change of magnetic flux linked with the closed loop or circuit

i.e., $$e \propto \frac{(-)\,\Delta\phi}{\Delta t} \Rightarrow e = -N\frac{\Delta\phi}{\Delta t}$$

[Proportionality constant is 1]

where, N = number of turns in loop and ϕ is flux linked with each turn. Negative sign indicates the direction of current induced.

4. If N is the number of turns and R is the resistance of a coil. The magnetic flux linked with its each turn changes by $\Delta\phi$ in short time interval Δt, then induced current flowing through the coil is

$$I = \frac{|e|}{R} = -\frac{1}{R}\left(N\frac{\Delta\phi}{\Delta t}\right)$$

5. **Lenz's Law** The direction of induced emf or induced current is such that it always opposes the cause that produces it.

If induced current is produced in a coil rotating in a uniform magnetic field, then

$$I = \frac{NBA\omega\sin\omega t}{R} = I_0\sin\omega t$$

where, N = number of turns in the coil,
ω = angular frequency

6. **Motional emf** The potential difference induced in a conductor of length l moving with velocity v, in a direction perpendicular to magnetic field B is given by

$$\varepsilon = \int(\mathbf{v} \times \mathbf{B}) \cdot d\mathbf{l} = vBl$$

7. The induced emf developed between two ends of conductor of length l rotating about one end with angular velocity ω in a direction perpendicular to magnetic field is given by, $\varepsilon = \dfrac{B\omega l^2}{2}$

8. **Eddy currents** are induced in solid metallic sheets/cylinders, when magnetic flux linked with them changes. Direction of eddy currents can be given by Lenz's law or by Fleming right hand rule.

9. Inductance is the ratio of the flux linkage and current.

10. **Mutual Induction** The phenomenon of generation of induced emf in secondary coil when current linked with primary coil changes.

$$N_2\phi_2 = MI_1$$

where, $N_2\phi_2$ = flux linked with secondary coil

I_1 = current in primary coil

Also, $e_2 = \frac{-MdI_1}{dt}$

SI unit of mutual inductance (M) is Henry (H).

Mutual inductance (M) of a pair of closely wound solenoids,

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

where, N_1 and N_2 = number of turns in primary and secondary solenoids,

A = area of solenoid

and l = length of solenoid

11. **Self-Induction** The phenomenon of production of induced emf in a coil, when a current passes through it, undergoes a change.

$\because$ Total flux linked with coil, $N\phi \propto I$ and $N\phi = LI$

Also, induced emf, $e = -L\frac{dI}{dt}$

SI unit of self-inductance (L) is Henry (H).

Coefficient of self-inductance $L = \frac{\mu N^2 A}{l}$

where, N = number of turns, A = area of solenoid

and l = length of solenoid.

12. In an AC generator mechanical energy is converted to electrical energy by virtue of electromagnetic induction.

Objective Questions Based on NCERT Text

Topic 1
The Experiments of Faraday and Henry : Magnetic Flux

1. The experiments of Michael Faraday in England and Joseph Henry in USA conducted around 1830, demonstrated conclusively that changing magnetic fields, induced the electric currents in
(a) open coils (b) closed coils
(c) generator (d) dynamo

2. The phenomenon in which electric current is generated by varying magnetic fields is appropriately called
(a) electromagnetic wave
(b) electromagnetic flux
(c) electromagnetic induction
(d) displacement of insulator

3. The pioneering experiments of Faraday and Henry have led directly to the development of modern day's
(a) generator
(b) transformer
(c) dynamo
(d) Both (a) and (b)

4. Which of the following phenomena is utilised in the functioning of mouth piece of a telephone now-a-days?
(a) Thermoelectric effect
(b) Photoelectric effect
(c) Change of resistance with pressure
(d) Electromagnetic induction

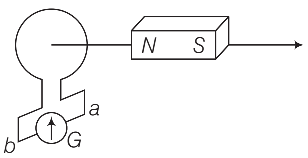
5. Which scientist demonstrated that electric currents were induced in closed coils when subjected to changing magnetic fields?
(a) Faraday (b) Maxwell
(c) Hertz (d) Marconi

6. Moving magnet produces
(a) electric current in closed coil
(b) static magnetic field
(c) static electric field
(d) displacement of insulator

7. The discovery and understanding of electromagnetic induction are based on a long series of experiments carried out by
(a) Faraday
(b) Henry
(c) Maxwell
(d) Both (a) and (b)

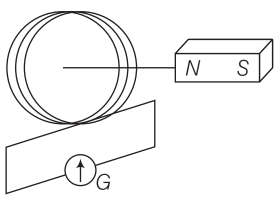
8. When the north pole of a bar magnet is pushed towards the coil along axis of coil, the pointer in the galvanometer deflects, this is indicating the
(a) absence of current in the coil
(b) presence of current in the coil
(c) induction in the coil
(d) Both (b) and (c)

9. In which direction will the galvanometer deflection be, when the magnet is pulled away from the coil? (Given deflection was towards a when magnet was pushed towards coil)



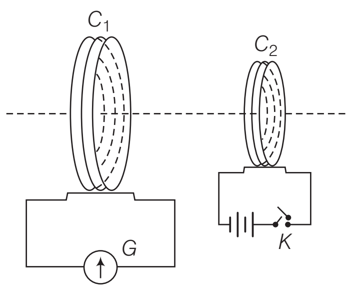
(a) towards a
(b) no deflection
(c) towards b
(d) indicator oscillates between a and b

10. Current in the coil is larger



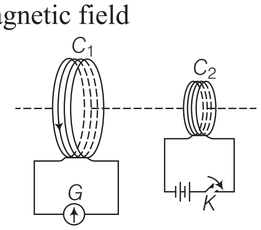
(a) when the magnet is pushed towards the coil faster
(b) when the magnet is pulled away the coil faster
(c) Both (a) and (b)
(d) Neither (a) nor (b)

11. What will happen with the galvanometer when the tapping key K is pressed?



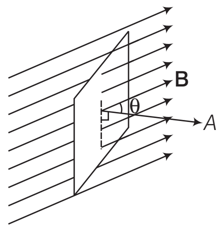
(a) A momentary deflection (b) A long time deflection
(c) No deflection (d) None of these

12. When the key K is released, the current in C_2 and the resulting magnetic field



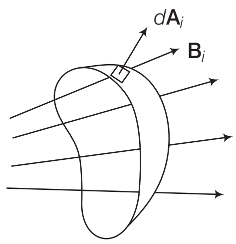
(a) increase from zero to maximum value
(b) first increase, then decrease
(c) remain same
(d) maximum value to zero

13. Magnetic flux through a plane of area A placed in a uniform magnetic field B (as shown in figure) can be written as



(a) $\phi_B = B \times A$
(b) $\phi_B = \mathbf{B} \times \mathbf{A}$
(c) $\phi_B = B \cdot A$
(d) $\phi_B = \mathbf{B} \cdot \mathbf{A}$

14. If the magnetic field has different magnitudes and directions at various parts of a surface as shown in given figure, then the magnetic flux through the surface is given by



(a) $\sum_{\text{all}} B_i \cdot dA_i$ (b) $\sum_{\text{all}} B_i \times (dA_i)^2$
(c) $\sum_{\text{all}} \mathbf{B}_i \times d\mathbf{A}_i$ (d) $\sum_{\text{all}} \mathbf{B}_i \cdot d\mathbf{A}_i$

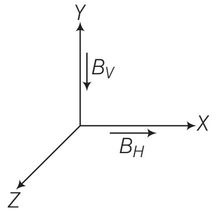
15. The net magnetic flux through any closed surface, kept in a magnetic field is
(a) zero (b) $\frac{\mu_0}{4\pi}$
(c) $4\pi\mu_0$ (d) $\frac{4\mu_0}{\pi}$

16. A square of side a metre lies in the YZ-plane in a region, where the magnetic field is given $\mathbf{B} = B_0\,(3\hat{\mathbf{i}} + 3\hat{\mathbf{j}} - 4\hat{\mathbf{k}})$ T, where B_0 is constant. The magnitude of flux passing through the square is
(a) $2B_0a^2$ Wb (b) $5B_0a^2$ Wb
(c) $3B_0a^2$ Wb (d) $4\ B_0a^2$ Wb

17. A circular disc of radius 0.2 m is placed in a uniform magnetic field of induction $\frac{1}{\pi}\left(\frac{\text{Wb}}{\text{m}^2}\right)$ in such a way that its axis makes an angle of 60° with $\mathbf{B}$. The magnetic flux linked with the disc is
(a) 0.02 Wb (b) 0.06 Wb
(c) 0.08 Wb (d) 0.01 Wb

18. A circular loop of radius R carrying current I lies in XY-plane with its centre at origin. The total magnetic flux through XY-plane is
(a) directly proportional to R
(b) directly proportional to I
(c) inversely proportional to I
(d) zero

19. At a given place, horizontal and vertical components of earth's magnetic fields B_H and B_V are along X and Y-axes, respectively as shown in the figure. What is the total flux of earth's magnetic field associated with an area S, if the area S is in the XY-plane?



(a) 0 (b) $B_H S$ (c) $B_V S$ (d) $(B_H + B_V)S$

20. 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 stop. This is due to **[AIEEE 2012]**
(a) development of air current when the plate is placed
(b) induction of electrical change on the plate
(c) shielding of magnetic lines of force as aluminium is a paramagnetic material
(d) electromagnetic induction is the aluminium plate giving rise to electromagnetic damping

21. A circular coil of diameter 21 cm is placed in a magnetic field of induction 10^{-4} T. The magnitude of flux linked with coil when the plane of coil makes an angle 30° with the field is
(a) 1.44×10^{-6} Wb
(b) 1.732×10^{-6} Wb
(c) 3.1×10^{-6} Wb
(d) 4.2×10^{-6} Wb

Topic 2
Faraday's Law of Induction

22. An .... is induced in a coil when magnetic flux through the coil changes with time.
(a) electric current (b) emf
(c) Both (a) and (b) (d) Neither (a) nor (b)

23. The time rate of change of magnetic flux through a circuit induces .... in circuit.
(a) electric current (b) change in mass
(c) change of size (d) emf

24. The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit, is statement of
(a) Fleming's right hand rule
(b) Fleming's left hand rule
(c) Newton's third law
(d) Faraday's law of electromagnetic induction

25. A square loop of side 10 cm and resistance 0.5 Ω is placed vertically in the east-west plane. A uniform magnetic field of 0.10 T is set-up across the plane in the north-east direction. The magnetic field is decreased to zero in 0.70 s at a steady rate. The magnitudes of induced emf and current during this time interval are
(a) 0.1 mV, 2A (b) 1 mV, 2 mA
(c) 1 V, 2 A (d) 1 mV, 0.2 A

26. A circular coil of radius 10 cm, 500 turns and resistance 2 Ω is placed with its plane perpendicular to the horizontal component of the earth's magnetic field. It is rotated about its vertical diameter through 180° in 0.25 s. Find the magnitude of the emf induced in the coil. Horizontal component of the earth's magnetic field at the place is 3.0×10^{-5} T.
(a) 3×10^{3} V (b) 3.8×10^{-3} mV
(c) 3.8×10^{3} mV (d) 3.8×10^{-3} V

27. A square loop of wire, side length 10 cm is placed at angle of 45° with a magnetic field that changes uniformly from 0.1 T to zero in 0.7 s. The induced current in the loop (its resistance is 1 Ω) is
(a) 1.0 mA (b) 2.5 mA (c) 3.5 mA (d) 4.0 mA

28. Flux (ϕ) (in weber) in a closed circuit of resistance 20 Ω varies with time t (in second) according to equation $\phi = 6t^2 - 5t + 1$. The magnitude of the induced current at $t = 0.25$ s, is
(a) 1.2 A (b) 0.8 A (c) 0.6 A (d) 0.1 A

29. A coil of resistance 400 Ω is placed in a magnetic field. If the magnetic flux ϕ (Wb) linked with the coil varies with time t(s) as $\phi = 50t^2 + 4$. Current at 2 s is **[CBSE AIPMT 2012]**
(a) 0.5 A (b) 0.1 A (c) 2 A (d) 1 A

30. The flux linked with a circuit is given by $\phi = t^3 + 3t - 7$. The graph between time (X-axis) and induced emf (Y-axis) will be a
(a) straight line through the origin
(b) straight line with positive intercept
(c) straight line with negative intercept
(d) parabola not through the origin

31. Wire loop is rotated in a magnetic field. The frequency of change of direction of the induced emf is **[NEET 2013]**
(a) once per revolution
(b) twice per revolution
(c) four times per revolution
(d) six times per revolution

32. The magnetic flux linked with the coil varies with time as $\phi = 3t^2 + 4t + 9$. The magnitude of the induced emf at 2s is
(a) 9 V (b) 16 V
(c) 3 V (d) 4 V

33. A copper disc of radius 0.1 m is rotated about its centre with 20 rev/ s in a uniform magnetic field of 0.1 T with its plane perpendicular to the field. The emf induced across the radius of the disc is
(a) $\frac{\pi}{20}$ V
(b) $\frac{\pi}{10}$ V
(c) 20π mV
(d) None of these

34. A varying magnetic flux linking a coil is given by $\phi = xt^2$. If at time $t = 3$ s, the emf induced is 9 V, then the value of x is
(a) 0.66 Wbs^{-2}
(b) 1.5 Wbs^{-2}
(c) – 0.66 Wbs^{-2}
(d) None of these

35. 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

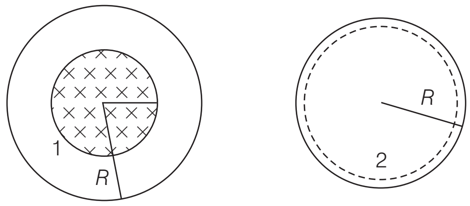
36. A coil having 500 turns of square shape each of side 10 cm is placed normal to a magnetic field, which is increasing at $1\,\text{Ts}^{-1}$. The induced emf is
(a) 0.1 V (b) 0.5 V
(c) 1 V (d) – 5 V

37. Which of the following is the fundamental significance of the Faraday's discovery?
(a) A changing magnetic field can exert a force on the stationary charge
(b) A changing magnetic field can exert a force on the neutral particle
(c) A constant magnetic field can exert a force on the stationary charge
(d) A constant magnetic field can exert a force on the neutral particle

38. A coil has 1000 turns and $500\,\text{cm}^2$ as its area. The plane of the coil is placed at right angle to a magnetic induction field of 2×10^{-5} Wbm^{-2}. The coil is rotated through $180°$ in 0.2 s. The average emf induced in the coil (in mV) is
(a) 5 (b) 10 (c) 15 (d) 20

39. A 50 turns circular coil has a radius of 3 cm, it is kept in a magnetic field acting normal to the area of the coil. The magnetic field B increased from 0.10 T to 0.35 T in 2 ms^{-1}. The average induced emf in the coil is
(a) 1.77 V (b) 17.7 V (c) 177 V (d) 0.177 V

40. A uniform magnetic field is restricted within a region of radius r. The magnetic field changes with time at a rate $\frac{dB}{dt}$. Loop 1 of radius $R > r$ encloses the region r and loop 2 of radius R is outside the region of magnetic field as shown in the figure. Then the emf generated is **[NEET 2016]**



(a) zero in loop 1 and zero in loop 2
(b) $\frac{-dB}{dt}\pi r^2$ in loop 1 and $\frac{-dB}{dt}\pi r^2$ in loop 2
(c) $\frac{-dB}{dt}\pi R^2$ in loop 1 and zero in loop 2
(d) $\frac{-dB}{dt}\pi r^2$ in loop 1 and zero in loop 2

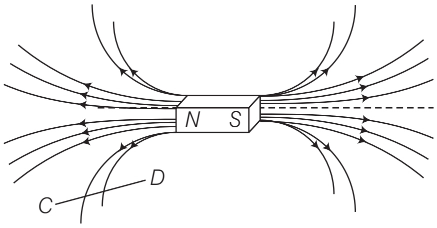
41. If a coil of 40 turns and area $4.0\,\text{cm}^2$ is suddenly removed from a magnetic field, it is observed that a charge of 2.0×10^{-4}C flows into the coil. If the resistance of the coil is 80 Ω, then magnetic flux density (in Wbm^{-2}) is
(a) 0.5 (b) 1.0
(c) 1.5 (d) 2.0

Topic 3

Lenz's Law and Conservation of Energy

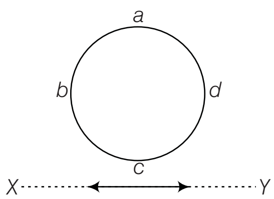
42. The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it, is statement of
(a) Faraday's law (b) Lenz's law
(c) Fleming's right hand rule (d) Fleming's left hand rule

43. What will happen, if an open circuit is used in place of the closed loop (in figure below *CD* is open circuit)?



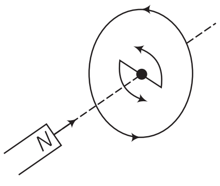
(a) emf is induced across the open ends with *C* positive
(b) emf is not induced across the open ends of the circuit
(c) emf is induced across ends with *C* negative
(d) emf is induced with both *C, D* positive and mid-point negative

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



(a) *abcd*
(b) *adcb*
(c) The current will reverse its direction as the electron goes past the coil
(d) No current induced

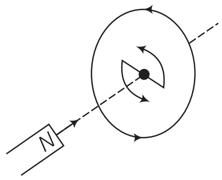
45. Suppose that the induced current was in the direction opposite to the one depicted in the given figure. In this case, the .... pole due to the induced current will face the approaching .... pole of the magnet.



(a) North, North (b) South, South
(c) North, South (d) South, North

46. In the physical situation of previous question will the bar magnet, then be attracted towards the coil at an ever increasing acceleration?
(a) Yes (b) No
(c) May be possible (d) Never possible

47. In the given situation, the bar magnet experiences a .... force due to the .... in coil.

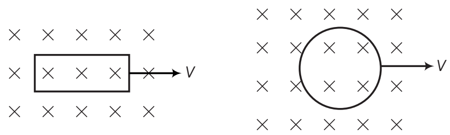


(a) an attractive, air
(b) an attractive, induced current
(c) repulsive, induced current
(d) attractive, vacuum

48. A closed loop moves normal to the constant electric field between the plates of a large capacitor. Is the current induced in the loop when it is wholly inside the region between the capacitor plates?
(a) Yes (b) No
(c) May be possible (d) May not be possible

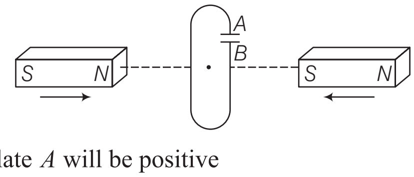
49. In the above question, is a current induced in the loop, when it is partially outside the plates of the capacitor?
(a) Yes (b) No
(c) May be possible (d) May not be possible

50. A rectangular loop and a circular loop are moving out of a uniform magnetic field region in the given figure to a field free region with a constant velocity *v*. In which loop do you expect the induced emf to be constant during the passage out of the field region?



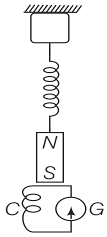
(a) Rectangular loop (b) Circular loop
(c) Both (a) and (b) (d) Neither (a) nor (b)

51. Predict the polarity of the capacitor in the situation described by in the given figures.



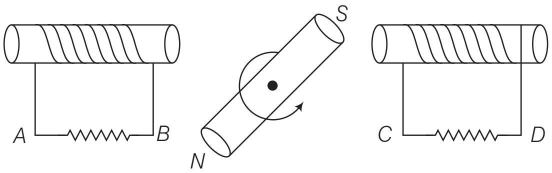
(a) Plate *A* will be positive
(b) Plate *B* will be positive
(c) Plate *A* will be negative
(d) Plate *B* will be negative

52. A magnet N-S is suspended from a spring and when it oscillates, the magnet moves in and out of the coil C. Then, as magnet oscillates



(a) G shows no deflection but the amplitude steadily decreases
(b) G shows deflection to the left and right
(c) G shows deflection to the left and right with constant amplitude
(d) G shows deflection on one side field

53. The magnet in figure rotates as shown on a pivot through its centre. At the instant shown, what are the directions of the induced current?

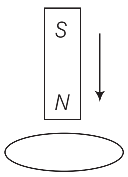


(a) A to B and C to D
(b) B to A and C to D
(c) A to B and D to C
(d) B to A and D to C

54. The north pole of a bar magnet is moved towards a coil along the axis passing through the centre of the coil and perpendicular to the plane of the coil. The direction of the induced current in the coil when viewed in the direction of the motion of the magnet is

(a) clockwise
(b) anti-clockwise
(c) no current in the coil
(d) Either clockwise or anti-clockwise

55. The north pole of a magnet is falling on a metallic ring as shown in the figure. The direction of induced current, if looked from upside in the ring will be



(a) clockwise or anti-clockwise depending on metal of the ring
(b) no induced current
(c) anti-clockwise
(d) clockwise

56. According to Lenz's law of electromagnetic induction,

(a) the induced emf is not in the direction opposing the change in magnetic flux
(b) the relative motion between the coil and magnet produces change in magnetic flux
(c) only the magnet should be moved towards coil
(d) only the coil should be moved towards magnet

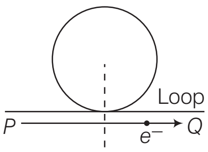
57. There is a uniform magnetic field directed perpendicular and into the plane of the paper. An irregular shaped conducting loop is slowly changing into a circular loop in the plane of the paper. Then,

(a) current is induced in the loop in the anti-clockwise direction
(b) current is induced in the loop in the clockwise direction
(c) AC is induced in the loop
(d) no current is induced in the loop

58. An infinitely long cylinder is kept parallel to an uniform magnetic field B directed along positive Z-axis. This direction of induced current as seen from the Z-axis will be

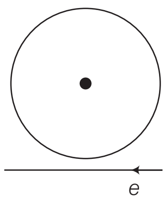
(a) clockwise of the positive Z-axis
(b) anti-clockwise of the positive Z-axis
(c) zero, no current is induced
(d) along the magnetic field

59. An electron moves along the line PQ which lies in the same plane as a circular loop of conducting wire as shown in figure. What will be the direction of the induced current in the loop?



(a) Anti-clockwise
(b) Clockwise
(c) Alternating
(d) Non-current will be induced

60. Near a circular loop of conducting wire as shown in the figure an electron moves along a straight line. The direction of the induced current, if any in the loop is



(a) variable
(b) clockwise
(c) anti-clockwise
(d) zero

Topic 4

Motional Electromotive Force and Eddy Current

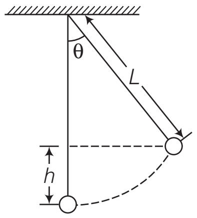
61. A conducting rod of length L is moving in a transverse magnetic field of strength B with velocity v. The resistance of the rod is R. The current in the rod is

(a) $\frac{BLv}{R}$ (b) BLv (c) zero (d) $\frac{B^2v^2L^2}{R}$

62. The magnitude of the earth's magnetic field at a place is B_0 and the angle of dip is δ. A horizontal conductor of length L lying in magnetic north-south moves Eastwards with a velocity v. The emf induced across the conductor is

(a) zero (b) $B_0Lv\sin\delta$
(c) $B_0\,Lv$ (d) None of these

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



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

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

64. Energy associated with a moving charge in space with electric and magnetic fields is due to

(a) electric field (b) magnetic field
(c) Both (a) and (b) (d) None of these

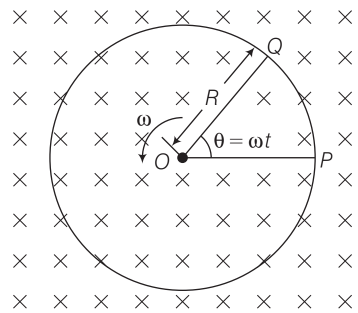
65. A horizontal straight wire 20 m long extending from east to west is falling with a speed of 5.0 ms^{-1} at right angles to the horizontal component of the earth's magnetic field 0.30×10^{-4} Wbm^{-2}. The instantaneous value of the emf induced in the wire will be

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

66. A metal conductor of length 1m rotates vertically about one of its ends at angular velocity 5 rad/s. If the horizontal component of earth's magnetic field is 0.2×10^{-4} T, then the emf developed between the ends of the conductor is

(a) 5 μV (b) 5 mV (c) 50 μV (d) 50 mV

67. A metallic rod of 1 m length is rotated with a frequency of 50 rev/s, with one end hinged at the centre and other end at the circumference of a circular metallic rings of radius of 1 m, about an axis passing through the centre and perpendicular to the plane of the ring (given figure). A constant and uniform magnetic field of 1 T parallel to the axis is present everywhere. What is the emf between the centre and the metallic ring?

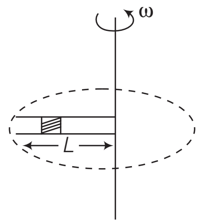


(a) 147 V (b) 157 V (c) 140 V (d) 164 V

68. A wheel with 10 metallic spokes each 0.5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of earth's magnetic field H_E at a place. If $H_E = 0.4$ G at the place, what is the induced emf between the axle and the rim of the wheel? (Take, 1G = 10^{-4} T)

(a) 6.28×10^{-5} V
(b) 62.8×10^{-5} V
(c) 0.628×10^{-5} V
(d) 62.8×10^{-5} mV

69. A horizontal rod of length L rotates about a vertical axis with a uniform angular velocity ω. A uniform magnetic field B exists parallel to axis of rotation. Then, potential difference between the two ends of the rod is



(a) ωL^2B (b) ω^2LB
(c) $\frac{1}{2}\omega L^2B$ (d) $\frac{1}{2}\omega^2LB$

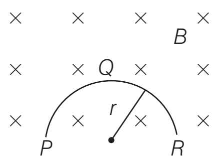
70. A helicopter rises vertically with a speed of 100 ms^{-1}. If helicopter has length 10 m and horizontal component of earth's magnetic field is $5 \times 10^{-3} \text{ Wbm}^{-2}$, then the induced emf between the tip of nose and tail of helicopter is

(a) 50 V (b) 0.5 V
(c) 5 V (d) 25 V

71. 2 m long wire is moved with a velocity 1 ms^{-1} in a magnetic field of intensity 0.5 Wbm^{-2} in direction perpendicular to the field. The emf induced will be

(a) 2 V (b) 1 V (c) 0.1 V (d) 0.5 V

72. A thin semicircular conducting ring (PQR) of radius r is falling with its plane vertical in a horzontal magnetic field B, as shown in figure. The potential difference developed across the ring when its speed is v, is **[CBSE AIPMT 2014]**



(a) zero
(b) $Bv\pi^2/2$ and P is at higher potential
(c) πrBv and R is at higher potential
(d) $2rBv$ and R is at higher potential

73. Two parallel rails of a railway track insulated from each other and with the ground are connected to a millivoltmeter. The distance between the rails is 1 m. A train is travelling with a velocity of 72 kmh^{-1} along the track. The reading of the millivoltmeter (in mV) is (vertical component of the earth's magnetic induction is 2×10^{-5} T)

(a) 1.44 (b) 0.72 (c) 0.4 (d) 0.2

74. A wire of length 50 cm moves with a velocity of 300 m-min^{-1}, perpendicular to a magnetic field. If the emf induced in the wire is 2V, the magnitude of the field (in tesla) is

(a) 2 (b) 5
(c) 0.4 (d) 0.8

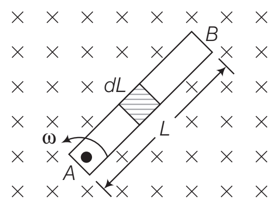
75. A horizontal straight wire 10 m long extending from east to west is falling with a speed of 5.0 ms^{-1}, at right angles to the horizontal component of the earth's magnetic field of strength $0.30 \times 10^{-4} \text{ Wbm}^{-2}$. The instantaneous value of the induced potential gradient in the wire from west to east is

(a) $+1.5 \times 10^{-3} \text{ Vm}^{-1}$ (b) $-1.5 \times 10^{-3} \text{ Vm}^{-1}$
(c) $+1.5 \times 10^{-4} \text{ Vm}^{-1}$ (d) $-1.5 \times 10^{-4} \text{ Vm}^{-1}$

76. A metal disc of radius 100 cm is rotated at a constant angular speed of 60 rads^{-1} in a plane at right angles to an external field of magnetic induction 0.05 Wbm^{-2}. The emf induced between the centre and a point on the rim will be

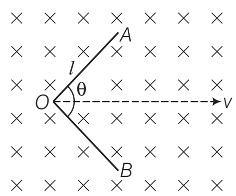
(a) 3 V (b) 1.5 V (c) 6 V (d) 9 V

77. A copper rod of length L rotates at an angular velocity ω in a uniform magnetic field B as shown. What is the induced emf across the ends?



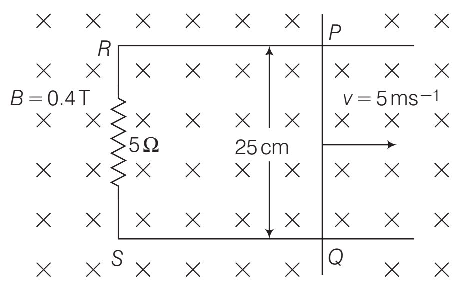
(a) $\frac{1}{2}\omega BL^2$ (b) $\frac{1}{3}\omega BL^2$ (c) $\frac{1}{2}\omega BL^3$ (d) $\frac{1}{4}\omega BL^2$

78. An $\angle AOB$ made of a conducting wire moves along its bisector through a magnetic field B as suggested by figure. Find the emf induced between the two free ends if the magnetic field is perpendicular to the plane of the paper.



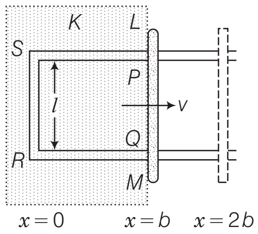
(a) $Bl \sin(\theta/2)$ (b) $Bv \sin(\theta/2)$
(c) $2Blv \sin(\theta/2)$ (d) $Blv \sin(\theta/4)$

79. Figure shows a conducting rod PQ in contact with metal rails RP and SQ, which are 25 cm apart in a uniform field of flux density 0.4 T acting perpendicular to the plane of the paper. Ends R and S are connected through a 5 Ω resistance. What is the magnitude and the direction of the current through the 5 Ω resister when the rod moves to the right with a velocity of 5 ms^{-1}?



(a) 0. 1 A from R to S (b) 0.1 A from S to R
(c) 0.5 A from R to S (d) 0.5 A from S to R

80. Refer to figure, the arm PQ of the rectangular conductor is moved from $x=0$, outwards. The uniform magnetic field is perpendicular to the plane and extends from $x=0$ to $x=b$ and is zero for $x>b$. Only the arm PQ possesses substantial resistance r. Consider the situation when the arm PQ is pulled outwards from $x=0$ to $x=2b$ and is then moved back to $x=0$ with constant speed v. Obtain expressions for the flux and the induced emf.



(a) $Blx, -Blv; 0 \le x < b$ (b) $2Bl, -2Bl$
(c) $Blb, 0, b \le x < 2b$ (d) Both (a) and (c)

81. In the above question, find the force necessary ($x=0$ to $x=b$ motion, $x=b$ to $x=2b$ motion) to pull the arm and the power dissipated as joule heat.

(a) Force $\dfrac{B^2l^2v}{r}$, 0; Power $\dfrac{B^2l^2v^2}{r}$, 0

(b) Force $\dfrac{B^2l^2v^2}{r}, \dfrac{B^2l^2v^2}{r}$; Power $\dfrac{B^2lv}{r}, \dfrac{B^2l^2v}{2r}$

(c) Force $\dfrac{Blv}{2v}, \dfrac{B^2l^2v^2}{2r}$; Power $\dfrac{B^2l^2v}{4r}, \dfrac{B^2l^2}{4r}z$

(d) Force $\dfrac{Blv}{4r}, \dfrac{Blv}{2r}$; Power $\dfrac{B^2l^2v^2}{4r}, \dfrac{B^2l^2v^2}{4r}$

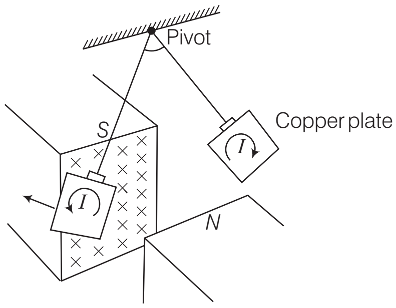
82. A rectangular loop of sides 10 cm and 5 cm with a cut is stationary between the pole pieces of an electromagnet. The magnetic field of the magnet is normal to the loop. The current feeding the electromagnet is reduced so that the field is decreased from its initial value of 0.3 T at the rate of 0.02 Ts^{-1}. If the cut is joined and the loop has a resistance of 2.0 Ω, the power dissipated by the loop as heat is

(a) 5 nW (b) 4 nW (c) 3 nW (d) 2 nW

83. A rectangular wire loop of sides 8 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of magnitude 0.3 T directed normal to the loop. Suppose the loop is stationary but the current feeding the electromagnet that produces the magnetic field is gradually reduced so that the field decreases from its initial value of 0.3 T at the rate of 0.02 T/s. If the cut is joined and the loop has a resistance of 1.6 Ω, how much power is dissipated by the loop as heat?

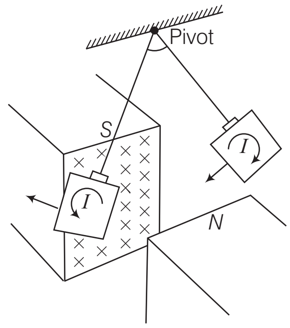
(a) 6.4×10^{10} W (b) 0.64×10^{10} W
(c) 64×10^{10} W (d) 6.4×10^{-10} W

84. A copper plate is allowed to swing like a simple pendulum between the pole pieces of a strong magnet (as shown in figure). It is found that the motion is .... and in a little while the plate comes to halt in the magnetic field. We can explain this phenomenon on the basis of …. .



(a) damped, induced current
(b) accelerated, induced current
(c) accelerated, electromagnetic induction
(d) damped, Gauss' law

85. Which part in the figure is allowed to swing like a simple pendulum between the pole pieces of a strong magnet to induce eddy currents in it?



(a) Copper plate (b) Rubber piece
(c) Wooden piece (d) Plastic sheet

86. The retarding force due to the eddy current inhibits the motion of the magnet. This phenomenon is called
(a) electromagnetic furnace
(b) electromagnetic damping
(c) Both (a) and (b)
(d) Neither (a) nor (b)

87. Eddy currents are generated in
(a) insulator (b) conductor
(c) Both (a) and (b) (d) Neither (a) nor (b)

88. The shining disc in analogue type electric power meter rotates due to
(a) continuously decreasing current
(b) motor fitted inside
(c) continuously increasing current
(d) eddy current

Topic 5
Inductance and AC Generator

89. An electric current can be induced in a coil by flux change produced by another coil in its vicinity or flux change produced by the same coil. In both cases, the flux through a coil is
(a) proportional to the square of current
(b) inversely proportional to the square of current
(c) proportional to the current
(d) inversely proportional to the current

90. If the geometry of the coil does not vary with time, then
(a) $\frac{d\phi_B}{dt} \propto \frac{dI}{dt}$ (b) $d\phi_B \propto dI$
(c) Both (a) and (b) (d) Neither (a) nor (b)

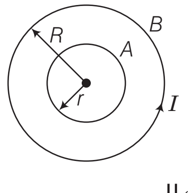
91. Choose the correct option.
(a) For a closely wound coil of N-turns, the magnetic flux linked with all turns is same
(b) When the flux ϕ_B through the coil changes, each turn contributes to the induced emf
(c) Both (a) and (b)
(d) Neither (a) nor (b)

92. Inductance depends on the
(a) geometry of the coil (b) intrinsic material properties
(c) Both (a) and (b) (d) Neither (a) nor (b)

93. If a medium of relative permeability μ_r had been present instead of air, the mutual inductance would be
(a) $M = \mu_r \mu_0 n_1 n_2 \pi r_1 l$ (b) $M = \mu_0 n_1 n_2 \pi r_1^2 l$
(c) $M = \mu_r n_1 n_2 \pi r_1^2 l$ (d) $M = \mu_r \mu_0 n_1 n_2 \pi r_1^2 l$

94. Mutual inductance of a pair of coil, solenoids etc., depends on their
(a) separation (b) relative orientation
(c) Neither (a) nor (b) (d) Both (a) and (b)

95. O is the centre of two coplanar concentric circular conductors A and B, of radii r and R respectively as shown in the figure. Here, $r <<< R$. The mutual inductance of the system of the conductor can be given by



(a) $\frac{\mu_0 \pi r^2}{2R}$ (b) $\frac{\mu_0 \pi R^2}{2r}$
(c) $\frac{\pi R^2}{\mu_0 r}$ (d) $\frac{\mu_0 \pi r}{2R}$

96. There are two identical coils A and B parallel placed along common axis, separated by some distance. If a current of 2A flows through A, a magnetic flux of 10^{-2} Wb passes through B (no current through B). If no current passes through A and a current of 1 A passes through B, what is the flux through A?
(a) 5×10^{-3} Wb (b) 0.5×10^{-3} Wb
(c) 50×10^{-3} Wb (d) 00.5×10^{-3} Wb

97. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon
(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

98. Two concentric circular coils, one of small radius r_1 and the other of large radius r_2, such that $r_1 << r_2$, are placed coaxially with centres coinciding. Obtain the mutual inductance of the arrangement.
(a) $\frac{\mu_0 \pi r_1^2}{2r_2}$ (b) $\frac{\mu_0 \pi r_2^2}{2r_1}$ (c) $\frac{\mu_0 \pi r_2^2}{r_1}$ (d) $\frac{\mu_0 \pi r_1^2}{r_2}$

99. According to phenomenon of mutual inductance,
(a) the mutual inductance does not dependent on geometry of the two coils involved
(b) the mutual inductance depends on the intrinsic magnetic property, like relative permeability of the material
(c) the mutual inductance is independent of the magnetic property of the material
(d) ratio of magnetic flux produced by the coil 1 at the place of the coil 2 and the current in the coil 2 will be different from that of the ratio defined by interchanging the coils

100. Which of the following plays the role of inertia for current flowing in coil?
(a) Resistance of coil (b) Self-inductance
(c) Both (a) and (b) (d) emf applied to coil

101. The self-induced emf always opposes
(a) any change of current in the coil
(b) decrease of current in coil
(c) increase of current in coil
(d) All of the above

102. Work needs to be done against the back emf (ε) in establishing the current. This work done is stored as
(a) magnetic kinetic energy
(b) magnetic potential energy
(c) electric kinetic energy
(d) electric potential energy

103. If the number of turns in a coil becomes doubled, then it self-inductance will become
(a) double (b) halved
(c) four times (d) unchanged

104. For the current I at an instant in a circuit with inductance L, the rate of work done is
(a) $\frac{dW}{dt} = LI\frac{dI}{dt}$ (b) $\frac{dW}{dt} = -LI\frac{dI}{dt}$
(c) $\frac{dW}{dt} = 2LI\frac{dI}{dt}$ (d) $\frac{dW}{dt} = -2LI\frac{dI}{dt}$

105. Total amount of work done in establishing the current I in coil of inductance L is
(a) $W = \int_0^I IdI$ (b) $W = \int_0^I LI^2 dI$
(c) $W = -\int_0^I IdI$ (d) $W = \int_0^I LIdI$

106. Two identical induction coils each of inductance L joined in series are placed very close to each other such that the winding direction of one is exactly opposite to that of other, what is the net inductance?
(a) L^2 (b) $2L$ (c) $L/2$ (d) Zero

107. In 0.2 s, the current in a coil increases from 1.5 A to 2.5 A. If inductance of this coil is 60 mH, then induced current in an external resistance of 3 Ω will be
(a) 1 A (b) 0.5 A (c) 0.2 A (d) 0.1 A

108. A current passing through a coil of self-inductance of 2 mH changes at the rate of $20\ \text{mAs}^{-1}$. The emf induced in the coil is
(a) $10\,\mu$V (b) $40\,\mu$V (c) 10 mV (d) 40 mV

109. The self-induced emf in a coil of 0.4 H self-inductance when current in it is changing at the rate of $50\ \text{As}^{-1}$, is
(a) 8×10^{-4} V (b) 8×10^{-3} V
(c) 20 V (d) 500 V

110. An inductor having coefficient of self-induction 40 mH. What is the energy stored in it, when a current of 2A is passed through it?
(a) 40 mJ (b) 80 mJ (c) 20 mJ (d) 100 mJ

111. Energy required to establish a current of 4 A in a coil of self-inductance $L = 200$ mH is
(a) 0.16 J (b) 0.18 J (c) 0.40 J (d) 1.6 J

112. A long solenoid has 1000 turns. When a current of 4A flow through it, the magnetic flux linked with each turn of the solenoid is 4×10^{-3} Wb. The self-inductance of the solenoid is **[NEET 2016]**
(a) 3 H (b) 2 H
(c) 1 H (d) 4 H

113. Current in a coil changes from 5 A to 10 A in 0.2 s. If the coefficient of self-induction is 10 H, then the induced emf is
(a) 112 V (b) 250 V
(c) 125 V (d) 230 V

114. The inductance of a coil is $L = 10$ H and resistance $R = 5\ \Omega$. If applied voltage of battery is 10 V and if switches off in 1 ms, find induced emf of inductor.
(a) 2×10^4 V (b) 1.2×10^4 V
(c) 2×10^{-4} V (d) None of these

115. Three solenoid coils of same dimension, same numbers of turns and same numbers of layers of winding are taken. Coil 1 with inductance L_1 was wound using a wire of resistance $11\ \Omega\text{m}^{-1}$, coil 2 with inductance L_2 was wound using the similar wire but the direction of winding was reserved in each layer, coil 3 with inductance L_3 was wound using a superconducting wire. The self- inductance of the coils L_1, L_2, L_3 are such that
(a) $L_1 = L_2 = L_3$ (b) $L_1 = L_2, L_3 = 0$
(c) $L_1 = L_3, L_2 = 0$ (d) $L_1 > L_2 > L_3$

116. If coil is open, then L and R respectively become
(a) $\infty, 0$ (b) $0, \infty$ (c) ∞, ∞ (d) $0, 0$

117. In a coil when current changes from 10 A to 2A in time 0.1 s, induced emf is 3.28 V. What is the self-inductance of coil?
(a) 4 H (b) 0.4 H (c) 0.04 H (d) 5 H

118. In 0.1 s, the current in a coil increases from 1A to 1.5 A. If inductance of coil is 60 mH, then induced current in external resistance of 3 Ω will be
(a) 1A (b) 0.5 A (c) 0.2 A (d) 0.1 A

119. A coil of $N = 100$ turns carries a current, $I = 5$A and creates a magnetic flux, $\phi = 10^{-5}\ \text{Tm}^2$ per turn. The value of its inductance L will be
(a) 0.05 mH (b) 0.10 mH
(c) 0.15 mH (d) 0.20 mH

120. A circular coil has 500 turns of wires and its radius is 5 cm. The self-inductance of the coil is
(a) 25×10^{-3} mH (b) 25 mH
(c) 50×10^{-3} H (d) 50×10^{-3} mH

121. The energy stored in an inductor of self-inductance L henry carrying a current of I ampere is
(a) $L^2 I$ (b) $-LI^2$ (c) $\frac{1}{2}LI^2$ (d) $\frac{1}{2}L^2 T$

122. Magnetic flux of $10\,\mu$ Wb is linked with a coil, when a current of 2 mA flows through it. What is the self-inductance of the coil?
(a) 10 mH (b) 5 mH (c) 15 mH (d) 20 mH

123. What is the self-inductance of a solenoid of length 31.4 cm, area of cross-section $10^{-3}\ \text{m}^2$ and total number of turns 10^3?

(a) 4 mH (b) 4 H (c) 40 H (d) 0.4 H

124. A solenoid 60 cm long has 50 turns on it and is wound on an iron rod of 7.5 mm radius. Find the flux through the solenoid when the current in it is 3A and the relative permeability of iron is 600.

(a) 1.66 Wb (b) 2.66 Wb
(c) 1.66 mWb (d) 1.66 μ Wb

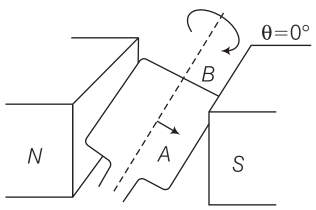
125. The expression for the magnetic energy stored in a solenoid in terms of magnetic field B, area A and length l of the solenoid, is

(a) $\frac{1}{2\mu_0}BAl$ (b) $\frac{1}{2\mu_0}B^2Al$
(c) $\frac{1}{\mu_0}B^2Al$ (d) $\frac{1}{\mu_0}BA^2l$

126. Which method is used to induce an emf or current in a loop in AC generator?

(a) A change in the loop's orientation
(b) A change in its effective area
(c) Both (a) and (b)
(d) Neither (a) nor (b)

127. As the coil rotates in a magnetic field B, the effective area of the loop (the face perpendicular to the field) is

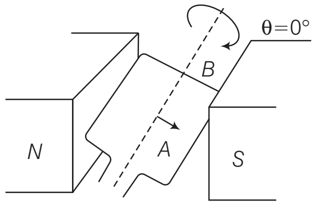


(a) $A\cos\theta$ (b) $A\sec\theta$ (c) $A\tan\theta$ (d) $A\cot\theta$

128. When the coil is rotated with a constant angular speed ω, the angle θ between the magnetic field vector B and the area vector A of the coil at any instant t, is

(a) $\theta = AB$ (b) $\theta = At$ (c) $\theta = \omega t$ (d) $\theta = Bt$

129. The effective area of the coil exposed to the magnetic field lines changes with time, the flux at any time is



(a) $\phi_B = BA\cot\omega t$ (b) $\phi_B = BA\cos\omega t$
(c) $\phi_B = BA\tan\omega t$ (d) $\phi_B = BA\sec\omega t$

130. $\varepsilon = NBA\,\omega\sin\omega t$, in the equation which of the following is the maximum value of the emf, which occurs when $\sin\omega t = \pm 1$?

(a) NBA (b) $NBA\omega\sin\omega t$
(c) $NBA\omega$ (d) $N\omega\sin\omega t$

131. The instantaneous value of the emf is ....
(given, $\varepsilon_0 = NBA\omega$)

(a) $\varepsilon_0\sin\omega t$ (b) $\sin\omega t$ (c) $\varepsilon_0\omega\sin\omega t$ (d) $\omega\sin\omega t$

132. The maximum value of emf is, when θ is equal to
(given, $\varepsilon = \varepsilon_0\sin\omega t$)

(a) 90° (b) 270°
(c) 180° (d) Both (a) and (b)

133. The change of flux is greatest at θ is equal to
(given, $\phi_B = NBA\cos\omega t$)

(a) 90°, 270° (b) 90°, 45°
(c) 60°, 90 (d) 180°, 90°

134. A current $I = 20\sin(100\pi t)$ A is passed in first coil, which induces a maximum emf 10πV in second coil. The mutual inductance between the coils is

(a) 10 mH (b) 15 mH (c) 25 mH (d) 5 mH

135. Two coils have mutual inductance 0.005 H. The current changes in the first coil according to equation $I = I_0\sin\omega t$, where $I_0 = 10$ A and $\omega = 100\pi\ \text{rad s}^{-1}$. The maximum value of emf in the second coil is

(a) 12π (b) 8π (c) 5π (d) 2π

136. A square coil of side 25 cm having 1000 turns is rotated with a uniform speed in a magnetic field about an axis perpendicular to the direction of the field. At an instant t, the emf induced in the coil is $\varepsilon = 200\sin 100\pi t$. The magnetic induction is

(a) 0.50 T (b) 0.02 T
(c) 10^{-3} T (d) None of these

137. Kamla paddles a stationary bicycle, the paddles of the bicycle are attached to a 100 turns coil of area $0.10\ \text{m}^2$. The coil rotates at half a revolution per second and it is placed in a uniform magnetic field of 0.01 T perpendicular to the axis of rotation of the coil. What is the maximum voltage generated in the coil?

(a) 3.14 V (b) 31.4 V (c) 0.314 V (d) 314 V

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

(a) 9.2×10^{-11} Wb (b) 6×10^{-11} Wb
(c) 3.3×10^{-11} Wb (d) 6.6×10^{-9} Wb

139. When a circular coil of radius 1 m and 100 turns is rotated in a horizontal uniform magnetic field, the peak value of emf induced is 100 V. The coil is unwound and then rewound into a circular coil of radius 2 m . If it is rotated now, with the same speed, under similar conditions, the new peak value of emf developed is

(a) 50 V (b) 25 V (c) 100 V (d) 200 V

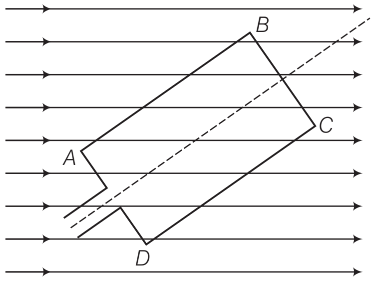
140. In a region of uniform magnetic induction $B = 10^{-2}$ T, a circular coil of radius 30 cm and resistance $\pi^2 \Omega$ is rotated about an axis which is perpendicular to the direction of B and which forms a diameter of the coil. If the coil rotates at 200 rpm the amplitude of the alternating current induced in the coil is

(a) $4\pi^2$ mA (b) 30 mA (c) 6 mA (d) 200 mA

141. A six pole generator with fixed field excitation develops an emf of 100 V, when operating at 1500rpm. At what speed it must rotate to develop 120 V?

(a) 1200 rpm (b) 1800 rpm (c) 1500 rpm (d) 400 rpm

142. A rectangular coil $ABCD$ which is rotated at constant angular velocity about an horizontal axis as shown in the figure. The axis of rotation of the coil as well as the magnetic field B are horizontal. Maximum current will flow in the circuit when the plane of the coil is



(a) inclined at 30° to the magnetic field

(b) perpendicular to the magnetic field

(c) inclined at 45° to the magnetic field

(d) parallel to the magnetic field

Special Format Questions

I. Assertion and Reason

Directions (Q. Nos. 143-152) *In the following questions, a statement of assertion is followed by a corresponding statement of reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

143. Assertion Faraday's law are consequence of conservation of energy.

Reason In purely resistive AC circuit, the current lags behind the emf in phase.

144. Assertion Lenz's law violates the principle of conservation of energy.

Reason Induced emf always opposes the change in magnetic flux responsible for its production.

145. Assertion In equation $\mathbf{F} = q(\mathbf{E} + v \times \mathbf{B})$ when $v = 0$, any force on the charge must arise from the electric field term E alone.

Reason To explain, the existence of induced emf or induced current in static conductor kept in time-varying magnetic field, we must assume that a time-varying magnetic field generates an electric field.

146. Assertion Eddy currents are undesirable.

Reason Eddy currents heat up the core and dissipate electrical energy in the form of heat.

147. Assertion Eddy current is produced in any metallic conductor when magnetic flux is changed around it.

Reason Electric potential determines the flow of charge.

148. Assertion If the inner solenoid was much shorter than (and placed well inside) the outer solenoid, then we could still have calculated the flux linkage $N_1\phi_1$.

Reason The inner solenoid is effectively immersed in a uniform magnetic field due to the outer solenoid.

149. Assertion Self-inductance is the electromagnetic analogue of mass in mechanics.

Reason Work needs to be done against the back emf (ε) in establishing the current.

150. Assertion The quantity L/R possesses dimensions of time.

Reason To reduce the rate of increase of current through a solenoid, we should increase the time constant (L/R)

151. Assertion An AC generator is based on the phenomenon of self-induction.

Reason In single coil, we consider self-induction only

152. Assertion Inductance coil are made of copper

Reason Induced current is more in wire having less resistance.

II. **Statement Based Questions** Type I

■ **Directions** (Q. Nos. 153-165) *In the following questions, a statement I is followed by a corresponding statement II. Of the following statements, choose the correct one.*

(a) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I.
(b) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I.
(c) Statement I is correct but Statement II is incorrect.
(d) Statement I is incorrect but Statement II is correct.

153. Statement I The flux can be altered by changing the shape of a coil in a magnetic field or rotating coil in a magnetic field such that the angle θ between B and A changes.

Statement II By changing the shape of a coil or the angle θ between B and A, an emf is induced in the coil.

154. Statement I $\phi_B = \mathbf{B} \cdot \mathbf{A}$ magnetic flux ϕ_B is scalar quantity.

Statement II Quantity obtained by product of two vectors is always scalar.

155. Statement I If magnetic field $B = 0$, then magnetic flux is also zero.

Statement II If magnetic flux, $\phi = 0$, then magnetic field is also zero.

156. Statement I Coil or loop used for electromagnetic induction, is made up of conducting material.

Statement II Prepared by using wires which are coated with insulating material.

157. Statement I The direction of induced emf is always such as to oppose the change that causes it.

Statement II Conservation of energy applies to know the direction of induced emf.

158. Statement I Electric fields produced by static electric charges have different properties from those produced by time-varying magnetic fields.

Statement II Electric field lines of electric field due to static electric charges form closed loops.

159. In galvanometer, with metallic core

Statement I when coil oscillates, electromagnetic damping occurs.

Statement II eddy currents generated in the core oppose the motion and bring the coil to rest quickly.

160. Statement I Inductance coils are made of conductor.

Statement II Induced current is more in wire having more resistance.

161. Statement I In self-induction, flux linkage through a coil of N-turns is proportional to the current through the coil.

Statement II $N\phi_B \propto I \Rightarrow N\phi_B = LI$

162. Statement I It would be extremely difficult to calculate the flux linkage with the outer solenoid when current flows in inner solenoid.

Statement II As the magnetic field due to the inner solenoid would vary across the length as well as cross-section of the outer solenoid (when inner solenoid is smaller in length and radius).

163. Statement I The self-induced emf is also called the back emf.

Statement II The self-induced emf opposes any change in the current in a circuit.

164. Statement I An exceptionally important application of phenomenon of electromagnetic induction is the generation of Alternating Currents (AC).

Statement II The modern AC generator with a typical output capacity of 100 MW is highly evolved machine.

165. Statement I The direction of the current changes periodically and therefore the current is called alternating current.

Statement II Equation $\varepsilon = \varepsilon_0 \sin \omega t$ can be written as $\varepsilon = \varepsilon_0 \sin 2\pi\nu t$.

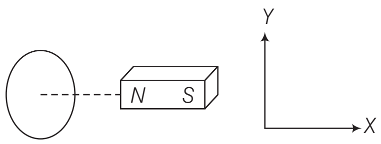
Statement Based Questions Type II

166. I. Joseph Henry, American experiment physicists professor at Princeton University and the first director of the Smithsonian Institution.
II. Henry made important improvement in electromagnets by winding coils of insulated wire around iron pole pieces and invented an electromagnetic motor.
III. Henry discovered self-induction and investigated how currents in one circuit induce currents in another.

Which of the above statements are incorrect? Choose the correct option.

(a) I and II (b) II and III
(c) I and III (d) None of these

167. Consider coil and magnet.



Current is induced in coil when

I. coil and magnet both are at rest.
II. coil is at rest and magnet moves along x.

III. magnet is at rest and coil moves along x.

IV. Both coil and magnet move along y with same speed.

Correct statements are

(a) I and IV (b) I and II
(c) III and IV (d) II and III

168. Consider the statements on the basis of figure in

I. magnetic flux associated with the plate keeps on changing as the plate moves in and out of the region between magnetic poles.

II. the flux change induces eddy currents in the plate.

III. directions of eddy currents are opposite when the plate swings into the region between the poles and when it swings out of the region.

(a) I is correct, II may be correct
(b) I and II are correct, III may be correct
(c) I, II and III are correct
(d) I and II are incorrect but III is correct

169. Consider the statements.

I. Inductance is a scalar quantity.

II. Inductance has the dimensions of $[ML^2T^2A^2]$ given by the dimensions of flux divided by the dimension of current.

III. The SI unit of inductance is henry and is denoted by H.

IV. Inductance is named in honour of Joseph Henry who discovered electromagnetic induction in USA, independently of Faraday in England.

Incorrect statement is

(a) only I (b) only II (c) only III (d) only IV

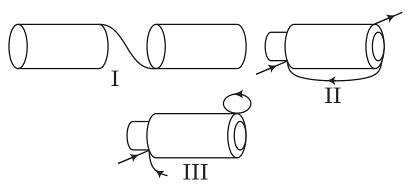
170. There are two solenoids of same length and inductance L_0 but their diameters differ to the extent that one can just fit into the other. They are connected in three different ways in series.

I. They are connected in series but separated by large distance.

II. They are connected in series with one inside the other and senses of the turns coinciding.

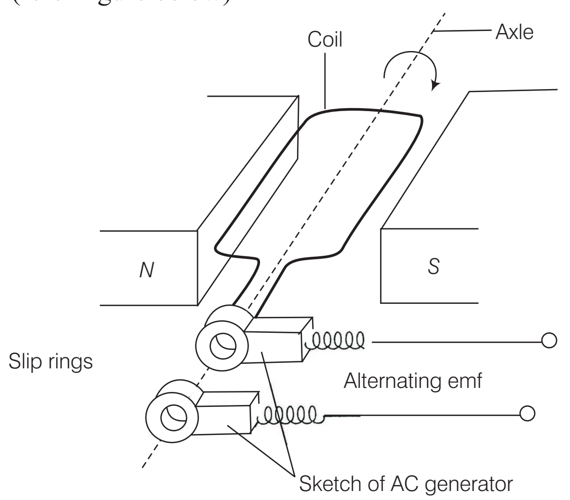
III. Both are connected in series with one inside the other with senses of the turns opposite as depicted in figures 1, 2 and 3, respectively.

The total inductance of the solenoids in each of the cases I, II and III are respectively



(a) $0, 4L_0, 2L_0$ (b) $4L_0, 2L_0, 0$
(c) $2L_0, 0, 4L_0$ (d) $2L_0, 4L_0, 0$

171. Which of the following statements are false? (refer figure below)



I. AC generator consists of a coil mounted on a rotor shaft.

II. The axis of rotation of the coil is perpendicular to the direction of the magnetic field.

III. The coil (called armature) is mechanically rotated in the uniform magnetic field by come external means.

IV. The rotation of coil causes the magnetic flux through coil to change, so an emf is induced in the coil.

(a) I, II and III (b) I, II and IV
(c) II, III and IV (d) None of these

172. I. Modern day generators produce electric power as high as 500 MW.

II. In most generators, the coils are held stationary and it is the electromagnets which are rotated.

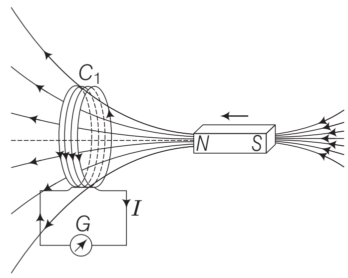
III. The frequency of rotation in India is 50MHz.

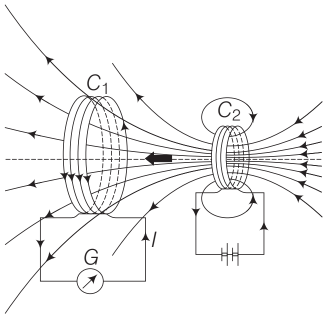
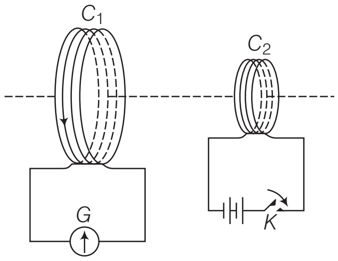
Incorrect statement (s) is/are

(a) only I (b) only III (c) I and II (d) only II

III. Matching Type

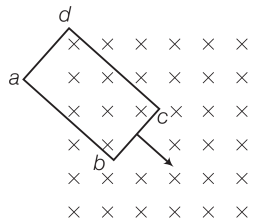
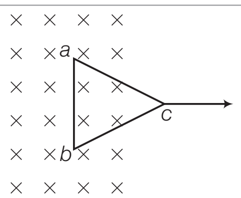
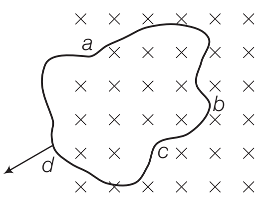
173. Match the items of Column I with the items of Column II and choose the correct option from the codes given below.

	Column I	Column II
A.		1. Current is induced in coil C_1 due to motion of the current carrying coil C_2

	Column I	Column II
B.		2. Coils C_1 and C_2 held stationary, current in C_1 is induced by changing current in C_2
C.		3. When the bar magnet is pushed towards the coil, the pointer in galvanometer G deflects

	A	B	C		A	B	C
(a)	2	1	3	(b)	1	2	3
(c)	3	2	1	(d)	3	1	2

174. Match the items of Column I with those of Column II and choose the correct option from the codes given below.

	Column I (Planar looks of different shapes)	Column II (Direction of induced current)
A.		1. *b a c b*
B.		2. *c d a b c*
C.		3. *b c d a b*

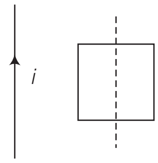
	A	B	C		A	B	C
(a)	3	1	2	(b)	2	1	3
(c)	1	2	3	(d)	1	3	2

175. Match the following columns.

Column I	Column II
A. Dielectric ring uniformly charged	1. Constant electrostatic field out of system
B. Dielectric ring uniformly charged rotating with angular velocity ω	2. Magnetic field strength
C. Constant current in ring i	3. Electric field
D. $i = i_0 \cos\omega t$	4. Magnetic dipole moment

	A	B	C	D
(a)	2	3,4	3,4	1,4
(b)	1	2,3,4	2	4
(c)	1	2,4	2,4	2,3,4
(d)	2,4	2,4	2,3,4	2,4

176. A square loop of conducting wire is placed near a long straight current carrying wire as shown.



Match the statements in Column I with the corresponding result in Column II.

Column I	Column II
A. If the magnitude of current I is increased	1. Induced current L in the loop will be clockwise
B. If the magnitude of current I is decreased	2. Induced current L in the loop will be anticlockwise
C. If the loop is moved away from the wire	3. Wire will attract the loop
D. If the loop is moved towards the wire	4. Wire will repel the loop
	5. Torque about the centre of mass of loop is zero

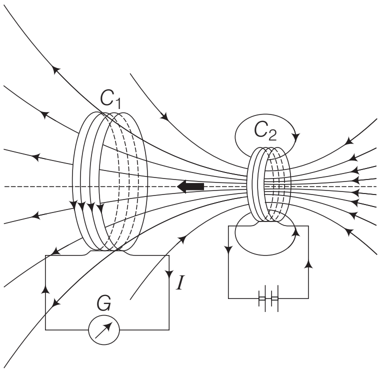
	A	B	C	D
(a)	1,4	2,4	1,3	2,4
(b)	2, 4	1,3	1, 4	2,4
(c)	1,3	2,4	1,3	2,4
(d)	1,4	2,3	2,4	1,3

IV. Passage Based Questions

■ **Directions** (Q. Nos. 177-180) *These questions are based on the following situation. Choose the correct options from those given below.*

The steady current in the coil C_2 produces a steady magnetic field. As coil C_2 is moved towards the coil C_1, the galvanometer shows a deflection. This indicates that electric current is induced in coil C_1.

When C_2 is moved away, the galvanometer shows a deflection again, but this time in the opposite direction.



177. I. Because of current in C_2, it acts as bar magnet.

II. The steady current in the coil C_2 produces a steady magnetic field.

III. If coil C_2 is moved towards the coil C_1, the galvanometer shows a deflection.

IV. This indicates that electric current is induced in coil C_1.

Which of the above statements are correct? Choose the correct option.

(a) I, II and III (b) II, III and IV
(c) I, III and IV (d) All of these

178. What will be the direction of deflection of galvanometer, when C_2 is moved away?

(a) Same direction
(b) Opposite direction
(c) No deflection
(d) Neither (a) nor (b)

179. For duration of deflection in G *i.e.,* current flow in coil C_1, which of the following is correct?

(a) The deflection lasts as long as C_2 is in motion
(b) The deflection lasts till 1 min after motion of C_2 stops
(c) The deflection lasts till 1 h after motion of C_2 stops
(d) The deflection lasts forever

180. When the coil C_2 is held fixed and C_1 is moved , then

(a) same effects are observed *i.e.,* current is induced in coil C_1.
(b) no current is induced in coil C_1.
(c) number of magnetic field lines through C_1 do not change.
(d) current in coil C_2 increases drastically.

■ **Directions** (Q. Nos. 181-182) *These questions are based on the following situation. Choose the correct options from those given below.*

When the North pole of a bar magnet is pushed towards the coil, the pointer in the galvanometer deflects. Fig. (i) show that it is the relative motion between the magnet and coil that is responsible for generation of electric current in the coil. In Fig. (ii), the bar magnet is replaced by a second coil C_2 connected to a battery. The steady current in the coil C_2 produces a steady magnet field.

As coil C_2 is moved toward the coil C_1, the galvanometer shows a deflection. Again, it is the relative motion between the coils that induces the electric current.

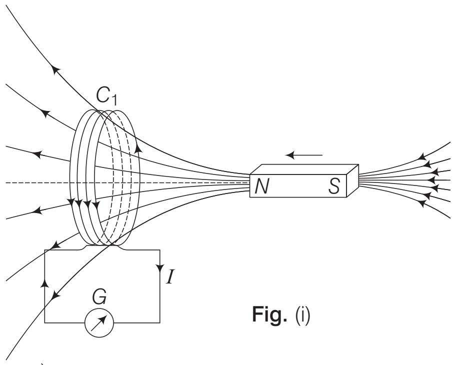


Fig. (i)

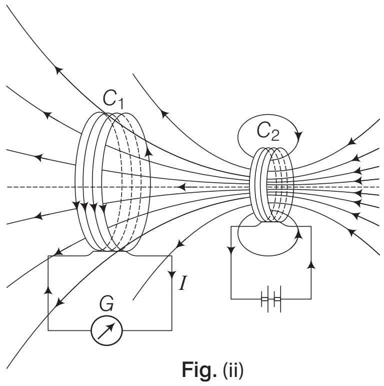


Fig. (ii)

181. Consider the motion of a magnet towards or away from coil C_1 in Fig. (i) and moving a current carrying coil C_2 towards or away from coil C_1 in Fig. (ii). Magnetic flux associated with coil C_1

(a) changes in both (i) and (ii) situations
(b) changes in situation (i) but do not change in situation (ii)
(c) does not change in situation (i) but changes in situation (ii)
(d) does not change in both situations (i) and (ii)

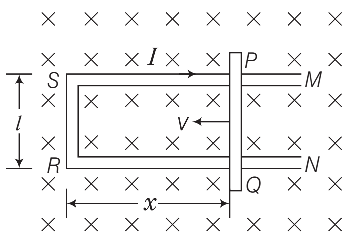
182. The change in magnetic flux

(a) decreases the radius of the coil C_1 to half the initial radius
(b) induces emf in the coil C_1
(c) increases the radius of coil C_1 to double the initial radius
(d) None of the above

■ **Directions** (Q. Nos. 183-187) *These questions are based on the following situation. Choose the correct options from those given below.*

A rectangular conduct or $PQRS$ in which the conductor PQ is free to move is shown in figure. The rod PQ is moved towards the left with a constant velocity v as shown in figure. Assume that there is no loss of energy due to friction. $PQRS$ forms a closed circuit enclosing an area that changes as PQ moves. It is placed in a uniform magnetic field B which is perpendicular to the plane of this system.

The length $RQ = x$ and $RS = l$.



183. The magnetic flux ϕ_B enclosed by loop $PQRS$ will be

(a) $\phi_B = lx$ (b) $\phi_B = Bx$

(c) $\phi_B = \frac{Blx}{2}$ (d) $\phi_B = Blx$

184. In the above equation for ϕ_B, x is changing with time, the rate of change of flux ϕ_B will induce an emf given by

(a) $\varepsilon = -\frac{d\phi_B}{dt}$ (b) $\varepsilon = -\frac{d}{dt}(Blx)$

(c) $\varepsilon = -Bl\frac{dx}{dt}$ (d) All of these

185. $\varepsilon = -Bl\frac{dx}{dt}$, in the given equation we use $dx/dt = -v$ which is the

(a) speed of the conductor PQ

(b) speed of $PQRS$ loop

(c) acceleration of the conductor PQ

(d) acceleration of $PQRS$ loop

186. The induced emf Blv is called

(a) constant emf

(b) accelerated emf

(c) motional emf

(d) Both (b) and (c)

187. It is also possible to explain the motional emf expression Blv by invoking .... acting on the free .... of conductor PQ.

(a) Lorentz force, neutral particles

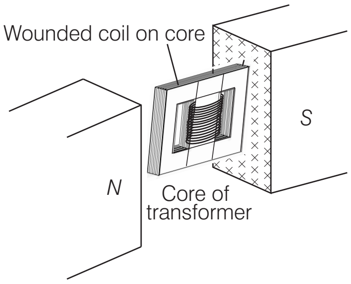
(b) Henry force, atoms

(c) Lorentz force, charge carriers

(d) Henry force, neutral particles

■ **Directions** (Q. Nos. 188-192) *These questions are based on the following situation. Choose the correct options from those given below.*

Coil is to be wound over metallic core which is helpful in reducing eddy currents in the metallic cores of transformers, electric motors and other such devices. Eddy current are undesirable since they heat up the core and dissipate electrical energy in the form of heat. Eddy currents are minimised by using laminations of metal to make a metal core.



188. How are eddy currents minimised to make a metal core of transformer on which coils are wound?

(a) By using laminations of metal

(b) By using solid metallic core

(c) Both (a) and (b)

(d) Neither (a) nor (b)

189. The plane of the laminations must be arranged parallel to the magnetic field, so that they cut across the

(a) keep on sliding

(b) keep on rotating

(c) cut across the induced eddy currents

(d) Both (a) and (b)

190. Induction furnace is used to produce

(a) low temperature to melt the metal

(b) high temperature to melt the metal

(c) constant low temperature 20°C

(d) high pressure

191. Induction furnace can be utilised to prepare

(a) alloys, by melting the constituent metals

(b) metal, by mixing electrons, protons, neutrons

(c) Both (a) and (b)

(d) Neither (a) nor (b)

192. When a high frequency alternating current is passed through a coil which surrounds the metal to be melted.

The .... generated in the metals produce .... temperatures sufficient to .... it.

(a) induced emf, low, freeze

(b) induced current, low, melt

(c) eddy current, high, melt

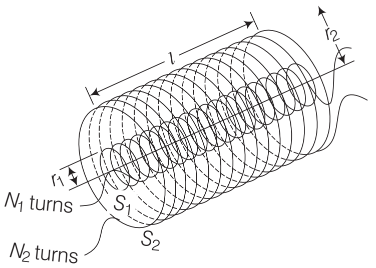
(d) mechanical energy, high, freeze

■ **Directions** (Q. Nos. 193-196) *These questions are based on the following situation. Choose the correct options from those given below.*

Consider the figure below which shows two long coaxial solenoids each of length l.

The radius of the inner solenoid S_1 is denoted by r_1 and the number of turns per unit length by n_1. The corresponding quantities for the outer solenoid S_2 are r_2 and n_2, respectively.

Let N_1 and N_2 be the total number of turns of coils in S_1 and S_2, respectively.



193. When a current I_2 is set-up through S_2, it in turn sets-up a magnetic flux through S_1. The corresponding flux linkage with solenoid S_1 is $N_1\phi_1$ which is given by

(a) $N_1\phi_1 = M_{12}I_1$

(b) $N_1\phi_1 = M_{12}I_2$

(c) $N_1\phi_1 = I_1M_{21}$

(d) None of these

194. Which of the following called the mutual inductance of solenoid S_1 with respect to solenoid S_2?

(a) M_{21} (b) M_{12}
(c) Both M_{12} and M_{21} (d) $M_{12}I_1$

195. I. M_{12} is referred to as the coefficient of mutual induction.
II. The magnetic field due to the current I_2 in S_2 in M_2I_2.

(a) Both I and II are correct
(b) Both I and II are incorrect
(c) I is correct, II is incorrect
(d) I is incorrect, II is correct

196. The flux linkage with coil S_1 is,

(a) $\mu_0 n_1 \pi r_1^2 l I_2$

(b) $\mu_0 n_2 \pi r_1^2 l I_2$

(c) $\mu_0 n_1 n_2 \pi r_1 l I_2$

(d) $\mu_0 n_1 n_2 \pi r_1^2 l I_2$

V. More than One Option Correct

197. SI unit of inductance, henry can be written as

(a) Weber/ampere
(b) Volt-second/ampere
(c) Joule/(ampere)^2
(d) Ohm-second

198. A current carrying infinitely long wire is kept along the diagonal of a square wire loop, without touching it, the incorrect statement(s) is/are

(a) the emf induced in the loop is zero, if the current is constant
(b) the emf induced in the loop is finite, if the current is constant
(c) the emf induced in the loop is zero if the current increases at a steady rate
(d) the emf induced in the loop is finite if the current decreases of a steady rate

199. A coil having 400 turns of square shape each of side 20 cm is placed normal to a magnetic field which is decreasing at $2\,\text{Ts}^{-1}$. Then

(a) angle between area vector and magnetic field is 0°
(b) emf induced is 32 V
(c) angle between area vector and magnetic field is 90°
(d) emf induced is 0 V

200. A circular coil of radius $R = 10$ cm having 500 turns and total resistance $2\,\Omega$ is placed initially perpendicular to the earth magnetic field of 3×10^5 T. The coil is rotated about its vertical diameter by an angle 2π in 0.5 s.

(a) The initial flux through the coil is $3\pi \times 10^{-7}$ Wb
(b) The final flux through the coil is $-7\pi \times 10^{-7}$ Wb
(c) The emf induced in the coil is 2×10^{-3} V
(d) Induced current in the coil is 1 mA

201. Mutual inductance of two concentric circular coils depends upon

(a) number of turns of both coils
(b) area of cross-section of coils
(c) distance between two coils
(d) magnetic permeability of medium between the coil

202. The main components of AC generator are

(a) armature (b) slip rings
(c) brushes (d) commutator

NCERT & NCERT Exemplar Questions

NCERT Exemplar

203. A long solenoid with 15 turns per cm has a small loop of area 2.0 cm^2 placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 2.0 A to 4.0 A in 0.1 s, what is the induced emf in the loop while the changing in current?

(a) 7.5×10^6 V (b) 5×10^6 V (c) 7×10^5 V (d) 5×10^5 V

204. A rectangular wire loop of sides 8 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of magnitude 0.3 T directed normal to the loop. What is the emf developed across the cut if the velocity of the loop is 1 cm/s in a direction normal to the longer side?

(a) 3×10^{-4} V (b) 2.4×10^{-4} V
(c) 5×10^{-4} V (d) 2×10^{-4} V

205. A 1.0 m long metallic rod is rotated with an angular frequency of 400 rad/s about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field of 0.5 T parallel to the axis exists everywhere. The emf developed between the centre and the ring is

(a) 200 V (b) 50 V
(c) 100 V (d) None of these

206. A circular coil of radius 8.0 cm and 20 turns is rotated about its vertical diameter with an angular speed of 50 rad/s in a uniform horizontal magnetic field of magnitude 3.0×10^{-2} T. The maximum emf induced, average emf induced and average power loss due to heating are respectively.

(a) 0.0603 V, 0 V and 0.018 W
(b) 0.0603 V, 0.02 V and 0.015 W
(c) 0 V, 0.0603 V and 0 W
(d) 0.05 V, 0.02 V and 0.018 W

207. A horizontal straight wire 10 m long extending from East to West is 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} Wbm^{-2}. What is the instantaneous value of the emf induced in the wire?

(a) 1.9×10^{-4} V (b) 1.5×10^{-3} V
(c) 2.0×10^{-4} V (d) 3.0×10^{-4} V

208. Current in a circuit falls from 5.0 A to 0.0 A in 0.1 s. If an average emf of 200 V induced, then an estimate of the self-inductance of the circuit is

(a) 5 H (b) 4 H (c) 3 H (d) 2 H

209. A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s. The change of flux linkage with the other coil is

(a) 60 Wb (b) 65 Wb
(c) 30 Wb (d) 50 Wb

210. An air-cored solenoid with length 30 cm, area of cross-section 25 cm^2 and number of turns 500, carries a current of 2.5 A. The current is suddenly switched off in a brief time of 10^{-3} s. How much is the average back emf induced across the ends of the open switch in the circuit? Ignore the variation in magnetic field near the ends of the solenoid.

(a) 6.5 V (b) 7.5 V
(c) 6.0 V (d) 8.0 V

NCERT Exemplar

211. A square of side L metres lies in the XY-plane in a region, where the magnetic field is given by $\mathbf{B} = B_0(2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 4\hat{\mathbf{k}})$ T, where B_0 is constant. The magnitude of flux passing through the square is

(a) $2B_0L^2$ Wb (b) $3B_0L^2$ Wb
(c) $4B_0L^2$ Wb (d) $\sqrt{29}B_0L^2$ Wb

212. A loop, made of straight edges has six corners at A (0, 0, 0), B (L, 0, 0), C (L, L, 0), D (0, L, 0), E (0, L, L) and F (0, 0, L). A magnetic field $\mathbf{B} = B_0(\hat{\mathbf{i}} + \hat{\mathbf{k}})$ T is present in the region. The flux passing through the loop $ABCDEFA$ (in that order) is

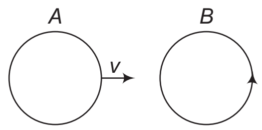
(a) B_0L^2 Wb (b) $2B_0L^2$ Wb
(c) $\sqrt{2}B_0L^2$ Wb (d) $4B_0L^2$ Wb

213. A cylindrical bar magnet is rotated about its axis. A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then,

(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 $T = \frac{2\pi}{\omega}$
(d) a time varying non-sinusoidal current flows through the ammeter A

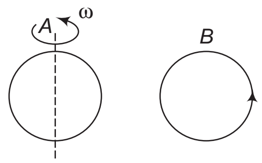
214. There are two coils A and B as shown in figure. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counter-clockwise. B is kept stationary when A moves.

We can infer that



(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 counter-clockwise direction in A

215. Same as Q. 214 except the coil A is made to rotate about a vertical axis (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 counter-clockwise and the coil A is as shown at this instant, $t = 0$, is



(a) constant current clockwise
(b) varying current clockwise
(c) varying current counter-clockwise
(d) constant current counter-clockwise

216. The self-inductance L of a solenoid of length l and area of cross-section A, with a fixed number of turns N increases as
(a) l and A increase
(b) l decreases and A increases
(c) l increases and A decreases
(d) Both l and A decrease

217. A metal plate is getting heated. It can be because
(a) a direct current is passing through the plate
(b) it is placed in a time varying magnetic field
(c) it is placed in a space varying magnetic field, but does not vary with time
(d) a current (either direct or alternating) is passing through the plate

218. An 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 in a constant magnetic field
(d) the coil is stationary in external spatially varying magnetic field, which does not change with time

219. The mutual inductance M_{12} of coil 1 with respect to coil 2
(a) increases when they are brought nearer
(b) depends on the current passing through the coils
(c) increases when one of them is rotated about an axis
(d) is the same as M_{21} of coil 2 with respect to coil 1

220. 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 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) there is a constant magnetic field in the perpendicular (to the plane of the coil) direction

Answers

1.	(b)	2.	(c)	3.	(d)	4.	(d)	5.	(a)	6.	(a)	7.	(d)	8.	(d)	9.	(c)	10.	(c)	11.	(a)	12.	(d)	13.	(d)	14.	(d)	15.	(a)
16.	(c)	17.	(a)	18.	(d)	19.	(a)	20.	(b)	21.	(b)	22.	(c)	23.	(d)	24	(d)	25.	(b)	26.	(d)	27.	(a)	28.	(d)	29.	(a)	30.	(d)
31.	(b)	32.	(b)	33.	(c)	34.	(d)	35.	(d)	36.	(d)	37.	(a)	38.	(b)	39.	(b)	40.	(d)	41.	(b)	42.	(b)	43.	(a)	44.	(c)	45.	(d)
46.	(a)	47.	(c)	48.	(b)	49.	(b)	50.	(a)	51.	(a)	52.	(b)	53.	(a)	54.	(b)	55.	(c)	56.	(b)	57.	(a)	58.	(c)	59.	(a)	60.	(a)
61.	(c)	62.	(b)	63.	(a)	64.	(a)	65.	(b)	66.	(c)	67.	(b)	68.	(a)	69.	(c)	70.	(c)	71.	(b)	72.	(d)	73.	(c)	74.	(d)	75.	(c)
76.	(b)	77.	(a)	78.	(c)	79.	(a)	80.	(d)	81.	(a)	82.	(a)	83.	(d)	84.	(a)	85.	(a)	86.	(b)	87.	(b)	88.	(d)	89.	(c)	90.	(c)
91.	(c)	92.	(c)	93.	(d)	94.	(d)	95.	(a)	96.	(a)	97.	(b)	98.	(a)	99.	(b)	100.	(b)	101.	(d)	102.	(b)	103.	(c)	104.	(a)	105.	(d)
106.	(d)	107.	(d)	108.	(b)	109.	(c)	110.	(b)	111.	(d)	112.	(c)	113.	(b)	114.	(a)	115.	(b)	116.	(b)	117.	(c)	118.	(d)	119.	(d)	120.	(b)
121.	(c)	122.	(b)	123.	(a)	124.	(c)	125.	(b)	126.	(c)	127.	(a)	128.	(c)	129.	(b)	130.	(c)	131.	(a)	132.	(d)	133.	(a)	134.	(d)	135.	(c)
136.	(d)	137.	(c)	138.	(a)	139.	(d)	140.	(c)	141.	(b)	142.	(d)	143.	(c)	144.	(d)	145.	(a)	146.	(a)	147.	(b)	148.	(a)	149.	(a)	150.	(c)
151.	(d)	152.	(a)	153.	(a)	154.	(c)	155.	(c)	156.	(a)	157.	(a)	158.	(c)	159.	(a)	160.	(c)	161.	(a)	162.	(b)	163.	(b)	164.	(b)	165.	(b)
166.	(d)	167.	(d)	168.	(c)	169.	(b)	170.	(d)	171.	(d)	172.	(b)	173.	(d)	174.	(a)	175.	(c)	176.	(b)	177.	(d)	178.	(b)	179.	(a)	180.	(a)
181.	(a)	182.	(b)	183.	(d)	184.	(d)	185.	(a)	186.	(c)	187.	(c)	188.	(a)	189.	(c)	190.	(b)	191.	(a)	192.	(c)	193.	(b)	194.	(b)	195.	(c)
196.	(d)	197.	(a,b,c,d)	198.	(b,d)	199.	(a,b)	200.	(a,c,d)	201.	(a,b)	202.	(a,b,c)	203.	(a)	204.	(b)	205.	(c)	206.	(a)	207.	(b)	208.	(b)	209.	(c)	210.	(a)

Hints *and* Explanations

2. (*c*) The phenomenon in which electric current is generated by varying magnetic fields is called electromagnetic induction.

3. (*d*) The pioneering experiments of Faraday and Henry have led directly to the development of modern day generators and transformers.

4. (*d*) Electromagnetic induction is utilised in the functioning of mouth piece of a telephone now-a-days.

5. (*a*) Faraday demonstrated that electric currents were induced in closed coils when subjected to changing magnetic fields.

6. (*a*) Moving magnet produce electric current in closed coil.

7. (*d*) The discovery and understanding of electromagnetic induction are based on a long series of experiments carried out by Faraday and Henry.

8. (*d*) When the north pole of a bar magnet is pushed towards the coil, the pointer in the galvanometer deflects, indicating the presence of electric current in the coil. Current is induced in the coil.

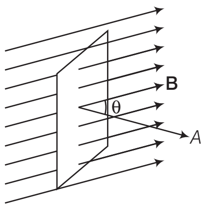
9. (*c*) The galvanometer indicator deflects in the opposite direction, when the magnet is pulled away from the coil.

10. (*c*) Current will be larger, when the magnet is pushed faster towards the coil, also current is large when magnet is pulled faster away but now it is in opposite direction.

11. (*a*) The galvanometer shows a momentary deflection when the tapping key K is pressed.

12. (*d*) Maximum value to zero.

13. (*d*) Magnetic flux through a plane of area A placed in a uniform magnetic field $\mathbf{B}$ can be written as

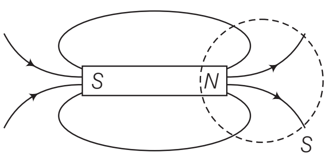


$$\phi_B = \mathbf{B}\cdot\mathbf{A} = BA\cos\theta$$

where, θ is angle between B and A.

14. (*d*) $\sum_{\text{all}} \mathbf{B}_i \cdot d\mathbf{A}_i$

15. (*a*) According to Gauss's theorem in magnetism, surface integral of magnetic field intensity over a surface (closed or open) is always zero.



Number of field lines entering and going out from S are equal. So, net flux through S is zero.

$$\oint B \cdot dA = 0$$

16. (*c*) $\mathbf{B} = B_0\,(3\hat{\mathbf{i}} + 3\hat{\mathbf{j}} - 4\hat{\mathbf{k}})$ T

$\mathbf{B}_x = (3B_0\,\hat{\mathbf{i}})$ T or $B_x = (3B_0)$ T = component of $\mathbf{B}$ along area $\mathbf{A}$

Area of the square, $A = a^2\,(\text{m}^2)$

Observing $\phi_B = BA\cos\theta$

$\Rightarrow \quad \phi_B = (B\cos\theta)A =$ (component of $\mathbf{B}$ along $\mathbf{A}$) A

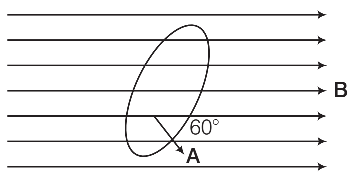
ϕ_B (magnitude of magnetic flux)

$$= B_x\,A = 3B_0a^2\ (\text{Tm}^2) = 3\,B_0a^2\ \text{Wb}$$

17. (*a*) The magnetic flux ϕ passing through a plane surface of area A placed in a uniform magnetic field B is given by

$$\phi = BA\cos\theta$$

where, θ is the angle between the direction of B and the normal to the plane.



Here, $\quad \theta = 60°,\ B = \dfrac{1}{\pi}\ \text{Wbm}^{-2},\ A = \pi(0.2)^2$

$\therefore \quad \phi = \dfrac{1}{\pi} \times \pi(0.2)^2 \times \cos 60° = (0.2)^2 \times \dfrac{1}{2} = 0.02$ Wb

18. (*d*) Whenever the flux of magnetic field through the area bounded by a closed conducting loop changes, an emf is produced in the loop, in this case the magnetic flux *i.e.*, number of magnetic lines of force entering and leaving the XY-plane is same hence magnetic flux is zero.

19. (*a*) The earth magnetic field, $\mathbf{B} = (B_H\,\hat{\mathbf{i}} - B_V\,\hat{\mathbf{j}})$

Given the area, $\mathbf{A} = S\,\hat{\mathbf{k}}$

$$\phi_{xy} = \mathbf{B}\cdot\mathbf{A} = (B_H\,\hat{\mathbf{i}} - B_V\,\hat{\mathbf{j}}).S\hat{\mathbf{k}} = 0$$

20. (*b*) According to Lenz's law electromagnetic induction takes place in the aluminium plate for which eddy current is develop. This causes in energy which result in damping of oscillatory motion of the coil.

21. (*b*) Magnetic flux, $\phi = \mathbf{B}\cdot\mathbf{A} = BA\cos\theta$, where θ is an angle between normal to the area A and magnetic field B.

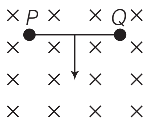
Here, $\quad \theta = (90° - 30°) = 60°$

and $\quad \phi = 10^{-4} \times \pi\left(\dfrac{21}{2} \times 10^{-2}\right)^2 \times \cos 60°\ (\because A = \pi r^2)$

$$= 1.732 \times 10^{-6}\ \text{Wb}$$

22. (*c*) An emf is induced in a coil when magnetic flux through the coil changes with time. This emf causes electric current in closed coil.

23. (*d*) Emf, observations indicate that if circuit is open, then opposite charges accumulate on opposite ends of conductor.



When conductor *PQ* moves downward (in figure) positive charge accumulates at *Q* and negative charge at *P*. So, emf across *PQ* is induced. Flow of charge (current) is induced in closed circuit only. Emf is induced in both open and closed circuits.

Here, in this question emf is most appropriate.

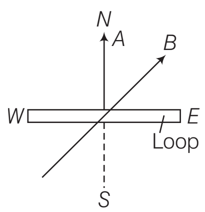
24. (*d*) The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit. Mathematically, the induced emf is given by

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

The negative sign indicates the direction of ε and hence the direction of current in a closed loop.

This is statement of Faraday's law of electromagnetic induction. Fleming's rules, Newton's third law deal with forces and their directions.

25. (*b*) The angle θ made by the area vector of the coil with the magnetic field is 45°. The initial magnetic flux is



$$\phi = BA\cos\theta = \frac{0.1\times 10^{-2}}{\sqrt{2}}\ \text{Wb}$$

$$(\text{as } A = 0.1\times 0.1 = 10^{-2}\,\text{m}^2)$$

Final flux, $\phi_{\min} = 0$

The change in flux is brought about is 0.70 s. The magnitude of the induced emf is given by

$$\varepsilon = \frac{|\Delta\phi\hat{\mathbf{B}}|}{\Delta t} = \frac{|(\phi - 0)|}{\Delta t} = \frac{10^{-3}}{\sqrt{2}\times 0.7} = 1.0\ \text{mV}$$

and the magnitude of the current is

$$I = \frac{\varepsilon}{R} = \frac{10^{-3}\ \text{V}}{0.5\ \Omega} = 2\ \text{mA}.$$

26. (*d*) Initial flux through the coil

$$\phi_{B\,(\text{initial})} = BA\cos\theta = 3.0\times 10^{-5}\times(\pi\times 10^{-2})\times\cos 0^\circ$$

$$= 3\pi\times 10^{-7}\ \text{Wb}$$

Final flux after the rotation

$$\phi_{B\,(\text{final})} = 3.0\times 10^{-5}\times(\pi\times 10^{-2})\times\cos 180^\circ$$

$$= -3\pi\times 10^{-7}\ \text{Wb}$$

$$\Rightarrow \quad \Delta\phi = \phi_{B\,(\text{final})} - \phi_{B\,(\text{initial})} = -6\pi\times 10^{-7}$$

Therefore, estimated value of the induced emf is

$$\varepsilon = -N\frac{\Delta\phi}{\Delta t} = 500\times(6\pi\times 10^{-7})/0.25 = 3.8\times 10^{-3}\ \text{V}$$

27. (*a*) More clearly

$$\because \quad \varepsilon = -N\frac{d\phi_B}{dt}$$

$$\Rightarrow \quad \varepsilon = 1\cdot\frac{d}{dt}(BA\cos 45^\circ) = \frac{A}{\sqrt{2}}\frac{dB}{dt}$$

$$= \frac{(10\times 10\times 10^{-4})}{-\sqrt{2}}\times\frac{0.1}{0.7} = -1\ \text{mV}$$

Magnitude of current $= \dfrac{1\text{mV}}{1\,\Omega} = 1$ mA

28. (*d*) From Faraday's second law, $e = -\dfrac{d\phi_B}{dt}$

$$= -\frac{d}{dt}(6t^2 - 5t + 1) = -(12t - 5)$$

At $\quad t = 0.25\ \text{s} = -[12\times(0.25) - 5] = +2\ \text{V}$

Now, $\quad i = \dfrac{e}{R} = \dfrac{2}{20} = 0.1$ A

29. (*a*) Induced emf of coil, $E = \left|-\dfrac{d\phi}{dt}\right|_t$

Given, $\quad \phi = 50t^2 + 4$ and $R = 400\,\Omega$

$$E = \left|-\frac{d\phi}{dt}\right|_{t=2} = 100t|_{t=2} = 200\text{V}$$

Current in the coil, $i = \dfrac{E}{R} = \dfrac{200}{400} = \dfrac{1}{2} = 0.5$ A

30. (*d*) $\phi = t^3 + 3t - 7$

$\therefore$ Induced emf, $e = -\dfrac{d\phi}{dt} = -(3t^2 + 3) = -3t^2 - 3$

At $\quad t = 0;\ e = -3$ V

Therefore, shape of graph will be a parabola not through origin. $(\because e \propto t^2)$

31. (*d*) If a wire loop is rotated in a magnetic field, the frequency of change in the direction of the induced emf is twice per revolution.

32. (*b*) $e = \dfrac{d\phi}{dt} = \dfrac{d}{dt}(3t^2 + 4t + 9) = 6t + 4 + 0$

At $\ t = 2\text{s},\ e = 6\times 2 + 4 = 16$ V

33. (*c*) From Faraday's law of electromagnetic induction

$$e = -\frac{d\phi}{dt} = -BAN \qquad (\because dt = 1\text{s})$$

Given, $\ B = 0.1$ T, $N = 20$, $A = \pi r^2 = \pi(0.1)^2$

$$\therefore \quad e = 0.1\times 20\times\pi(0.1)^2 = 20\pi\ \text{mV}$$

34. (*d*) From Faraday's law, induced emf is

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

Given, $\phi = xt^2$

$\therefore \quad e = \frac{-d\,(xt^2)}{dt} = -2tx$

Given, $t = 3, e = 9\text{ V}$

$\therefore \quad x = \frac{-9}{3 \times 2} = -1.5 \text{ Wbs}^{-2}$

35. (*d*) $|e| = \frac{d\phi}{dt} = \frac{8 \times 10^{-4}}{0.4} = 2 \times 10^{-3}$ V

36. (*d*) The magnetic flux through area A placed in magnetic field B is

$$\phi = BA\cos\theta$$

Given, $\theta = 0°, \frac{dB}{dt} = 1 \text{ Ts}^{-1}, A = (10)^2 \text{ cm}^2 = 10^{-2} \text{ m}^2$

$\Rightarrow \quad \frac{d\phi}{dt} = 1 \times 10^{-2}$ V

By Faraday's law, induced emf is

$$e = -N\frac{d\phi}{dt} = -500 \times 10^{-2} = -5\text{ V} \quad (\text{here, } \phi \text{ is } \phi_B)$$

37. (*a*) Changing magnetic flex cheats emf or potential difference which creats electric field. Electric field of can credit force of stationary change.
A changing magnetic field can exert a force on the stationary charge.

38. (*b*) $N = 1000, A = 500 \text{ cm}^2 = 500 \times 10^{-4} = 5 \times 10^{-2} \text{ m}^2$

$B = 2 \times 10^{-5} \text{ Wb m}^{-2}, \theta_1 = 0°, \theta_2 = 180°, \Delta t = 0.2$ s.

Initial flux linked with coil

$$\phi_1 = NBA\cos\theta_1 = NBA\cos 0° = NBA$$

Final flux, $\phi_2 = NBA\cos 180°$

$NBA\,(-1) = -NBA$

Change in flux $\Delta\phi = (\phi_2 - \phi_1) = -NBA - (NBA) = -2NBA$

$\therefore$ Induced emf, $e = -\frac{\Delta\phi}{\Delta t} = \frac{-(-2NBA)}{\Delta t} = \frac{2NBA}{\Delta t}$

$$= \frac{2 \times 1000 \times 2 \times 10^{-5} \times 5 \times 10^{-2}}{0.2}$$

$$= 10 \times 10^{-3} \text{ V} = 10 \text{ mV}$$

39. (*b*) Induced emf $(e) = \frac{-NA\,(B_2 - B_1)\cos\theta}{\Delta t}$

$$= \frac{50 \times \pi \times (3 \times 10^{-2})^2\,(0.35 - 0.10)\cos 0°}{2 \times 10^{-3}} = 17.7 \text{ V}$$

40. (*d*) Induced emf in the region is given by $|e| = \frac{d\phi}{dt}$

where, $\phi = BA = \pi r^2 B \quad \Rightarrow \quad \frac{d\phi}{dt} = -\pi r^2 \frac{dB}{dL}$

Rate of change of magnetic flux associates with loop 1

$$e_1 = -\frac{d\phi_1}{dt} = -\pi r^2 \frac{dB}{dt}$$

Similarly, e_2 = emf associated with loops

$$= \frac{d\phi_2}{dt} = 0 \qquad (\because \phi_2 = 0)$$

41. (*b*) $e = \frac{d\phi}{dt} \quad \Rightarrow \quad q = \int i\,dt = \int \frac{e}{R}\,dt$

$\Rightarrow \quad \frac{1}{R}\int \frac{d\phi}{dt}\cdot dt = \frac{1}{R}\int d\phi = \frac{\phi}{R}$

for N turns, $q = \frac{N\phi}{R}$

$$q = \frac{N}{R}\phi = \frac{N}{R}(BA) \quad \left(\because q = it = \frac{\varepsilon}{R}t = \frac{N\phi}{Rt}t\right)$$

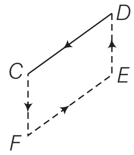
$$\frac{dq}{dt}R = \frac{d\phi_B}{dt} \quad \Rightarrow \quad qR = NBA$$

$\Rightarrow \quad B = \frac{qR}{NA} = \frac{2 \times 10^{-4} \times 80}{40 \times 4 \times 10^{-4}} = 1 \text{ Wb m}^{-2}$

42. (*b*) The statement of Lenz's law is 'the polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it'.

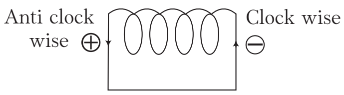
Faraday's law gives magnitude of induced emf. Fleming's rules give force on charged particle in field.

43. (*a*) An emf is induced across the open ends of the circuit. The direction of the induced emf can be found using Lenz's law. For conductor *CD, C* is at positive potential.



We shall use lenz's law to find polarity.

When S-role of magnet goes away from coil it induces N-pole at C and S-pole at D so that movement of magnet is prevents. Creation of N-pole at C induces anti cloclewise current at C or $+ve$ polarity at C. It c and c are foiled lay wire current will flow from C to D through the wire.



North polarity creats anti-clock wise current

44. (*c*) First current develops in direction of *abcd* but when electron moves away then magnetic field inside loop decreases and current changes its direction.

45. (*d*) Suppose that the induced current was in the direction opposite to the one depicted. In that case, the south-pole due to the induced current will face the approaching north-pole of the magnet.

46. (*a*) Yes. The bar magnet will then be attracted towards the coil at an ever increasing acceleration.

47. (*c*) In this situation, the bar magnet experiences a repulsive force due to the induced current. Therefore, a person has to do work in moving the magnet. Where does the energy spend by the person go? This energy is dissipated by Joule heating produced by the induced current.

48. (*b*) **Case I** Closed coil is moving inside constant electric field.
Case II Closed coil is fully inside constant electric field.
No current is induced in either case. Current cannot be induced by changing the electric flux.

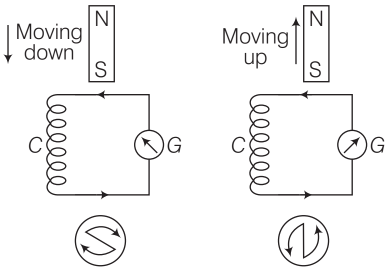
49. (*b*) No.

50. (*a*) The induced emf is expected to be constant only in the case of the rectangular loop. In the case of circular loop, the rate of change of area of the loop during its passage out of the field region is not constant, hence induced emf will vary accordingly.

51. (*a*) The polarity of plate 'A' will be positive with respect to plate 'B' in the capacitor. Both magnets, by motion, increase rightward magnetic flux through coil, induced emf with produce leftward flux, positive charge will come at A.

52. (*b*) When the south-pole of a magnet is moved towards the coil, then by Lenz's law the face of coil, towards magnet becomes south-pole and the current flows clockwise to cancel change in the magnetic flux. So, to bring the magnet near to the coil, more work has to be done against the force of repulsion produced between them. So, the galvanometer shows deflection to the left. Now when the south-pole is moved away, current flows in anti-clockwise direction to make the face of the coil towards magnet, a north-pole.

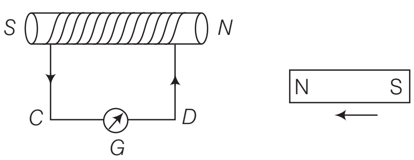
Thus will try to attract the magnet. So, the galvanometer shows the deflection to the right. Since, of flux varies hence, amplitude will not be constant and will decrease.



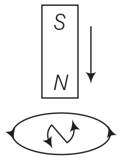
53. (*a*) In the rotation of magnet, N-pole moves closer to coil CD and S-pole moves closer to coil AB.

As per Lenz's law, N pole should develop at the end corresponding to C. Induced current flows from C to D. Again S-pole should develop at the end corresponding to B. Therefore, induced current in the coil flows from A to B.

54. (*b*) When the north pole of the magnet is brought towards one end of the coil, the induced current flows in the coil in such a direction that the end of the coil near the magnet becomes a north pole which repels the magnet and opposes the motion of the north pole of the magnet towards the coil, thus direction of induced current is anti-clockwise.



55. (*c*) By Lenz's law the direction of induced current in the ring is such as to oppose the falling of N-pole of the magnet.



So, the direction of induced current will be anti-clockwise, because the induced current makes the ring a magnetic dipole, with its N-pole upward which opposes (repel) the N-pole of falling magnet. Hence, the direction of the current in the ring will be anti-clockwise.

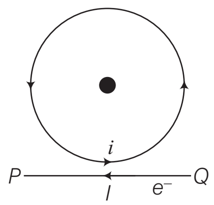
56. (*b*) According to Lenz's law of electromagnetic induction, the relative motion between the coil and magnet produces change in magnetic flux.

57. (*a*) As the shape of the loop is changing and hence, the flux linked with the loop changes. There will an induced emf and hence induced current in the coil. As circle has maximum area, for given perimeter.

So, magnetic flux through the coil is increasing. Induced emf opposes it by giving induced current in anti-clockwise direction.

58. (*c*) In uniform magnetic field, change in magnetic flux is zero. Therefore, induced current will be zero.

59. (*a*) From right hand thumb rule, the magnetic field passing through the loop due to the current i will be perpendicular to the plane of the page pointing downwards. The direction of the current in the loop will be such as to oppose the increase of this field (Lenz's law), hence direction of induced current in the loop anti-clockwise.



60. (*a*) Since, electron is moving from right to left, the flux linked with loop will first increase and then decrease as the electron passes. Therefore, induced current I in the loop will be first clockwise and then will move in anti-clockwise direction.

61. (*c*) Emf across rod is induced, charges get accumulated across end. Current flowing is zero because circuit is open.

62. (*b*) Vertical component of magnetic field

$$\text{Rate of flux} = B_0 \sin\delta$$

$$\Rightarrow \quad \text{emf induced} = B_0 \cdot vL\sin\delta$$

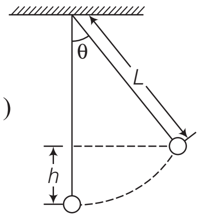
63. (*a*) $\because \quad h = L - L\cos\theta$

$$\Rightarrow \quad h = L(1-\cos\theta)$$

$$\therefore \quad v^2 = 2gh = 2g\,L(1-\cos\theta)$$

$$= 2gL\,(2\sin^2\theta/2)$$

$$\Rightarrow \quad v = 2\sqrt{gL}\,\sin\theta/2$$



Thus, maximum potential difference

$$V_{\max} = BvL = B \times 2\sqrt{gL}\,(\sin\theta/2)\,L$$

$$= 2BL(\sin\theta/2)\,(gL)^{1/2}$$

64. (*a*) A uniformly moving charge can travel both electric and magnetic fields. Energy associated with it will be due to electric field only as magnetic force acts perpendicular to velocity, it does not affect energy of moving charge.

65. (*b*) Induced emf across the ends of wire

$$e = B_H\, lv = 0.30 \times 10^{-4} \times 20 \times 5 = 3 \text{ mV}$$

66. (*c*) The emf induced between ends of the conductor

$$e = \frac{1}{2} B\omega L^2 = \frac{1}{2} \times 0.2 \times 10^{-4} \times 5 \times 1^2$$

$$= 0.5 \times 10^{-4} \text{ V}$$

$$= 5 \times 10^{-5} \text{ V} = 50 \mu\text{V}$$

67. (*b*) As the rod is rotated, free electrons in the rod move towards the outer end and due to force and get distributed over the ring. Thus, the resulting separation of charges produces an emf across the ends of the rod. At a certain value of emf, there is no more flow of electrons and a steady state is reached. The magnitude of the emf generated across a length dr of the rod as it moves at right angles to the magnetic field is given by

$$d\varepsilon = Bvdr$$

Hence, $\varepsilon = \int d\varepsilon = \int_0^R Bvdr = \int_0^R B\omega r dr = \dfrac{B\omega R^2}{2}$

Note that, we have used $v = \omega r$. This gives

$$\varepsilon = \frac{1}{2} \times 1.0 \times 2\pi \times 50 \times (1)^2 = 157 \text{ V}$$

68. (*a*) Induced emf $= (1/2)\,\omega B R^2$

$$= (1/2) \times 4\pi \times 0.4 \times 10^{-4} \times (0.5)^2 = 6.28 \times 10^{-5} \text{ V}$$

$$\left(\because \omega = \frac{2\pi \times 120}{60} = 4\pi \,\text{rads}^{-1}\right)$$

The number of spokes is immaterial because the emf 's across the spokes are in parallel.

69. (*c*) The potential difference across the ends of the conductor

$$dE = Bvdr,$$

$$V = \int dE = \int_0^L Bvdr = \int_0^L Br\omega\, dr = \frac{1}{2}\omega L^2 B$$

70. (*c*) In case of motional emf, the motion of the conductor in the field exerts force on the free charge in conductor, so that one end of the conductor becomes positive, while the other negative resulting in a potential difference across its ends due to which a non-conservative electric field is set up in the conductor. In steady state the magnetic force on the free charge is balanced by the electric force due to induced field.

$$qE = qvB \quad \Rightarrow \quad q(V/l) = qvB$$

i.e., $\quad V = Bvl$

So, the induced emf between tip of nose and tail of helicopter is given by

$$\varepsilon = Bvl = 5 \times 10^{-3} \times 10 \times 100 = 5 \text{ V}$$

71. (*b*) The emf induced, $e = vBl = 1 \times 0.5 \times 2 = 1$ V

72. (*d*) For motional emf $e = (Bv \times 2r) = 2rBv$ will be at higher potential, we can find it by using right hand rule. The electrons of wire will move towards and P due to electric force and at end R the excess positive charge will be left.

73. (*c*) Induced emf, $\varepsilon = Bvl$

$$v = \text{velocity of train} = 72 \times \frac{5}{18} = 20 \,\text{ms}^{-1}$$

Induced emf, $\varepsilon = 2 \times 10^{-5} \times 20 \times 1$

$$= 2 \times 10^{-5} \times 20 = 40 \times 10^{-5} \text{ V}$$

$$= 40 \times 10^{-2} \text{ mV} = 0.4 \text{ mV}$$

74. (*d*) Emf induced in the wire is given by, $\varepsilon = Blv$

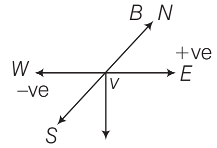
Given, $\quad l = 50$ cm $= 0.5$ m

$$v = 300 \text{ m-min}^{-1} = \frac{300}{60} = 5 \text{ ms}^{-1}$$

$$e = 2 \text{ V}$$

Magnetic field, $B = \dfrac{\varepsilon}{lv} = \dfrac{2}{0.5 \times 5} = 0.80$ T

75. (*c*) Given, $B = 0.30 \times 10^{-4}$ Wb m^{-2}, $v = 5 \,\text{ms}^{-1}$ and $l = 10$ m



As induced emf or potential, $e = Bvl$

So, induced potential gradient $= \dfrac{e}{l} = Bv$

$$= 0.3 \times 10^{-4} \times 5 = 1.5 \times 10^{-4} \text{ Vm}^{-1}$$

Here, East end B at positive potential gradient means increasing potential.

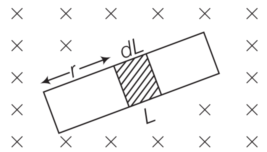
76. (*b*) The emf developed between the centre and the rim is

$$e = \frac{1}{2} B\omega l^2 = \frac{1}{2} \times 0.05 \times 60\,(1)^2 = 1.5 \text{ V}$$

77. (*a*) Induced emf for element on the rod

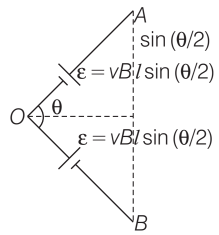
$$de = BvdL\sin 90° = BvdL$$

Net emf, $e = \int de = \int_0^L BvdL = \int_0^L Br\omega\, dL = \left(\dfrac{Br^2\omega}{2}\right)_0^L$



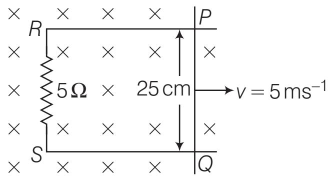
$$e = \frac{1}{2} BL^2\omega$$

78. (*c*) The rod OA is equivalent to a cell with emf $vBl\sin\theta/2$. the positive changes shift towards A due to the force $q\mathbf{v} \times \mathbf{B}$. The positive terminal of the equivalent will appears towards A. Similarly, the rod BO is equivalent to a cell of emf $vBl\sin\theta/2$, with the positive terminal towards O. The equivalent circuit is shown in figure. Clearly, the emf between the points A and B is $2Blv\sin\theta/2$.



79. (*a*) Here, $B = 0.4$ T, $v = 5\ \text{ms}^{-1}$, $l = 25$ cm $= 0.25$ cm

Induced emf produced,



$$\varepsilon = Blv = 0.4 \times 0.25 \times 5$$
$$= 0.5 \text{ V}$$

Current through the 5Ω resistance

$$i = \frac{\varepsilon}{R} = \frac{0.5}{5} = 0.1 \text{ A}$$

According to Lenz's law when the rod *PQ* moves towards right, the induced current should flow in a direction, so that the rod *PQ* experiences force towards left. According to Fleming's left hand rule, then the current through the rod *PQ* will flow from end *Q* to *P* *i.e.*, from end *R* to *S* through the resistance of 5Ω.

80. (*d*) Let us consider the forward motion from $x = 0$ to $x = 2b$.

The flux ϕ_B linked with the circuit *SPQR* is

$$\phi_B = Blx, \quad 0 \le x < b$$

The induced emf is

$$\varepsilon = -\frac{d\phi_B}{dt} = -\frac{Blx}{t} = -Blv, \quad 0 \le x < b$$

$$\phi_B = Blb, \quad b \le x < 2b$$

$$e = -\frac{d\phi}{dt} = 0, \quad b \le x < 2b$$

81. (*a*) When the induced emf is non-zero, the current I is $\dfrac{Blv}{r}$.

The force required to keep the arm *PQ* in constant motion is IlB. Its direction is to the left. In magnitude

$$F = BIl = \frac{B^2 l^2 v}{r}, \quad 0 \le x < b$$

$$F = 0, \quad b \le x < 2b$$

The joule heating loss is

$$P_j = Fv = \frac{B^2 l^2 v^2}{r}, \quad 0 \le x < b$$

$$P = 0, \quad b \le x < 2b$$

82. (*a*) Here, $A = 10 \times 5 = 50\ \text{cm}^2 = 50 \times 10^{-4}\ \text{m}^2$

$$\frac{dB}{dt} = 0.02\ \text{T s}^{-1}, \quad R = 2\Omega$$

$$\varepsilon = \frac{d\phi_B}{dt} = A \cdot \frac{dB}{dt} = 50 \times 10^{-4} \times 0.02 = 10^{-4}\ \text{V}$$

Power dissipated in the form of heat $= \dfrac{\varepsilon^2}{R}$

$$= \frac{10^{-4} \times 10^{-4}}{2} = 0.5 \times 10^{-8}\ \text{W}$$

$$= 5 \times 10^{-9}\ \text{W} = 5\text{nW}$$

83. (*d*) Here $dB/dt = 0.02$ T/s,

Area of the loop,

$$A = l \times b = 8\ \text{cm} \times 2\ \text{cm} = 16\ \text{cm}^2 = 16 \times 10^{-4}\ \text{m}^2$$

Resistance of the loop, $R = 1.6\,\Omega$

Let ε be the magnitude of the induced emf in the loop.

Clearly, $\varepsilon = \dfrac{d\phi_B}{dt} = \dfrac{d}{dt}(\phi_B) \Rightarrow \dfrac{d}{dt}(BA) = A\left(\dfrac{dB}{dt}\right)$

(as $\phi_B = BA$ and A is a constant)

or $\quad \varepsilon = (16 \times 10^{-4}\ \text{m}^2)\,(0.02\ \text{T/s}) = 32 \times 10^{-6}\ \text{V}$

When the cut in the loop is joined, power dissipated

$$P = \frac{\varepsilon^2}{R} = \frac{(32 \times 10^{-6}\ \text{V})^2}{1.6\,\Omega} = 6.4 \times 10^{-10}\ \text{W}$$

84. (*a*) **Electromagnetic Induction** A copper plate is allowed to swing like a simple pendulum between the pole pieces of a strong magnet.

It is found that the motion is damped and in a little while the plate comes to a halt in the magnetic field. We can explain this phenomenon on the basis of electromagnetic induction.

Magnetic flux associated with the plate keeps on changing as the plate moves in and out of the region between magnetic poles. The flux change induces eddy currents in the plate. Directions of eddy currents are opposite when the plate swings into the region between the poles and when it swings out of the region. Heat is produced in copper plate, copper plate moves slower.

85. (*a*) A copper plate is allowed to swing like a simple pendulum between the pole pieces of a strong magnet to induce eddy currents in it. Eddy currents are not induced in insulators.

86. (*b*) Electromagnetic damping.

87. (*b*) Conductor.

88. (*d*) The disc in analogue type electric power meter rotates due to eddy currents.

89. (*c*) An electric current can be induced in a coil by flux change produced by another coil in its vicinity or flux change produced by the same coil. In both the cases, the flux through a coil is proportional to the current. That is, $\phi_B \propto I$.

90. (*c*) Further, if the geometry of the coil does not vary with time, then

$$\frac{d\phi_B}{dt} \propto \frac{dI}{dt}$$

For a closely wound coil of N turns, the same magnetic flux is linked with all the turns. When the flux ϕ_B through the coil changes, each turn contributes to the induced emf. Therefore, a term called flux linkage is used which is equal to $N\phi_B$ for a closely wound coil and in such a case $N\phi_B \propto I$.

91. (*c*) For a closely wound coil of N turns the magnetic flux linked with all turns is same. When the flux ϕ_B through the coil changes, each turn contributes to the induced emf.

92. (*c*) Geometry of coil and intrinsic material properties.

93. (*d*) Air as the medium within the solenoids. Instead, if a medium of relative permeability μ_r had been present, the mutual inductance would be $M = \mu_r \mu_0 n_1 n_2 \pi r_1^2 l$.

It is also important to know that the mutual inductance of a pair of coils, solenoids etc., depends on their separation as well as their relative orientation.

95. (*a*) Mutual inductance for two concentric coplanar circular coils,

$\because$ Magnetic flux linked with A, $\phi_A = B \cdot \pi r^2$

$$\Rightarrow \qquad \phi_A = \frac{\mu_0 I}{2R} \cdot \pi r^2$$

$\left(\because B = \dfrac{\mu_0 I}{2R}\right.$, magnetic field at the centre of B and $\left. N_1 = 1 = N_2\right)$

Now, the coefficient M;

$$\because \qquad \phi_A = MI$$

$$\Rightarrow \qquad M = \frac{\frac{\mu_0 I \cdot \pi r^2}{2R}}{I} = \frac{\mu_0 \pi r^2}{2R}$$

96. (*a*) Here, $I_A = 2A$,

ϕ_B [flux linked with B due to current (in A)] $= 10^{-2}$ Wb

As, $\phi_B = M_{BA} I_A$

$$M_{BA} = \frac{\phi_{BA}}{I_A} = \frac{10^{-2}\text{ Wb}}{2\text{A}} = 5 \times 10^{-3}\text{ H}$$

When, $I_B = 1\text{ A}$, $\phi_A = M_{AB} I_B = (5 \times 10^{-3}\text{ H})\ (1\text{ A})$
$= 5 \times 10^{-3}$ Wb

97. (*b*) Mutual inductance of the pair of coils depends on distance between two coils and geometry of two coils.

98. (*a*) Let a current I_2 flow through the outer circular coil. The field at the centre of the coil is $B_2 = \mu I_2 / 2r_2$. Since, the other co-axially placed coil has a very small radius. B_2 may be considered constant over it's cross-sectional area. Hence,

$$\phi = \pi r_1^2 B_2 = \frac{\mu_0 \pi r_1^2}{2r_2} I_2 = M_{12} I_2 \quad \left(\because B = \frac{\mu_0 I}{2r}\right)$$

Thus, $$M_{12} = \frac{\mu_0 \pi r_1^2}{2r_2}$$

$$\Rightarrow \qquad M_{12} = M_{21} = \frac{\mu_0 \pi r_1^2}{2r_2}.$$

99. (*b*) Mutual induction depends upon the magnetic permeability of medium between the coils (μ_r) or nature of material on which two coils are wound.

101. (*d*) The self-induced emf always opposes any change (increase or decrease) of current in coil.

103. (*c*) From formula for a circular coil $L = \mu_0 n^2 A l$

$$L \propto n^2$$

So, if n is double, so inductance will be four times.

104. (*a*) Rate of work done, $\dfrac{dW}{dt} = LI \dfrac{dI}{dt}$.

105. (*d*) Work done, $W = \int_0^I LIdI$.

106. (*d*) When the two coils are joined in series such that, the winding of one is opposite to the other, then the emf produced in first coil is 180° out of phase of the emf produced in second coil.

Thus, emf produced in first coil is negative and the emf produced in second coil is positive, so net inductance is

$$L = L_1 + L_2 = L + L$$

From Faraday's law of electromagnetic induction

$\phi = LI$, where ϕ is flux and I is the current.

$$L = -\frac{\phi}{I} + \frac{\phi}{I} \quad \Rightarrow \quad L = 0 = \text{net inductance}$$

107. (*d*) The coefficient of self-induction of a coil is numerically equal to the emf (e) induced in the coil when the rate of change of current $\left(\dfrac{\Delta i}{\Delta t}\right)$ in the coil is unity.

$$\therefore \qquad L = -\frac{e}{\frac{\Delta i}{\Delta t}} \quad \Rightarrow \quad e = -L\frac{\Delta i}{\Delta t}$$

Given, $L = 60\text{ mH} = 60 \times 10^{-3}\text{ H}$,

$\Delta i = (2.5 - 1.5)\text{ A} = 1\text{ A}$ and $\Delta t = 0.2\text{ s}$

$$\therefore \qquad e = -\frac{60 \times 10^{-3} \times 1}{0.2} = -0.3\text{ V}$$

Induced current, $i = \dfrac{e}{R} = \dfrac{0.3}{3} = 0.1\text{ A}$

108. (*b*) By Faraday's second law, induced emf

$$e = -\frac{Nd\phi}{dt} \text{ which gives, } e = -L\frac{dI}{dt}$$

$$\therefore \qquad |e| = 2 \times 10^{-3} \times 20 \times 10^{-3}\text{ V} = 40\,\mu\text{V}$$

109. (*c*) The induced emf is given by

$$|e| = \left(L\frac{di}{dt}\right) = 0.4 \times 50 = 20\text{ V}$$

110. (*b*) Energy stored inductor

$$E = \frac{1}{2}LI^2 = \frac{1}{2} \times 40\,(2)^2\text{ mJ} = 80\text{ mJ}$$

111. (*d*) Energy stored in a self-inductor,

$$E = \frac{1}{2}Li^2 = \frac{1}{2} \times 200 \times 10^{-3} \times (4)^2 = 1.6\text{ J}.$$

112. (*c*) Given, number of turns of solenoid, $N = 1000$.

Current, $I = 4$ A

Magnetic flux, $\phi_B = 4 \times 10^{-3}$ Wb

$\because$ Self-inductance of solenoid is given by

$$L = \frac{\phi_B \cdot N}{I} \qquad \ldots\text{(i)}$$

Substitute the given values in Eq. (i), we get

$$L = \frac{4 \times 10^{-3} \times 1000}{4} = 1\text{H}$$

113. (*b*) Induced emf in the coils given by

$$e = L\frac{dI}{dt}$$

$$\Rightarrow \qquad e = 10 \times \frac{(10-5)}{0.2} = 250\text{ V}$$

114. (*a*) The emf induced in the inductor is given by

$$|e| = L\frac{di}{dt}$$

Current, $I = \frac{V}{R} = \frac{10}{15} = 2\text{ A}$

Circuit switches off in 1 ms.

or $dt = 1\times 10^{-3}$ s, $dI = 2$ A

and $L = 10$ H

$\therefore$ Induced emf in inductor is

$$|e| = L\frac{dI}{dt} = 10\times\frac{2}{1\times 10^{-3}} = 2\times 10^{4}\text{ V}$$

115. (*b*) Solenoids 1 and 2 were wound using the similar wire and same number of turns $\Rightarrow L_1 = L_2$

Solenoid 3 was wound using superconducting wire (means $R = 0$) infinite current will flow, so resistance to change of current = 0 $\Rightarrow$ $L_3 = 0$

So, $L_1 = L_2$ and $L_3 = 0$

116. (*b*) When coil is open, there is no current in it, hence no flux associated with it *i.e.*, $\phi = 0$. Also, we know that flux linked with the coil is directly proportional to the current in the coil,

i.e., $\phi \propto i \Rightarrow \phi = Li$

where, L is proportionally constant known as self-inductance.

$$\therefore \quad L = \frac{\phi}{i} = 0$$

Again, since $i = 0$, hence $R = \infty$. $\left(\because R = \frac{V}{I}\right)$

117. (*c*) The induced emf is

$$e = -L\frac{di}{dt}$$

Here, $di = (2-10)\text{A} = -8\text{A}$,

$\Rightarrow$ $dt = 0.1\text{s}, e = 3.28$ V

$$\therefore \quad 3.28 = -\frac{L(-8)}{0.1}$$

$$\Rightarrow \quad L = \frac{3.28\times 0.1}{8} = 0.04\text{ H}$$

118. (*d*) Induced emf, $|e| = L\frac{di}{dt} = (60\times 10^{-3})\times\frac{(1.5-1)}{0.1}$

$$= \frac{60\times 10^{-3}\times 0.5}{0.1} = 0.3$$

Induced current, $i = \frac{e}{R} = \frac{0.3}{3} = 0.1$ A

119. (*d*) The inductance of a coil of wire of N turns is given by

$$L = N\frac{\phi}{i}$$

where, i is current and ϕ is magnetic flux.

Given, $N = 100, i = 5\text{A}, \phi = 10^{-5}\text{ Tm}^2\text{ (turn)}^{-1}$

$$\therefore \quad L = 100\times\frac{10^{-5}}{5} = 0.20\text{ mH}$$

120. (*b*) Self-inductance of coil is given as

$$\left[N\left(\frac{\mu_0 I}{2R}\right)\right](\pi R^2)N = LI$$

$$\Rightarrow \quad L = \frac{\mu_0 N^2\pi R}{2} = \frac{4\pi\times 10^{-7}}{2}\times(500)^2\times\pi\times(5\times 10^{-2})$$

$$= 25\times 10^{-3}\text{ H} = 25\text{ mH}$$

121. (*c*) The energy stored in an inductor

$$U = \frac{1}{2}LI^2$$

122. (*b*) Flux $\phi = Li$ (L = self-inductance of the coil)

$\Rightarrow$ Self-inductance, $L = \frac{\phi}{i} = \frac{10\times 10^{-6}}{2\times 10^{-3}} = 5\times 10^{-3} = 5$ mH

123. (*a*) Area, $A = 10^{-3}\text{ m}^2$

Length, $l = 31.4\text{ cm} = 0.314$ m

$A = 10^{-3}\text{m}^2, n = \frac{10^3}{0.314}$ = turns per unit length

$\Rightarrow$ $(\mu_0 nI)(nl)(A) = LI$

$\Rightarrow$ $L = \mu_0 n^2 Al$

$$\Rightarrow \quad L = 4\pi\times 10^{-7}\times\left(\frac{10^3}{0.314}\right)^2\times 10^{-3}\times 0.314 = 4\text{ mH}$$

124. (*c*) $\phi = \mu_r\mu_o\frac{N^2}{l}Ai$

$$= 600\times 4\pi\times 10^{-7}\times 50\times 50\pi\times\frac{(7.5\times 10^{-3})^2\times 3}{6\times 10^{-1}}$$

$$= 16.6\times 10^{-3}\text{ Wb} = 1.66\text{ m Wb}$$

125. (*b*) The magnetic energy is

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

$$= \frac{1}{2}L\left(\frac{B}{\mu_0 n}\right)^2 \quad (\text{Since, } B = \mu_0 nI\text{, for a solenoid})$$

$$= \frac{1}{2}(\mu_0 n^2 Al)\left(\frac{B}{\mu_0 n}\right)^2 = \frac{1}{2\mu_0}B^2 Al$$

126. (*c*) One method to induce an emf or current in a loop is through a change in the loop's orientation or a change in its effective area.

As the coil rotates in a magnetic field **B**, the effective area of the loop (the face perpendicular to the field) is $A\cos\theta$, where, θ is the angle between **A** and **B**.

This method of producing a flux change is the principle of operation of a simple AC generator. An AC generator converts mechanical energy into electrical energy.

128. (*c*) When the coil is rotated with a constant angular speed ω the angle θ between the magnetic field vector **B** and the area vector **A** of the coil at any instant t is $\theta = \omega t$ (assuming $\theta = 0°$ at $t = 0$).

129. (*b*) The effective area of the coil exposed to the magnetic field lines changes with time, the flux at any time t is

$$\phi_B = BA\cos\theta = BA\cos\omega t$$

130. (*c*) The maximum value of the emf is $NBA\omega$.

131. (*a*) From Faraday's law, the induced emf for the rotating coil of N turns is then,

$$\varepsilon = N\frac{d\phi_B}{dt} = -NBA\frac{d}{dt}(\cos\omega t)$$

Thus, the instantaneous value of the emf is

$$\varepsilon = NBA\ \omega\sin\omega t$$

where, $NBA\omega$ is the maximum value of the emf, which occurs when $\sin\omega t = \pm 1$. If we denote $NBA\omega$ as ε_0, then

$$\varepsilon = \varepsilon_0\sin\omega t$$

133. (*a*) $\frac{d\phi_B}{dt} = -NBA\omega\sin\omega t$, change of flux is greatest for $\omega t = \theta = 90°, 270°, \theta = 90°, 270°$.

134. (*d*) From Faraday's law of electromagnetic induction

$$e = -\frac{Mdi}{dt}$$

$$\Rightarrow \quad M = -\frac{e}{di/dt}$$

Given, $e = 5\pi$ V and $i = 10\sin(100\pi t)$,

$$\therefore \quad \left(\frac{di}{dt}\right)_{\max} = 10\times 100\pi$$

$$\therefore \quad M = -\frac{5\pi}{10\times 100\pi} = -5\times 10^{-3}\ \text{H} = 5\ \text{mH}$$

135. (*c*) Mutual inductance between two coils $M = 0.005$ H

Peak current $I_0 = 10$ A

Angular frequency $\omega = 100\pi$ rad s^{-1}

The current $\quad I = I_0\sin\omega t$

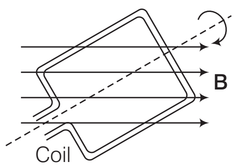
or $\quad \frac{d}{dt} = \frac{d}{dt}(I_0\sin\omega t) = I_0\cos\omega t\cdot\omega$

$$= 10\times 1\times 100\pi = 1000\pi$$

Hence, induced emf is given by

$$e = M\times\frac{di}{dt} = 0.005\times 1000\times\pi = 5\pi\text{V}$$

136. (*d*) $\varepsilon = 200\sin 100\pi t$



$$\varepsilon_0 = 200, \omega = 100\pi$$

$$\because \quad BAN\omega = \varepsilon_0$$

$$\therefore \quad B = \frac{\varepsilon_0}{AN\omega} = \frac{200}{(0.25\times 0.25)\times 1000\times 100\pi} = 0.01\ \text{T}$$

137. (*c*) Here, $\nu = 0.5$ Hz, $N = 100$, $A = 0.1\text{m}^2$ and $B = 0.01$ T

$(\because \varepsilon = \varepsilon_0\sin\omega t = NBA\omega\sin\omega t)$

$\varepsilon_{\max} = NBA\omega \qquad (\because \sin\omega t = 1)$

$$\varepsilon_0 = NBA\ (2\pi\nu) = 100\times 0.01\times 0.1\times 2\times 3.14\times 0.5$$

$$= 0.314\ \text{V}$$

The maximum voltage is 0.314 V.

138. (*a*) Mutual inductance of two coils

$$M = \frac{\mu_0 R_1^2\pi R_2^2}{2(R_1^2\times x^2)^{3/2}}$$

where, x = distance between the centres

Flux through the bigger coil

$$M = \frac{\mu_0}{4\pi}\cdot\frac{\pi^2 R_1^2 R_1^2}{(R_1^2\times x^2)}$$

On substituting the values, we get

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

On solving, we get, $M = 9.216\times 10^{-11} \approx 9.2\times 10^{-11}$ Wb

139. (*d*) Induced emf $= \frac{N\Delta\phi}{\Delta t}$

Peak value $= N_1 BA_1\omega = 100$ V

Here, $2\pi r_1\times 100 = 2\pi r_2\times N_2$ (given)

$$N_2 = \frac{r_1\times 100}{r_2} = \frac{1\times 100}{2} = 50 = \frac{N_1}{2}$$

$$\because \quad e_0 = N_2 BA_2\omega$$

$$\Rightarrow \quad e_0 = \frac{N}{2}\times B\times 4A_1\times\omega = 2\times(\text{initial emf}) = 200\ \text{V}$$

$(\because A_2 = 4A_1)$

140. (*c*) When a coil of N number of turns and area A is rotated in external magnetic field **B**, magnetic flux linked with the coil changes and hence an emf is induced in the coil. At this instant t, if e is the emf induced in the coil, then alternating emf induced is

$$e = e_0\sin\omega t$$

Maximum current $i_0 = \frac{e_0}{R} = \frac{NBA\omega}{R}$

Given, $N = 1, B = 10^{-2}$ T

$$A = \pi(0.3)^2\ \text{m}^2, R = \pi^2\ \Omega$$

$$f = \frac{200}{60}\text{s}^{-1} \text{ and } \omega = 2\pi\left(\frac{200}{60}\right)$$

$$\therefore \quad i_0 = \frac{1\times 10^{-2}\times\pi(0.3)^2\times 2\pi\times 200}{60\times\pi^2}$$

$$= 6\times 10^{-3}\ \text{A} = 6\ \text{mA}$$

141. (*b*) The emf induced is directly proportional to rate at which flux is intercepted which varies directly as the speed of rotation of the generator.

Now, speed $= \frac{120}{100}\times 1500$ rpm $= 1800$ rpm

142. (*d*) As the coil is rotated, angle θ (angle which normal to the coil makes with B at any instant t) changes, therefore magnetic flux ϕ linked with the coil changes and hence, an emf is induced in the coil. At this instant t , if e is the emf induced in the coil, then

$$e=-\frac{d\phi}{dt}=-\frac{d}{dt}(NAB\cos\omega t)$$

where, N is number of turns in the coil.

$$\Rightarrow \quad e=-NAB\frac{d}{dt}(\cos\omega t)$$

$$=-NAB(-\sin\omega t)\,\omega$$

$$\Rightarrow \quad e=NAB\,\omega\sin\omega t$$

The induced emf will be maximum.

When $\sin\omega t=\text{maximum}=1$

$$\therefore \quad e_{\max}=e_0=NAB\omega\times 1$$

$$\Rightarrow \quad e=e_0\sin\omega t$$

Therefore, e would be maximum, hence current is maximum (as $i_0=e_0/R$) when $\theta=90°$, *i.e.*, normal to plane of coil is perpendicular to the field or plane of coil is parallel to magnetic field.

143. (*c*) According to Faraday's law of the conservation mechanical energy into electrical energy is in accordance with the law of conservation of energy. It is also clearly known that in pure resistance, the emf is in phase with the current.

144. (*d*) Lenz's law is based on conservation of energy and induced emf always opposes the cause of it, change in magnetic flux.

145. (*a*) Both assertion and reason are correct and reason is correct explanation of assertion.

Increasing **B** causes induced current I due to induced electric field E along I.

Note This induced electric field is non-conservative, makes closed loop electric field lines.

So, time varying magnetic field generates electric field.

146. (*a*) Both assertion and reason are correct and reason is the correct explanation of assertion.

148. (*a*) If the inner solenoid was much shorter than (and placed well inside) the outer solenoid, then we could still have calculated the flux linkage $N_1\theta_1$ because the inner solenoid is effectively immersed in a uniform magnetic field due to the outer solenoid.

150. (*c*) The relation of induced emf is

$$e=\frac{Ldi}{dt}\text{ and current } i \text{ is given by } i=\frac{e}{R}=\frac{1}{R}\frac{Ldi}{dt}$$

$$\Rightarrow \quad \frac{di}{dt}=i\frac{R}{L}=\frac{i}{L/R}$$

In order to decrease the rate of increase of current through solenoid we have to increase the time constant $=\frac{L}{R}$.

152. (*a*) The inductance coils made of copper will have very small ohmic resistance. Due to change in magnetic flux a large induced current will be produced in such an inductance coil which will offer appreciable opposition to the flow of current.

153. (*a*) If $B=0$, then $\phi=B\cdot A=0$.

If $\phi=0$, then $\phi=B\cdot A=0$. B may or may not be zero because angle between B and A may be 90°. $BA\cos\theta=0$ for $\theta=90°$.

154. (*c*) Scalar product of two vectors can be scalar or vector.

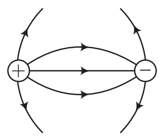
155. (*c*) If $B=0$, then $\phi=\mathbf{B}\cdot\mathbf{A}=0$

When $\phi=0$, B may or may not be zero.

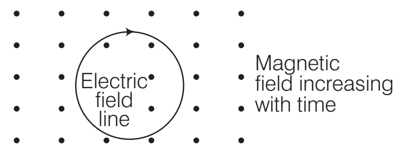
156. (*a*) Wherever the term 'coil' or 'loop' is used, it is assumed that they are made up of conducting material.

157. (*a*) The direction of induced emf is always such as to oppose the change that causes it. It is based upon conservation of energy.

158. (*c*) Electric field lines of electric field of static electric charges do not form closed loops, they start from positive charge and end at negative charge.



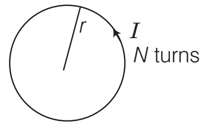
Electric field lines of electric field due to time varying magnetic field form closed loops.



159. (*a*) Coil comes to rest quickly because of eddy current generated.

160. (*c*) The inductance coils made of conductor will have very small ohmic resistance. Due to change in magnetic flux a large induced current will be produced in such an inductance, which will offer appreciable opposition to the flow of current.

161. (*a*) In self-induction, flux linkage through a coil of N turns is proportional to the current through the coil.



Magnetic field at centre $=B=N\frac{\mu_0 I}{2r}\propto NI$

In general, magnetic field inside circle of radius $\propto NI$

$\Rightarrow$ Flux through coil $\propto NI\pi r^2\propto NI\propto I$

$\Rightarrow$ Flux linkage $\propto I \Rightarrow N\phi_B\propto I\Rightarrow N\phi_B=LI$

162. (*b*) It would be extremely difficult to calculate the flux linkage with the outer solenoid as the magnetic field due to the inner solenoid would vary across the length as well as cross-section of the outer solenoid.

163. (*b*) The self-induced emf is also called the back emf as it opposes any change in the current in a circuit. Physically, the self-inductance plays the role of inertia. It is the electromagnetic analogue of mass in mechanics. So, work needs to be done against the back emf (ε) in establishing the current. This work done is stored as magnetic potential energy.

164. (*b*) An exceptionally important application is the generation of Alternating Currents (AC). The modern AC generator with a typical output capacity of 100 MW is a highly evolved machine.

165. (*b*) Alternating current changes direction periodically.

$$\omega = 2\pi\nu \text{ and } \varepsilon = \varepsilon_0 \sin 2\pi\nu t.$$

166. (*d*) Joseph Henry (1797-1878) American experimental physicist professor at Princeton University and first director of the Smithsonian Institution. He made important improvements in electromagnets by winding coils of insulated wire around iron pole pieces and invented an electromagnetic motor and a new, efficient telegraph.

He discovered self-induction and investigated how currents in one circuit induce currents in another.

167. (*d*) Relative motion between the magnet and the coil that is responsible for induction in the coil.

169. (*b*) I, III and IV are correct. Inductance has dimension $[ML^2T^{-2}A^{-2}]$

170. (*d*) When two solenoids of inductance L_0 are connected in series at large distance and current i passed through them, the total flux linkage ϕ_{total} is the sum of the flux linkages $L_0 i$ and $L_0 i$,

i.e., $$\phi_{total} = L_0 i + L_0 i$$

If L be the equivalent inductance of the system, then

$$\phi_{total} = Li \quad \therefore \; Li = L_0 i + L_0 i$$

($\because$ current remains same in series)

$$\Rightarrow \qquad L = 2L_0$$

When solenoids are connected in series with one inside the other and senses of the turns coinciding, then there will be a mutual inductance L between them.

In this case the resultant induced emf in the coils is the sum of the emf 's e_1 and e_2 in the respective coils, *i.e.*,

$$e = e_1 + e_2 = \left(-L_0 \frac{di}{dt} \pm L_0 \frac{di}{dt}\right) + \left(-L_0 \frac{di}{dt} \pm L_0 \frac{di}{dt}\right)$$

where, $(+)$ sign is for positive coupling and $(-)$ sign for negative coupling.

But $$e = -L\frac{di}{dt}$$

$$\therefore \qquad -L\frac{di}{dt} = -L_0\frac{di}{dt} - L_0\frac{di}{dt} \pm 2L_0\frac{di}{dt}$$

Overall inductance will increase

i.e., $$L = L_0 + L_0 + 2L_0 = 4L_0 \text{ (for positive coupling)}$$

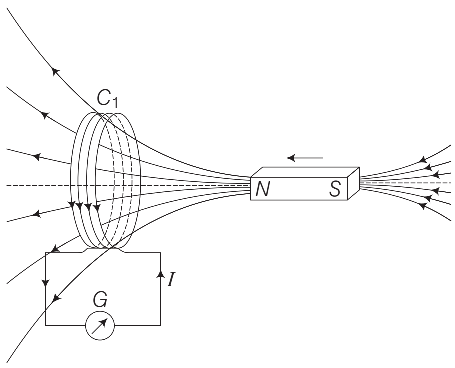
But for negative coupling, $L = L_0 + L_0 - 2L_0 = 0$

171. (*d*) An AC generator consists of a coil mounted on a rotor shaft. The axis of rotation of the coil is perpendicular to the direction of the magnetic field. The coil (called armature) is mechanically rotated in the uniform magnetic field by some external means.

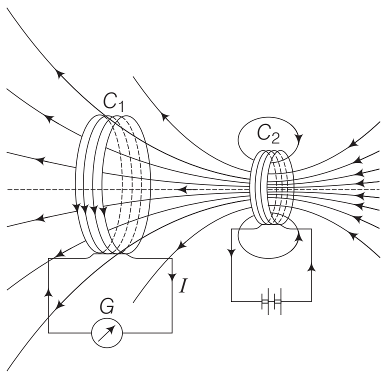
The rotation of the coil causes the magnetic flux through it to change, so an emf is induced in the coil. The ends of the coil are connected to an external circuit by means of slip rings and brushes.

172. (*b*) Modern day generators produce electric power as high as 500 MW. In most generators, the coils are held stationary, electromagnets are rotated. In India frequency of rotation of armature is 50 MHz.

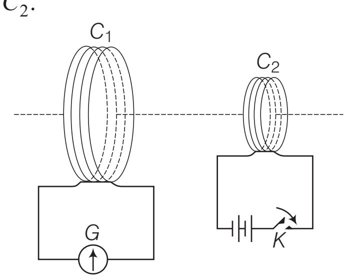
173. (*d*)



When the bar magnet is pushed towards the coil, the pointer in the galvanometer G deflects.



Current is induced in coil C_1 due to motion of the current carrying coil C_2.



Current in C_1 is induced by changing current in C_2.

174. (*a*)

(i) The magnetic flux through the rectangular loop *abcd* increases, due to the motion of the loop into the region of magnetic field. The induced current must flow along the path *bcdab*, so that it opposes the increasing flux.

(ii) Due to the outward motion, magnetic flux through the triangular loop *abc* decreases due to which the induced current flows along *bacb*, so as to oppose the change in flux.

(iii) As the magnetic flux decreases due to motion of the irregular shaped loop *abcd* out of the region of magnetic field, the induced current flows along *cdabc*, so as to oppose change in flux.

176. (*b*) Due to current carrying wire, the magnetic field in loop will be inwards w.r.t. the paper. As current is increased, magnetic flux associated with loop increases. So a current will be induced so as to decrease magnetic flux inside the loop. Hence, induced current in the loop will be anti-clockwise. The current in left side of loop shall be downwards and hence repelled by wire. The current in right side of loop is upwards and hence attracted by wire. Since left side of loop is nearer to wire, repulsive force will dominate.

Hence wire will repel the loop (*b*) Options in (*b*) will be opposite of that in (*a*) (*c*) When the loop is moved away from wire, magnetic flux decreases in the loop. Hence the options for this case shall be same as in (*b*) (*d*) When the loop is moved towards the wire, magnetic flux increases in the loop. Hence, the options for this case shall be same as in (*a*).

177. (*d*) The steady current in the coil C_2 produces a steady magnetic field. As coil C_2 is moved towards the coil C_1, the galvanometer shows a deflection. This indicates that electric current is induced in coil C_1. When C_2 is moved away, the galvanometer shows a deflection again, but this time in the opposite direction. The deflection lasts as long as coil C_2 is in motion. When the coil C_2 is held fixed and C_1 is moved, the same effects are observed. It is the relative motion between the coils that induces the electric current.

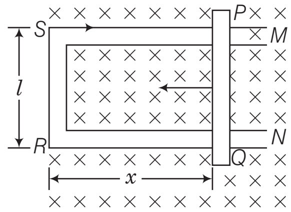
178. (*b*) Opposite direction. Refer to sol. 177.

179. (*a*) Coil C_2 is in motion. Refer to sol. 177.

180. (*a*) Galvanometer shows the deflection, same effects are observed.

181. (*a*) The motion of a magnet towards or away from coil C_1 in Fig. (i) and moving a current-carrying coil C_2 towards or away from coil C_1 in Fig. (ii), change the magnetic flux associated with coil C_1. The change in magnetic flux induces emf in coil C_1. It is this induced emf which causes electric current to flow in coil C_1 and through the galvanometer.

183. (*d*) A rectangular conductor $PQRS$ in which the conductor PQ is free to move. The rod PQ is moved towards the left with a constant velocity **v** as shown in the figure. Assume that there is no loss of energy due to friction. $PQRS$ forms a closed circuit enclosing an area that changes as PQ moves.



It is placed in a uniform magnetic field **B** which is perpendicular to the plane of this system. If the length $RQ = x$ and $RS = l$, the magnetic flux ϕ_B enclosed by the loop $PQRS$ will be $\phi_B = Blx$.

184. (*d*) Since, x is changing with time, the rate of change of flux ϕ_B will induce an emf given by

$$\varepsilon = \frac{-d\phi_B}{dt} = -\frac{d}{dt}(Blx)$$

$$= -Bl\frac{dx}{dt} = Blv$$

185. (*a*) Here, we have used $dx/dt = -v$ which is the speed of the conductor PQ.

186. (*c*) The induced emf Blv is called motional emf. Thus, we are able to produce induced emf by moving a conductor instead of varying the magnetic field, that is by changing the magnetic flux enclosed by the circuit.

187. (*c*) It is also possible to explain the motional emf expression in equation, $\varepsilon = Blv$ by involving the Lorentz force acting on the free charge carriers of conductor PQ. Consider any arbitrary charge q in the conductor PQ. When the rod moves with speed v, the charge will also be moving with speed v in the magnetic field **B**.

The Lorentz force on this charge is qvB in magnitude and its direction is towards Q.

All charges experience the same force, in magnitude and direction, irrespective of their position in the rod PQ.

The work done in moving the charge from P to Q is,

$$W = qvBl$$

Since, emf is the work done per unit charge,

$$\varepsilon = \frac{W}{q} = Blv$$

This equation gives emf induced across the rod PQ and is identical to motional emf equation.

188. (*a*) Eddy current are minimised by using laminations of metal to make a metal core.

The laminations are separated by an insulating material like lacquer. The plane of the laminations must be arranged parallel to the magnetic field, so that they cut across the eddy current paths. This arrangement reduces the strength of the eddy current. Since, the dissipation of the strength of electric current, heat loss is substantially reduced.

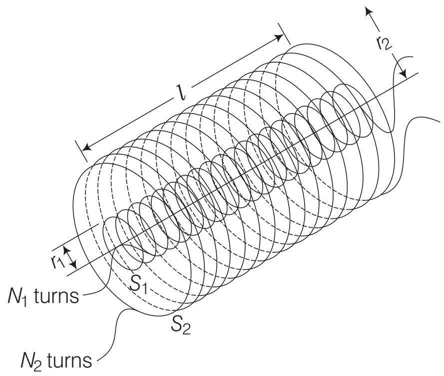
189. (*c*) Eddy currents paths. Refer to solution 188.

190. (*b*) Induction furnace can be used to produce high temperatures and can be utilised to prepare alloys, by melting the constituent metals. A high frequency alternating current is passed through a coil which surrounds the metals to be melted. The eddy currents generated in the metals produce high temperatures sufficient to melt it.

191. (*a*) Alloys, by melting the constituent metals.

192. (*c*) Eddy current generated in the metal produce high temperature sufficient to melt it.

193. (*b*) Two long co-axial solenoids each of length l are shown in the following figure. We denote the radius of the inner solenoid S_1 by r_1 and the number of turns per unit length by n_1. The corresponding quantities for the outer solenoid S_2 by r_2 and n_2, respectively. Let N_1 and N_2 be the total number of turns of coils S_1 and S_2, respectively.



When a current I_2 is set up through S_2, it in turn sets up a magnetic flux through S_1. Let us denote it by ϕ_1. The corresponding flux linkage with solenoid S_1 is

$$N_1\phi_1 = M_{12}I_2$$

M_{12} is called the mutual inductance of solenoid S_1 w.r.t. solenoid S_2. It is also referred to as the coefficient of mutual induction.

194. (*b*) M_{12}. Refer to solution 193.

195. (*c*) M_{12} is coefficient of mutual induction. Magnetic field in $S_2 = \mu_0 n_2 I_2$

196. (*d*) Magnetic field due to the current.

$$I_2 \text{ in } S_2 \text{ is } \mu_0 n_2 I_2$$

The resulting flux linkage with coil S_1 is

$$N_1\phi_1 = (nl)(\pi r_1^2)(\mu_0 n_2 I_2)$$
$$= \mu_0 n_1 n_2 \pi r_1^2 l I_2$$

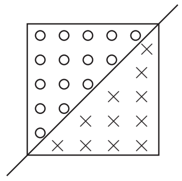
197. (*a, b, c, d*) From $\phi = Li$; $L = \text{meter/ampere}$

From $e = L\dfrac{di}{dt}$; $L = \dfrac{\text{volt -second}}{\text{ampere}}$

From $E = \dfrac{1}{2}Li^2$; $L = \text{Joule/ampere}^2$.

From $R = \omega L$; $L = \text{ohm-sec}$

198. (*b,d*) $\phi_0 = 0$ for all cases. So, induced emf = 0



199. (*a,b*) The magnetic flux through area A placed in magnetic field B is

$$\phi = BA\cos\theta$$

Given, $\theta = 0°$, $-\dfrac{dB}{dt} = 2\ \text{Ts}^{-1}$

$$A = (20)^2\ \text{cm}^2 = 4\times10^{-2}\ \text{m}^2$$

By Faraday's law, induced emf is

$$e = -N\frac{\Delta\phi}{\Delta t} = -400\times A\frac{dB}{dt}$$
$$= -(400)(4\times10^{-2})\left(-\frac{dB}{dt}\right)$$
$$= 400\times4\times10^{-2}\times2 = 32\ \text{V}$$

200. (*a,c,d*) Here, radius $r = 10\,\text{cm} = 10\times10^{-2}$ m

Number of turn $N = 500$

Magnetic field $B = 3\times10^{-5}$ T

Resistance $R = 2\,\Omega$

Initial flux through the coil $\phi B_i = BA\cos\theta$

$$= 3\times10^{-5}\times\pi\times(10\times10^{-2})^2\cos0°$$
$$= 3\pi\times10^{-7}\ \text{Wb}$$

Final flux after rotation

$$\phi_{B_f} = 3\times10^{-5}\times\pi\times(10\times10^{-2})\times\cos180°$$
$$= -3\pi\times10^{-7}\ \text{Wb}$$

Emf induced in the coil

$$E = -N\frac{\Delta\phi_B}{\Delta t} = -N\left(\frac{\phi_{B_f}-\phi_{B_i}}{\Delta t}\right)$$
$$= -\frac{500\times(-3\pi\times10^{-7}-3\pi\times10^{-7})}{0.5}$$
$$= \frac{500\times6\pi\times10^{-2}}{0.5} = \frac{500\times6\pi\times10^{-2}}{0.5} = 2\times10^{-3}\ \text{V}$$

Induced current in the coil, $I = \dfrac{2\times10^{-3}}{2\,\Omega} = 10^{-3}\ \text{A} = 1\,\text{mA}$

203. (*a*) Given, number of turns $n = 15$ per cm $= 1500$ per metre

Area of small loop $A = 2\,\text{cm}^2 = 2\times10^{-4}\ \text{m}^2$

Change in current $\dfrac{dI}{dt} = \dfrac{4-2}{0.1} = \dfrac{2}{0.1} = 20\ \text{A/s}$

Let e be the induced emf,

According to Faraday's law,

$$e = \frac{d\phi}{dt} = \frac{d}{dt}(BA) \qquad (\because \phi = BA)$$

or $\qquad e = A\dfrac{dB}{dt} = A\dfrac{d}{dt}(\mu_0 nI)$

($\because$ Magnetic field inside the solenoid $B = \mu_0\, nI$)

or $\qquad e = A\,\mu_0 n\,\dfrac{dI}{dt}$

$\Rightarrow \qquad e = 2\times 10^{-4}\times 4\times 3.14$
$\times 10^{-7}\times 1500\times 20$

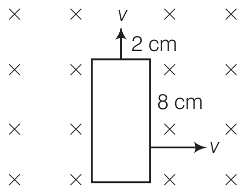
($\because\ \mu_0 = 4\pi\times 10^{-7}$)

$\Rightarrow \qquad e = 7.5\times 10^{6}$ V

Thus, the induced emf in the loop is 7.5×10^{6} V.

204. (*b*) (i) When velocity is normal to the longer side
($l = 8\,\text{cm} = 8\times 10^{-2}$ m)

Given, length of the loop



$$l = 8\,\text{cm} = 8\times 10^{-2}\ \text{m}$$

Width of the loop $b = 2\,\text{cm} = 2\times 10^{-2}$ m

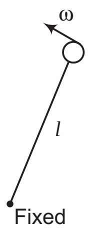
Velocity of the loop = $1\,\text{cms}^{-1} = 0.01\ \text{ms}^{-1}$

Magnitude of magnetic field $B = 0.3$ T

In this case, motional emf $e = Blv = 0.3\times 8\times 10^{-2}\times 0.01$

$$= 2.4\times 10^{-4}\ \text{V}$$

205. (*c*) Length of rod $l = 1$ m



Angular frequency of rod $\omega = 400\,\text{rads}^{-1}$

Magnetic field $B = 0.5$ T

The linear velocity of fixed end = 0

The linear velocity of other end = $l\omega$
($\because v = r\omega$)

Average linear velocity $v = \dfrac{0 + l\omega}{2} = \dfrac{l\omega}{2}$ ...(i)

By using the formula of motional emf,

$$e = Bvl = \frac{Bl\omega}{2}\cdot l \qquad \text{[from Eq. (i)]}$$

$\Rightarrow \qquad e = \dfrac{0.5\times 1\times 400\times 1}{2}$

$\Rightarrow \qquad e = 100$ V

Thus, the emf developed between the centre and ring is 100 V.

206. (*a*) Given, radius of coil = 8 cm = 0.08 m

Number of turns = 20

Resistance of closed-loop = 10 Ω

Angular speed $\omega = 50\,\text{rads}^{-1}$

Magnitude of magnetic field $B = 3\times 10^{-2}$ T

Induced emf produced in the coil $e = NBA\omega\sin\omega t$

For maximum emf, $\sin\omega t = 1$

$\therefore$ Maximum emf

$$e_0 = NBA\omega = 20\times 3\times 10^{-2}\times 3.14\,(0.08)^2\times 50$$

$\Rightarrow \qquad e_0 = 0.603$ V

Maximum current in the coil $I_0 = \dfrac{e_0}{R} = \dfrac{0.603}{10} = 0.0603$ A

Average induced emf

$$e_{\text{av}} = \frac{1}{T}\int_0^{2\pi} e\,dt = \frac{1}{T}\int_0^{2\pi} NBA\omega\sin\omega t\,dt$$

$$\Rightarrow \qquad e_{\text{av}} = \frac{1}{T}\cdot NAB\omega\left[\frac{\cos\omega t}{\omega}\right]_0^{2\pi}$$

$$= \frac{NBA}{T}[\cos 2\pi - \cos 0^\circ]$$

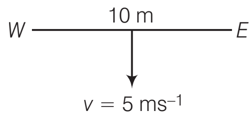
$$\Rightarrow \qquad e_{\text{av}} = \frac{NBA}{T}[1-1] = 0$$

For full cycle average emf, $e_{\text{av}} = 0$

Average power loss due to heating

$$= \frac{e_0 I_0}{2} = \frac{0.603\times 0.0603}{2} = 0.018\ \text{W}$$

207. (*b*) Given, velocity of straight wire = $5\,\text{ms}^{-1}$



Magnetic field of straight wire,

$$B = 0.30\times 10^{-4}\ \text{Wbm}^{-2}$$

Length of wire, $l = 10$ m

Emf induced in the wire $e = Blv\sin\theta$

Here, $\theta = 90^\circ$

$\therefore \qquad \sin\theta = 1$

($\because$ Wire is falling at right angle to earth's horizontal magnetic field component.)

$$= 0.3\times 10^{-4}\times 10\times 5 = 1.5\times 10^{-3}\ \text{V}$$

208. (*b*) Change in current, $dI = 5 - 0 = 5$ A

Time taken in current change $dt = 0.1$ s

Induced average emf $e_{\text{av}} = 200$ V

Induced emf in the circuit, $e = L\dfrac{dI}{dt}$

$$\Rightarrow \qquad 200 = L\left(\frac{5}{0.1}\right) \quad \text{or} \quad L = \frac{200}{50} = 4\ \text{H}$$

209. (*c*) Given, mutual inductance of coil

$$M = 1.5 \text{ H}$$

Current change in coil $dI = 20 - 0 = 20$ A

Time taken in change $dt = 0.5$ s

Induced emf in the coil $e = M\dfrac{dI}{dt} = \dfrac{d\phi}{dt}$

or $\quad d\phi = M.dI = 1.5 \times 20$

$\Rightarrow \quad d\phi = 30$ Wb

Thus, the change of flux linkage is 30 Wb.

210. (*a*) Given, length of solenoid $l = 30 \text{ cm} = 30 \times 10^{-2}$ m

Area of cross-section $A = 25 \text{ cm}^2 = 25 \times 10^{-4} \text{ m}^2$

Number of turns $N = 500$

Current $I_1 = 2.5$ A, $I_2 = 0$

Brief time $dt = 10^{-3}$ s

Induced emf in the solenoid

$$e = \frac{d\phi}{dt} = \frac{d}{dt}(BA) \qquad (\because \phi = BA)$$

Magnetic field induction B at a point well inside the long solenoid carrying current I is

$$B = \mu_0 nI$$

$$\left(\text{where, } n = \text{Number of turns per unit length} = \frac{N}{l}\right)$$

$$\therefore \quad e = NA\frac{dB}{dt} = A\frac{d}{dt}\left(\mu_0\frac{N}{l}I\right) = A\,\frac{\mu_0 N}{l}\cdot\frac{dI}{dt}$$

$\Rightarrow$

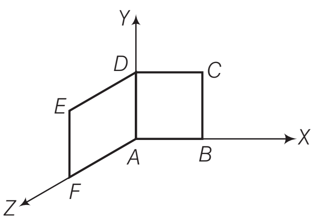
$$e = 500 \times 25 \times 10^{-4} \times 4 \times 3.14 \times 10^{-7} \times \frac{500}{30 \times 10^{-2}} \times \frac{2.5}{10^{-3}}$$

$\Rightarrow e = 6.5$ V

211. (*c*) Here, $A = L^2\hat{\mathbf{k}}$ and $\mathbf{B} = B_0(2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 4\hat{\mathbf{k}})$ T

$$\phi = \mathbf{B}\cdot\mathbf{A} = B_0(2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 4\hat{\mathbf{k}}).L^2\hat{\mathbf{k}} = 4B_0L^2 \text{ Wb}$$

212. (*b*) Also, the magnetic flux linked with uniform surface of area A in uniform magnetic field is given by



$$\phi = \mathbf{B}\cdot\mathbf{A}$$

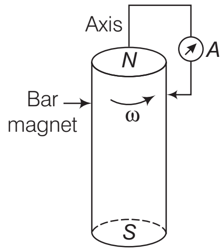
$$\mathbf{A} = \mathbf{A}_1 + \mathbf{A}_2 = (L^2\hat{\mathbf{k}} + L^2\hat{\mathbf{i}})$$

and $\quad \mathbf{B} = B_0(\hat{\mathbf{i}} + \hat{\mathbf{k}})$ T

Now, $\quad \phi = \mathbf{B}\cdot\mathbf{A} = B_0(\hat{\mathbf{i}} + \hat{\mathbf{k}})\cdot(L^2\hat{\mathbf{k}} + L^2\hat{\mathbf{i}})$

$$= 2B_0L^2 \text{ Wb}$$

213. (*b*) When cylindrical bar magnet is rotated about its axis, no change in flux linked with the circuit takes place, consequently no emf induces and hence, no current flows through the ammeter A.



214. (*d*) When the A stops moving the current in B become zero, it possible only if the current in A is constant. If the current in A would be variable, there must be an induced emf (current) in B even if the A stops moving.

215. (*a*) When the current in B (at $t = 0$) is counter-clockwise and the coil A is considered above to it. The counter-clockwise flow of the current in B is equivalent to north pole of magnet and magnetic field lines are emanating upward to coil A. When coil A start rotating at $t = 0$, the current in A is constant along clockwise direction by Lenz's rule.

216. (*b*) The self-inductance of a long solenoid of cross-sectional area A and length l, having n turns per unit length, filled the inside of the solenoid with a material of relative permeability (*e.g.*, soft iron, which has a high value of relative permeability) is given by

$$L = \mu_r\mu_0 n^2 Al$$

where, $\quad n = N / l$

217. (*a,b,d*) A metal plate is getting heated when a DC or AC current is passed through the plate, known as heating effect of current. Also, when metal plate is subjected to time varying magnetic field, the magnetic flux linked with the plate changes and eddy currents comes into existence which makes the plate hot.

218. (*a,b,c*) Here, magnetic flux linked with the isolated coil change when the coil being in a time varying magnetic field, the coil moving in a constant magnetic field or in time varying magnetic field.

219. (*a,d*) The mutual inductance M_{12} of coil increases when they are brought nearer and is the same as M_{21} of coil 2 with respect to coil 1.

220. (*b,c*) 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 way that the cross-product of magnetic field and surface area of plane of coil remain constant at every instant.