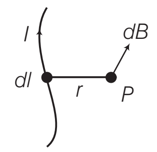
CHAPTER

4

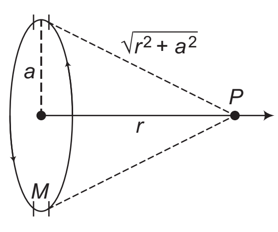
Moving Charges and Magnetism

A Quick Recapitulation of the Chapter

1. The space in the surroundings of a magnet or a current-carrying conductor in which its magnetic influence can be experienced is called **magnetic field**. Its SI unit is Tesla (T).
2. **Lorentz force** is the total force F experienced by charge (q) when it is moving with velocity v in the presence of electric field $\mathbf{E}$ and magnetic field $\mathbf{B}$.
$$\mathbf{F} = q(\mathbf{v} \times \mathbf{B} + \mathbf{E}) \qquad \text{(vector form)}$$
Magnitude of magnetic force, $F = qvB \sin\theta$ and direction of force is given by right hand palm rule or Fleming's left hand rule.
3. Force experienced by a current-carrying conductor having current I and length l, when placed in a magnetic field B is $\mathbf{F} = \mathbf{I} \times \mathbf{B} = IB \sin\theta$
4. When charged particle enters into a magnetic field perpendicularly, then
(i) $\frac{mv^2}{r} = qvB$ (ii) $r = \frac{mv}{qB}$
(iii) $T = \frac{2\pi m}{qB}$ (iv) $\nu = \frac{qB}{2\pi m}$
(v) $\text{KE} = \frac{q^2B^2r^2}{2m}$
5. The frequency of a charged particle (q) when it enters perpendicularly into the magnetic field B and it attains a circular path, is $\nu = \frac{qB}{2\pi m}$
where, m is the mass of charged particle. This is called **cyclotron frequency**.
6. KE_{max} of charged particle accelerated by cyclotron is
$$\text{KE}_{max} = \frac{q^2B^2R^2}{2m}$$
where, R = radius of circular track of charged particle.
7. **Biot-Savart's law** According to this law, the magnetic field due to small current-carrying element Idl at any nearby point is given by

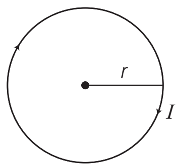


$$d\mathbf{B} = \frac{\mu_0}{4\pi} \cdot \frac{Id\mathbf{l}\hat{\mathbf{r}}}{|\mathbf{r}|^2}$$
or $$dB = \frac{\mu_0}{4\pi} \cdot \frac{Idl \sin\theta}{r^2}$$
8. Magnetic field at any point along the **axis of circular current-carrying conductor** is
$$B = \frac{\mu_0 I a^2}{2(r^2 + a^2)^{3/2}}$$



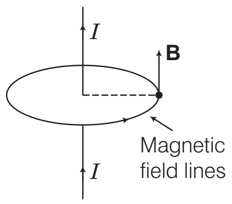
9. Magnetic field at the **centre of a circular current-carrying conductor/ coil**

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



where, r is the radius of a circular loop.

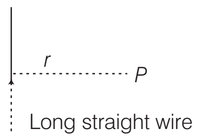
10. **Ampere's circuital law** The line integral of the magnetic field **B** around any closed loop is equal to μ_0 times the total current I flowing through the loop,



i.e., $$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I$$

Magnitude of magnetic field of a straight wire using Ampere's law, $B = \frac{\mu_0 I}{2\pi r}$

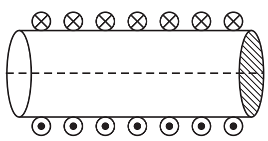
11. Magnetic field due to **straight current-carrying conductor** at any point P at a distance r from the wire is given by



$$B = \frac{\mu_0}{4\pi} \cdot \frac{2I}{r}$$

$\Rightarrow$ $$B \propto \frac{1}{r}$$

12. **Magnetic field due to a straight solenoid**



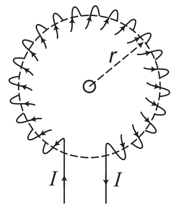
(i) At any point inside the solenoid, $B = \mu_0 n I$
where, n = number of turns per unit length.

(ii) At the ends of the solenoid, $B = \frac{1}{2}\mu_0 n I$

13. **Magnetic field due to toroidal solenoid**

(i) Inside the toroidal solenoid,

$$B = \mu_0 n I$$

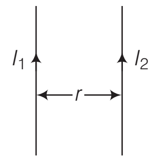


Here, $n = \frac{N}{2\pi r}$,
N = total number of turns

(ii) In the open space, exterior of toroidal solenoid,

$$B = 0$$

14. Force between the two parallel current-carrying conductors is



$$F = \frac{\mu_0}{4\pi} \cdot \frac{2 I_1 I_2}{r} . L$$

If the direction of flow of current is same, then they attract each other otherwise they will repel each other.

15. Torque on a current loop,

$$\tau = \mathbf{M} \times \mathbf{B} = N I \mathbf{A} \mathbf{B}$$

where, M is the magnetic moment.

16. Magnetic moment, $\mathbf{M} = N I \mathbf{A}$
where, A is the area and I is the current.

17. The magnetic field due to current in a circular current loop as magnetic dipole, is

$$B = \frac{\mu_0}{4\pi} \frac{2\pi r^2 i}{x^3}$$

Here, x is the distance along the axis from the centre of the loop.

18. The ratio $\frac{\mu_l}{l} = \frac{e}{2m_e}$ is called the gyromagnetic ratio and is constant. Its value is 8.8×10^{10} C/kg for an electron.

19. Current sensitivity, $\frac{\phi}{I} = \frac{NAB}{k}$
where, ϕ is deflection produced and k is spring constant.

20. Voltage sensitivity, $\frac{\phi}{V} = \frac{NAB}{kR}$

Objective Questions Based on NCERT Text

Topic 1

Magnetic Force

1. If a proton is projected in a direction perpendicular to a uniform magnetic field with velocity v and an electron is projected along the lines of force, what will happen to proton and electron?

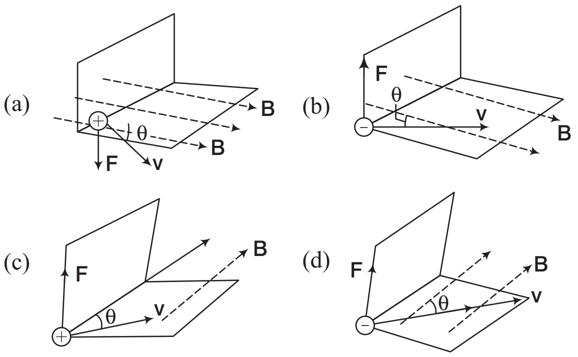
(a) The electron will travel along a circle with constant speed and the proton will move along a straight line

(b) Proton will move in a circle with constant speed and there will be no effect on the motion of electron

(c) There will not be any effect on the motion of electron and proton

(d) The electron and proton both will follow the path of a parabola

2. Which of the following diagrams is correct?



3. Magnetic field produced by a wire carrying current

(a) is parallel along the axis of wire

(b) is perpendicular to the plane of the wire

(c) forms circular loops along the axis of wire and coplanar to the wire

(d) direction of field is not constant

4. An electron is travelling horizontally towards East. A magnetic field in vertically downward direction exerts a force on the electron along

(a) East (b) West

(c) North (d) South

5. If a particle of charge 10^{-12} C moving along the $\hat{\mathbf{X}}$-direction with a velocity $10^5\ \text{ms}^{-1}$ experiences a force of 10^{-10} N in $\hat{\mathbf{Y}}$-direction due to magnetic field, then the minimum magnetic field is

(a) 6.25×10^3 T in $\hat{\mathbf{Z}}$-direction

(b) 10^{-15} T in $\hat{\mathbf{Z}}$-direction

(c) 6.25×10^{-3} T in $\hat{\mathbf{Z}}$-direction

(d) 10^{-3} T in $\hat{\mathbf{Z}}$-direction

6. When a charged particle moves in the region of magnetic field, then

(a) magnitude of its velocity keeps on changing

(b) velocity of particle remains constant

(c) direction of momentum keeps on changing

(d) kinetic energy of particle keeps on changing

7. A proton enters a magnetic field of flux density $1.5\ \text{Wbm}^{-2}$ with a velocity of $2 \times 10^7\ \text{ms}^{-1}$ at an angle of $30°$ with the field. The force on the proton will be

(a) 2.4×10^{-12} N

(b) 0.24×10^{-12} N

(c) 24×10^{-12} N

(d) 0.024×10^{-12} N

8. An ionised gas contains both positive and negative ions. If it is subjected simultaneously to an electric field along the $+x$-direction and a magnetic field along the $+z$-direction, then

(a) positive ions deflect towards $+y$-direction and negative ions towards $-y$-direction

(b) all ions deflect towards $+y$-direction

(c) all ions deflect towards $-y$-direction

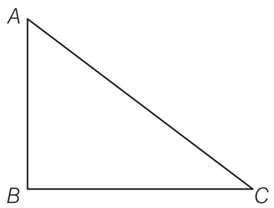
(d) positive ions deflect towards $-y$-direction and negative ions towards $+y$-direction

9. A current-carrying wire of area A, length l, number of density of charge carriers n is placed in a region of external magnetic field B. What will be net force on charged carriers?

(a) $(nAl)q\ (\mathbf{v}_d \times \mathbf{B})$ (b) $q\ (\mathbf{v}_d \times \mathbf{B})$

(c) $nq\ (\mathbf{v}_d \times \mathbf{B})$ (d) $Alq\ (\mathbf{v}_d \times \mathbf{B})$

10. A current-carrying closed loop in the form of a right angled isosceles ΔABC is placed in a uniform magnetic field acting along AB. If the magnetic force on the arm BC is $\mathbf{F}$, then force on the arm AC is



(a) $-\mathbf{F}$ (b) $\mathbf{F}$ (c) $\sqrt{2}\mathbf{F}$ (d) $-\sqrt{2}\mathbf{F}$

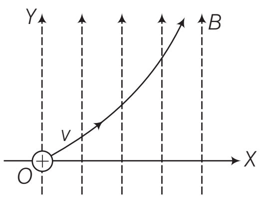
11. A square current-carrying loop is suspended in a uniform magnetic field acting in the plane of the loop. If the force on one arm of the loop is F, the net force on the remaining three arms of the loop is

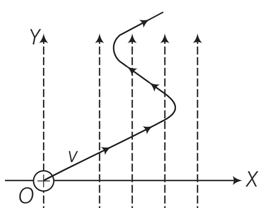
(a) 3 **F** (b) –**F**
(c) –3 **F** (d) **F**

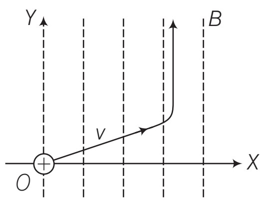
12. An electron enters a region of magnetic field perpendicularly with a speed of 3×10^7 ms^{-1}. Strength of magnetic field is 6×10^{-4} T. Frequency and energy of electron respectively are

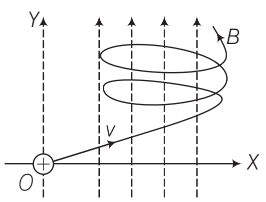
(a) 2 MHz, 25 keV
(b) 20 MHz, 2.5 keV
(c) 20 MHz, 25 keV
(d) 2 MHz, 2.5 keV

13. Which one is a correct figure to represent path of a moving charge in magnetic field?

(a)


(b)


(c)


(d)


14. A proton, a deuteron and an α-particle enter a region of perpendicular magnetic field (to their velocities) with same kinetic energy. If r_p, r_d and r_α are the radii of circular paths of these particles, then

(a) $r_\alpha = r_d < r_p$
(b) $r_\alpha = r_d = r_p$
(c) $r_\alpha < r_d < r_p$
(d) $r_\alpha > r_d > r_p$

15. Two particles of masses m_a and m_b with same charge are projected in a perpendicular magnetic field. They travel along circular path of radii r_a and r_b such that $r_a > r_b$. Which is correct?

(a) $m_a v_a > m_b v_b$
(b) $m_a > m_b$ and $v_a > v_b$
(c) $m_a = m_b$ and $v_a > v_b$
(d) $m_b v_b > m_a v_a$

16. A particle of mass m and charge q moves with a constant velocity v along the positive x-direction. It enters a region containing a uniform magnetic field B directed along the negative z-direction, extending from $x = a$ to $x = b$. The minimum value of v required so that the particle can just enter the region $x > b$ is

(a) $qb\,B/m$ (b) $q\,(b - a)\,B/m$
(c) $q\,aB/m$ (d) $q\,(b + a)\,B/2m$

17. An α-particle with a specific charge of 2.5×10^7 C/kg moves with a speed of 2×10^5 ms^{-1} in a perpendicular magnetic field of 0.05 T. The radius of circular path described by the particle is

(a) 8 cm (b) 4 cm (c) 16 cm (d) 2 cm

18. A proton of energy 1 MeV describes a circular path in plane at right angles to a uniform magnetic field of 6.28×10^{-4} T. The mass of proton is 1.7×10^{-27} kg. The frequency of proton is nearly equal to

(a) 10^7 Hz (b) 10^5 Hz
(c) 10^6 Hz (d) 10^4 Hz

19. A proton of mass 1.67×10^{-27} kg and charge 1.6×10^{-19} C is projected with a speed of 2×10^6 ms^{-1} at an angle of 60° to the X-axis. If a magnetic field of 0.104 T is applied along Y-axis, then path of proton is

(a) a circle of radius 0.2 m and time period of $\pi \times 10^{-7}$ s
(b) a circle of radius 0.1 m and time period $2\pi \times 10^{-7}$ s
(c) a helix of radius 0.2 m and time period of $2\pi \times 10^{-7}$ s
(d) a helix of radius 0.2 m and time period of $4\pi \times 10^{-7}$ s

20. A straight wire of mass 200 g and length 1.5 m carries a current of 2 A. It is held in mid-air by a uniform horizontal magnetic field. What is the magnitude of magnetic field?

(a) 1 T (b) 0.65 T (c) 0.35 T (d) 0.85 T

21. An electron moves in a circular orbit with a uniform speed v. It produces a magnetic field B at the centre of the circle. The radius of the circle is proportional to

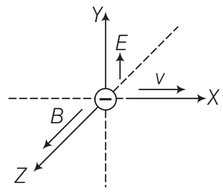
(a) $\frac{B}{v}$ (b) $\frac{v}{B}$
(c) $\sqrt{\frac{v}{B}}$ (d) $\sqrt{\frac{B}{v}}$

22. A deuteron of kinetic energy 50 keV is describing a circular orbit of radius 0.5 m in a plane perpendicular to magnetic field B. The kinetic energy of the proton that describes a circular orbit of radius 0.5 m in the same plane with the same magnetic field B is

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

Topic 2
Motion in Combined Electric and Magnetic Field

23. In the given figure, E and B are magnitudes of electric and magnetic fields which are acting on a moving electron as shown. The direction of velocity of electron is along X-axis.

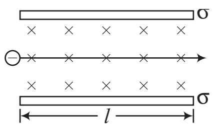


Then, force on electron is given by

(a) $\mathbf{F} = q\,(E + vB)\,\hat{\mathbf{j}}$ (b) $\mathbf{F} = q(E - vB)\,\hat{\mathbf{j}}$

(c) $\mathbf{F} = q\,(E + vB)\,\hat{\mathbf{k}}$ (d) $\mathbf{F} = q\,(E - vB)\,\hat{\mathbf{k}}$

24. An electron moves straight inside a charged parallel plate capacitor. Plates of capacitor have charge density σ. The space between plates is filled with constant magnetic field of induction $\mathbf{B}$.



Time taken by electron to pass through the region is

(a) $\dfrac{e\sigma}{\varepsilon_0 lB}$ (b) $\dfrac{\varepsilon_0 lB}{\sigma}$ (c) $\dfrac{\sigma e}{\varepsilon_0 B}$ (d) $\dfrac{\varepsilon_0 B}{e\sigma}$

25. A cyclotron is used to accelerate charged particles or ions to high energies. It uses

(a) only electric field
(b) only magnetic field
(c) Both electric and magnetic fields
(d) None of the above

26. An alternating electric field of frequency ν, is applied across the dees (radius $= R$) of a cyclotron that is being used to accelerate protons (mass $= m$). The operating magnetic field (B) used in the cyclotron and the kinetic energy (K) of the proton beam produced by it, are given by **[CBSE AIPMT 2012]**

(a) $B = \dfrac{m\nu}{e}$ and $K = 2m\pi^2\nu^2R^2$

(b) $B = \dfrac{2\pi m\nu}{e}$ and $K = m^2\pi\nu R^2$

(c) $B = \dfrac{2\pi m\nu}{e}$ and $K = 2m\pi^2\nu^2R^2$

(d) $B = \dfrac{m\nu}{e}$ and $K = m^2\pi\nu R^2$

27. A proton and an α-particle both enter a region of uniform magnetic field B, moving at right angles to the field B. If the radius of circular orbits for both the particles is equal and the kinetic energy acquired by proton is 1 MeV, the energy acquired by the α-particle will be **[CBSE AIPMT 2015]**

(a) 4 MeV (b) 0.5 MeV (c) 1.5 MeV (d) 1 MeV

28. Cyclotron frequency of an electron circulating in a magnetic field of 1T is

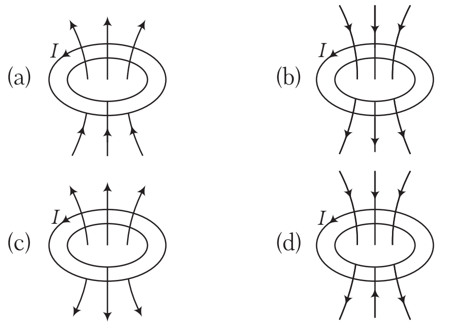
(a) 28 MHz (b) 280 MHz (c) 2.8 GHz (d) 28 GHz

29. An electron is moving in a cyclotron at a speed of 3.2×10^7 ms^{-1} in a magnetic field of 5×10^{-4} T perpendicular to it. What is the frequency of this electron? ($q = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg)

(a) 1.4×10^5 Hz (b) 1.4×10^7 Hz

(c) 1.4×10^6 Hz (d) 1.4×10^9 Hz

30. Which of the following figures correctly depicts the direction of magnetic field of a current-carrying coil?



31. A tightly wound coil of 100 turns with radius 10 cm, magnitude of carrying-current in coil is 1 A, what will be the magnitude of magnetic field at centre of coil?

(a) 6.28×10^{-6} T (b) 6.28×10^{-7} T

(c) 6.28×10^{-5} T (d) 6.28×10^{-4} T

32. A copper coil of 100 turns, radius 8.0×10^{-2} m carries a current of 0.40 A. Magnitude of magnetic field at centre of coil is

(a) $B = 3.1 \times 10^{-3}$ T (b) $B = 3.1 \times 10^{-2}$ T

(c) $B = 3.1 \times 10^{-4}$ T (d) $B = 3.1 \times 10^{-7}$ T

33. Two concentric circular coils X and Y of radii 16 cm and 10 cm lie in same vertical plane containing North to South direction. Coil X has 20 turns, coil Y has 25 turns and current in coil X is 16 A whereas in coil Y is 18 A. Current in X is anti-clockwise and in Y is clockwise. For an observer facing West and looking at coils, magnetic field at the centre of assembly of coils is

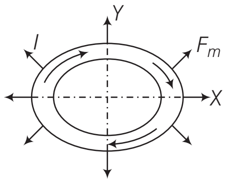
(a) 1.57×10^{-3} T towards East

(b) 1.57×10^{-3} T towards West

(c) 1.57×10^{-3} T towards North

(d) 15.7×10^{-3} T towards South

34. A conducting loop carrying a current I is placed in a uniform magnetic field pointing into the plane of the paper as shown in figure.



The loop will have a tendency to

(a) contract
(b) expand
(c) move towards positive X-axis
(d) move towards negative X-axis

35. A straight long wire carries a current of 35 A. Its magnitude of magnetic field at a distance of 0.20 m from the wire is

(a) 3.5×10^{-5} T
(b) 3.5×10^{5} T
(c) 3.5 T
(d) 7 T

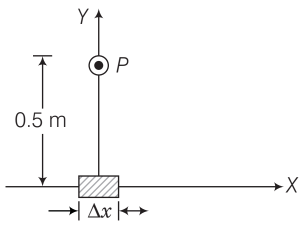
Topic 3
Biot-Savart's Law and Ampere's Law

36. Vector form of Biot-Savart's law is

(a) $d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{\mathbf{l}\times d\mathbf{l}}{r^2}$ (b) $d\mathbf{B} = \frac{I\, d\mathbf{l}\times \mathbf{r}}{r^3}$

(c) $d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{I\, d\mathbf{l}\times \mathbf{r}}{r^3}$ (d) $d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{I\, d\mathbf{l}\times \mathbf{r}}{r^2}$

37. An element $\Delta I = \Delta x\, \hat{\mathbf{i}}$ is placed at the origin and carries a current $I = 10$ A.



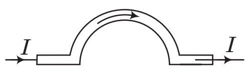
If $\Delta x = 1$ cm, magnetic field at point P is

(a) $4\times 10^{-8}\, \hat{\mathbf{k}}$ T
(b) $4\times 10^{-8}\, \hat{\mathbf{i}}$ T
(c) $4\times 10^{-8}\, \hat{\mathbf{j}}$ T
(d) $-4\times 10^{-8}\, \hat{\mathbf{j}}$ T

38. There is a thin conducting wire carrying current. What is the value of magnetic field induction at any point on the conductor itself?

(a) 1 (b) Zero
(c) -1 (d) Either (a) or (b)

39. A straight wire carrying a current of 12 A is sent into a semicircular loop of radius 2.0 cm. What will be magnetic field at the centre of the semicircular loop?



(a) $\mathbf{B} = 1.9\times 10^{-4}$ T
(b) $\mathbf{B} = 1.9\times 10^{4}$ T
(c) $\mathbf{B} = 1.9\times 10^{-4}$ T, ⊗
(d) $\mathbf{B} = 1.9\times 10^{4}$ T, ⊗

40. If a current loop of radius R carrying a anti-clockwise current I is placed in a plane parallel to YZ-plane, then magnetic field at a point on the axis of the loop is given by

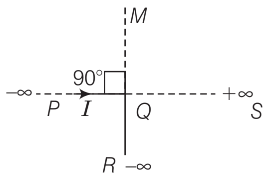
(a) $\mathbf{B} = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}\, \hat{\mathbf{j}}$

(b) $\mathbf{B} = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}\, \hat{\mathbf{k}}$

(c) $\mathbf{B} = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}\, \hat{\mathbf{i}}$

(d) $\mathbf{B} = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}\, (\hat{\mathbf{i}}\times\hat{\mathbf{k}})$

41. An infinitely long conductor PQR is bent to form a right angle as shown. A current I flows through PQR. The magnetic field due to this current at the point M is H_1. Now, another infinitely long straight conductor QS is connected at Q, so that the current is 1/2 in QR as well as in QS. The current in PQ remaining unchanged. The magnetic field at M is now H_2. The ratio H_1/H_2 is given by



(a) $\frac{1}{2}$ (b) 1 (c) $\frac{2}{3}$ (d) 2

42. A polygon shaped wire is inscribed in a circle of radius R. The magnetic induction at the centre of polygon, when current flows through the wire is

(a) $\frac{\mu_0 n I}{2\pi R} \tan\left(\frac{2\pi}{n}\right)$ (b) $\frac{\mu_0 n I}{2\pi R} \tan\left(\frac{4\pi}{n}\right)$

(c) $\frac{\mu_0 n I}{2\pi R} \tan\left(\frac{\pi}{n}\right)$ (d) $\frac{\mu_0 n I}{2\pi R} \tan\left(\frac{\pi}{n^2}\right)$

43. Two identical wires A and B, each of length l, carry the same current I. Wire A is bent into a circle of radius R and wire B is bent form a square of side a. If B_A and B_B are the values of magnetic field at the centres of the circle and square respectively, then the ratio B_A / B_B is **[JEE Main 2016]**

(a) $\frac{\pi^2}{8}$ (b) $\frac{\pi^2}{16\sqrt{2}}$

(c) $\frac{\pi^2}{16}$ (d) $\frac{\pi^2}{8\sqrt{2}}$

44. The magnetic field at the centre of a circular current carrying-conductor of radius r is B_c. The magnetic field on its axis at a distance r from the centre is B_a. The value of $B_c : B_a$ will be

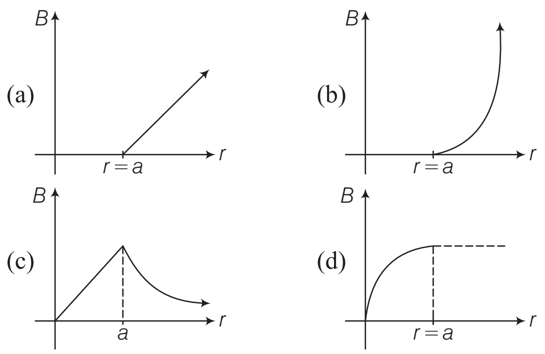
(a) $1:\sqrt{2}$ (b) $1:2\sqrt{2}$

(c) $2\sqrt{2}:1$ (d) $\sqrt{2}:1$

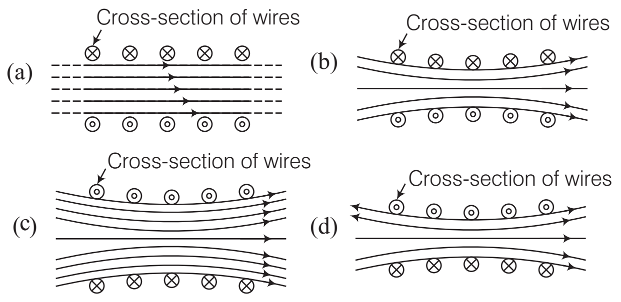
45. A long straight wire of radius a carries a steady current I. The current is uniformly distributed over its cross-section. The ratio of the magnetic fields $\mathbf{B}$ and $\mathbf{B'}$ at radial distances $\frac{a}{2}$ and $2a$ respectively, from the axis of the wire is **[NEET 2016]**

(a) $\frac{1}{2}$ (b) 1 (c) 4 (d) $\frac{1}{4}$

46. For a cylindrical conductor of radius a, which of the following graphs shows a correct relationship of B *versus* r?



47. Which of the following represent a correct figure to display of magnetic field lines due to a solenoid?



48. A solenoid of length 0.5 m has a radius of 1 cm and is made up of 500 turns. It carries a current of 5A. What is the magnetic field inside the solenoid?

(a) 6.28×10^{-3} T (b) 6.28×10^{3} T

(c) 6.28×10^{-5} T (d) 6.28×10^{5} T

49. A long solenoid has 20 turns cm^{-1}. The current necessary to produce a magnetic field of 20 mT inside the solenoid is approximately

(a) 1A (b) 2 A (c) 4 A (d) 8 A

50. For a toroid, magnetic field strength in the region enclosed by wire turns is given by

(a) $B = \mu_0 n I$, where n = number of turns

(b) $B = \mu_0 I / n$, n = number of turns per metre

(c) $B = \frac{\mu_0 I}{2r}$, r = mean radius

(d) $B = \frac{\mu_0 NI}{2\pi r}$, $\begin{cases} N = & \text{number of turns} \\ r = & \text{radius of toroid} \end{cases}$

51. A toroid of core of inner radius 0.25 m and outer radius 0.26 m around which 3500 turns of a wire are wound. If the current in the wire is 11 A, then magnetic field inside the core of the toroid is

(a) 3×10^2 T (b) 3×10^{-2} T (c) 3×10^{-7} T (d) 3×10^7 T

52. If two parallel current-carrying conductors placed 1 m apart in vacuum are placed such that each carries 1 A current, then there is a force of

(a) 2×10^{-7} N per metre of length

(b) 2×10^{7} N per metre of length

(c) 9×10^{9} N per metre of length

(d) 9×10^{-9} N per metre of length

53. Two identical long conducting wires AOB and COD are placed at right angle to each other, with one above other such that O is their common point for the two. The wires carry I_1 and I_2 currents, respectively. Point P is lying at distance d from O along a direction perpendicular to the plane containing the wires. The magnetic field at the point P will be **[CBSE AIPMT 2014]**

(a) $\frac{\mu_0}{2\pi d}\left(\frac{I_1}{I_2}\right)$ (b) $\frac{\mu_0}{2\pi d}(I_1 + I_2)$

(c) $\frac{\mu_0}{2\pi d}(I_1^2 - I_2^2)$ (d) $\frac{\mu_0}{2\pi d}(I_1^2 + I_2^2)^{1/2}$

54. Two long parallel straight wires A and B carrying currents of 4.0 A and 5.0 A in same direction separated by a distance of 4×10^{-2} m.

The force on a 0.20 m section of wire A is

(a) 2×10^{-5} N towards B

(b) 2×10^{-5} N away from B

(c) 2×10^{-5} N perpendicular to B

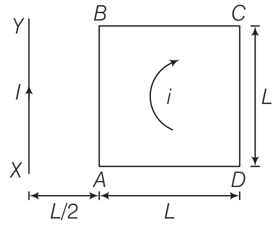
(d) 2×10^{-5} N parallel to B

55. Two very long, straight and parallel wires carry steady currents I and I, respectively. The distance between the wires is d. At a certain instant of time a point charge q is at a point equidistant from the two wires in the plane of the wires. Its instantaneous velocity v is perpendicular to this plane.

The magnitude of the force due to the magnetic field acting on the charge at their instant is

(a) $\frac{\mu_0 \mathbf{I} qv}{2\pi d}$ (b) $\frac{\mu_0 \mathbf{I} qv}{\pi d}$ (c) $\frac{2\mu_0 \mathbf{I} qv}{\pi d}$ (d) 0

56. A square loop $ABCD$ carrying a current i, is placed near and coplanar with a long straight conductor XY carrying a current I, the net force on the loop will be



(a) $\frac{\mu_0 Ii}{2\pi}$ (b) $\frac{2\mu_0 IiL}{3\pi}$ (c) $\frac{\mu_0 IiL}{2\pi}$ (d) $\frac{2\mu_0 Ii}{3\pi}$

57. The wire which connects the battery of a car to its starter motor carries current of 300 A during starting. Force per unit length between wires (wires are 0.7 m long and 0.015 m distant apart) is

(a) 1.2 Nm^{-1} repulsive (b) 1.2 Nm^{-1} attractive
(c) 2.4 Nm^{-1} repulsive (d) 2.4 Nm^{-1} attractive

58. Two thin long parallel wires separated by a distance d carry a current of I ampere in same direction. They will

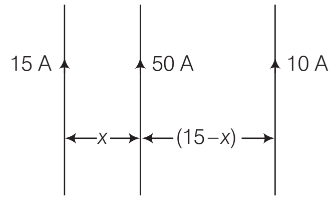
(a) attract each other with a force of $\frac{\mu_0 I^2}{2\pi d}$

(b) repel each other with a force of $\frac{\mu_0 I^2}{2\pi d}$

(c) attract each other with a force of $\frac{\mu_0 I^2}{2\pi d^2}$

(d) repel each other with a force of $\frac{\mu_0 I^2}{2\pi d^2}$

59. Three long, straight and parallel wires carrying currents are arranged as shown in the figure.

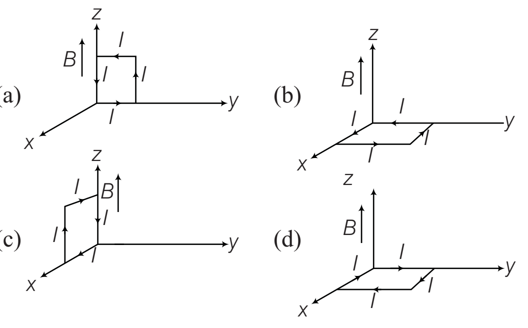


The wire C which carries a current of 50 A is so replaced that it experiences no force. The distance of wire C from wire A is

(a) 9 cm (b) 7 cm
(c) 5 cm (d) 3 cm

Topic 4
Torque on Current Loop and Magnetic Dipole

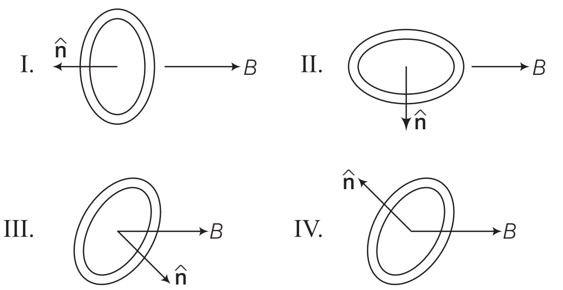
60. A rectangular loop of sides 10 cm and 5 cm carrying a current I of 12 A is placed in different orientations as shown in the figures.



If there is a uniform magnetic field of 0.3 T in the positive z-direction in which orientations the loop would be in (i) stable equilibrium and (ii) unstable equilibrium? **[JEE Main 2015]**

(a) (a) and (b) respectively (b) (a) and (c) respectively
(c) (b) and (d) respectively (d) (b) and (c) respectively

61. A current-carrying loop is placed in a uniform magnetic field in four different orientations, I, II, III and IV. Arrange them in the decreasing order of potential energy.



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

62. A steady current i flows in a small square loop of wire of side L in a horizontal plane. The loop is now folded about its middle such that half of it lies in a vertical plane. Let μ_1 and μ_2 respectively denote the magnetic moments due to the current loop before and after folding. Then,

(a) $\mu_2 = 0$

(b) μ_1 and μ_2 are in the same direction

(c) $\dfrac{|\mu_1|}{|\mu_2|} = \sqrt{2}$

(d) $\dfrac{|\mu_1|}{|\mu_2|} = \left(\dfrac{1}{\sqrt{2}}\right)$

63. A coil in the shape of an equilateral triangle of side l is suspended between the pole pieces of a permanent magnet such that **B** is in plane of the coil. If due to a current i in the triangle a torque τ acts on it, the side l of the triangle is

(a) $\dfrac{2}{\sqrt{3}}\left(\dfrac{\tau}{Bi}\right)^{1/2}$ (b) $\dfrac{2}{\sqrt{3}}\left(\dfrac{\tau}{Bi}\right)$

(c) $2\left(\dfrac{\tau}{\sqrt{3}Bi}\right)^{1/2}$ (d) $\dfrac{1}{\sqrt{3}}\dfrac{\tau}{Bi}$

64. Torque on a current-carrying loop of magnetic moment **m**, placed in region of magnetic field **B** is given by

(a) $\tau = \dfrac{1}{2}\,\mathbf{m}\times\mathbf{B}$ (b) $= \mu_0\,\mathbf{m}\times\mathbf{B}$

(c) $\tau = \dfrac{\mu_0}{4\pi}(\mathbf{m}\times\mathbf{B})$ (d) $\tau = \mathbf{m}\times\mathbf{B}$

65. A current loop in a magnetic field **[NEET 2013]**

(a) experiences a torque whether the field is uniform or non-uniform in all orientations

(b) can be in equilibrium in one orientations

(c) can be equilibrium in two orientations, both the equilibrium states are unstable

(d) can be in equilibrium in two orientations, one stable while the other is unstable

66. A circular coil of 25 turns and radius 12 cm is placed in a uniform magnetic field of 0.5 T normal to the plane of the coil. If the current in the coil is 6 A, then total torque acting on the coil is

(a) zero (b) 3.4 N m (c) 3.8 N m (d) 4.4 N m

67. For a circular current loop magnitude of magnetic field on axis of loop at a point distant x from centre of loop ($x >> R$ and magnetic dipole moment of loop is $\mathbf{m} = I\mathbf{A}$) is

(a) $\mathbf{B} = \dfrac{\mu_0 \mathbf{m}}{x^3}$ (b) $\mathbf{B} = \dfrac{\mu_0}{4\pi}\dfrac{\mathbf{m}}{x^3}$

(c) $\mathbf{B} = \dfrac{\mu_0}{4\pi}\dfrac{2\mathbf{m}}{x^3}$ (d) $\mathbf{B} = \dfrac{\mu_0 \mathbf{m}\cdot R}{2\pi x^3}$

68. Two similar coils are placed mutually perpendicular such that their centres coincide. At centre, the ratio of the magnetic field due to one coil and the resultant magnetic field of both coils for same current will be

(a) $1:\sqrt{2}$ (b) $1:2$ (c) $2:1$ (d) $\sqrt{3}:1$

69. Magnetic moment (or magnetic dipole moment) of a current-carrying coil is given by

(a) $\mathbf{m} = IN\mathbf{A}$ (b) $\mathbf{m} = \dfrac{I}{A}$

(c) $\mathbf{m} = N\mathbf{A}$ (d) $\mathbf{m} = \dfrac{NI}{A}$

70. The magnitude of the magnetic field at the centre of the tightly wound 150 turns coil of radius 12 cm carrying a current of 2A, is

(a) 18 G (b) 19.7 G

(c) 15.7 G (d) 17.7 G

71. A loop of flexible wire of irregular shape carrying current is placed in an external field. Then,

(a) it rotates in a direction perpendicular to its axis

(b) it rotates along an axis perpendicular to its plane

(c) it does not show any change

(d) it assumes a circular shape

72. A circular current loop of magnetic moment M is in an arbitrary orientation in an external magnetic field B. The work done to rotate the loop by 90° about an axis perpendicular to its plane is

(a) MB (b) $\dfrac{\sqrt{3}}{2}MB$

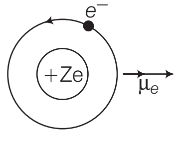
(c) $\dfrac{MB}{2}$ (d) zero

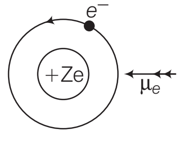
73. Magnetic field at the centre of a circular loop of area A is B. The magnetic moment of the loop will be

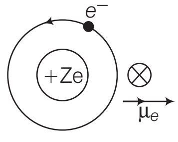
(a) $\dfrac{BA^2}{\mu_0\pi}$ (b) $\dfrac{BA^{3/2}}{\mu_0\pi}$

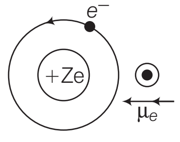
(c) $\dfrac{BA^{3/2}}{\mu_0\pi^{1/2}}$ (d) $\dfrac{2BA^{3/2}}{\mu_0\pi^{1/2}}$

74. For hydrogen atom, which of the following figure correctly, shows the direction of magnetic moment related to revolving electron?

(a) 

(b) 

(c) 

(d) 

75. In a hydrogen atom, an electron revolves around the nucleus in an orbit of radius r with velocity v, the current corresponding to the revolving electron is

(a) $I = \frac{er}{2\pi v}$ (b) $I = \frac{ev}{2\pi}$ (c) $I = \frac{ev}{2\pi r}$ (d) $I = \frac{ev}{\pi r}$

76. In a hydrogen atom, an electron moves in a circular orbit of radius 5.2×10^{-11} m and produces a magnetic induction of 12.56 T at its centre. The current produced by the motion of the electron will be

(a) 6.53×10^{-3} A (b) 13.25×10^{-10} A
(c) 9.6×10^{6} A (d) 1.04×10^{-3} A

77. The value of Bohr magneton is

(a) 9.27×10^{-24} Am^2 (b) 9.27×10^{-27} Am^2
(c) 8.8×10^{-10} Am^2 (d) 6.25×10^{-12} Am^2

78. Magnitude of angular magnetic moment associated with a revolving electron in a hydrogen atom will be

(a) $\mu_l = \frac{e}{2m_e}$ (b) $\mu_l = \frac{-el^2}{2m_e}$
(c) $\mu_l = \frac{-e}{4m_e}$ (d) $\mu_l = \frac{-el}{2m_e}$

Topic 5
Moving Coil Galvanometer

79. A moving coil galvanometer is an instrument which
(a) is used to measure EMF
(b) is used to measure potential difference
(c) is used to measure resistance
(d) is a deflection instrument which gives a deflection when a current flows through its coil

80. In a moving coil galvanometer of coil of N-turns of area A have a spring of stiffness k.
If coil is deflected by some angle ϕ due to flow of I current in uniform radial magnetic field B, then

(a) $\phi = \left(\frac{NAB}{k}\right)I$ (b) $\phi = \left(\frac{k}{BNA}\right)I$
(c) $\phi = \left(\frac{kA}{BN}\right)I$ (d) $\phi = \left(\frac{BN}{kA}\right)I$

81. To make the field radial in a moving coil galvanometer
(a) number of turns of coil is kept small
(b) magnet is taken in the form of horse-shoe
(c) poles are of very strong magnets
(d) poles are cylindrically cut

82. The deflection in a moving coil galvanometer is
(a) directly proportional to torsional constant of spring
(b) directly proportional to the number of turns in the coil
(c) inversely proportional to the area of the coil
(d) inversely proportional to the current in the coil

83. In a moving coil galvanometer having a coil of N-turns of area A and carrying current I is placed in a radial field of strength B.
The torque acting on the coil is

(a) NA^2B^2I (b) $NABI^2$ (c) N^2ABI (d) $NABI$

84. What is the shape of magnet used in moving coil galvanometer to make the magnetic field radial
(a) concave (b) horse-shoe magnet
(c) convex (d) None of these

85. In ballistic galvanometer, the frame on which the coil is wound is non-metallic to
(a) avoid the production of induced emf
(b) avoid the production of eddy current
(c) increase the production of eddy current
(d) increase the production of induced emf

86. Current sensitivity of a galvanometer is

(a) $\frac{NBA}{k}$ (b) $\frac{k}{NBA}$ (c) $\frac{NBA}{kR}$ (d) $\frac{kR}{NBA}$

87. To increase the current sensitivity of a moving coil galvanometer, we should decrease
(a) strength of magnet (b) torsional constant of spring
(c) number of turns in coil (d) area of coil

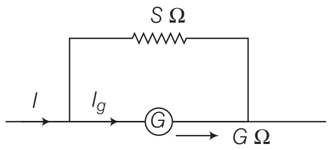
88. The coil of a galvanometer consists of 100 turns and effective area of 1 cm^2. The restoring couple is 10^{-8} Nm rad^{-1}. The magnetic field between poles is of 5 T. Current sensitivity of this galvanometer is

(a) 5×10^{4} rad /μ amp (b) 5×10^{6} per amp
(c) 2×10^{-7} per amp (d) 5 rad /μ amp

89. A galvanometer has a coil of resistance 15 Ω and meter shows full scale deflection for a current of 4 mA. To convert it into an ammeter of 0 to 6 A range,
(a) a resistance of 10 mΩ is required in series
(b) a resistance of 10 mΩ is required in parallel
(c) a resistance of 1000 Ω is required in series
(d) a resistance of 1000 Ω is required in parallel

90. In two galvanometers A and B, to produce a deflection of 10 divisions, currents of 3 mA and 5 mA are required respectively, then
(a) A is more sensitive than B
(b) B is more sensitive than A
(c) both are equally sensitive
(d) sensitivity of B is $5/3$ that A

91. For the given ammeter circuit,



(a) $I_g S = IG$ (b) $(I - I_g)S = I_g G$

(c) $I_g G = (I + I_g)S$ (d) $\frac{I}{I_g} = \frac{G}{S}$

92. To convert a galvanometer into an ammeter,

(a) a low resistance is connected in series with the coil of galvanometer

(b) a low resistance is connected in parallel with the coil of galvanometer

(c) a high resistance is connected in series with galvanometer coil

(d) a high resistance is connected in parallel with the galvanometer coil

93. A galvanometer of resistance 70 Ω, is converted into an ammeter by a shunt resistance $r_s = 0.03$ Ω. The value of its resistance will become

(a) 0.025 Ω (b) 0.022 Ω (c) 0.035 Ω (d) 0.030 Ω

94. To increase current sensitivity of a moving coil galvanometer by 50%, its resistance is increased so that its new resistance is twice of its initial resistance. Its voltage sensitivity changes by a factor of

(a) increases by a factor of 2

(b) decreases by a factor of 1/ 2

(c) increases by a factor of 4

(d) decreases by a factor of 1/4

95. Voltage sensitivity of a galvanometer is

(a) $\frac{NBA}{k}$ (b) $\frac{k}{NBA}$ (c) $\frac{NBA}{kR}$ (d) $\frac{kR}{NBA}$

96. To convert a galvanometer into a voltmeter,

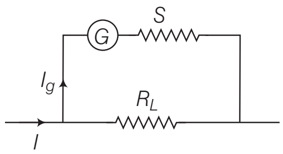
(a) a low resistance in parallel is used

(b) a low resistance in series is used

(c) a high resistance in series is used

(d) a high resistance in parallel is used

97. For the voltmeter circuit given,



(a) $\frac{I_g}{I} = \frac{G}{S}$ (b) $\frac{I}{I_g} = \frac{R_L + G}{S}$

(c) $(I - I_g)R_L = I_g(G + S)$ (d) $IR_L = I_g G$

98. A galvanometer with a coil of resistance 12 Ω shows full scale deflection for a current of 2.5 mA. The ratio of net resistance of an ammeter of range 0 to 7.5 A and a voltmeter of range 0 to 10 V is

(a) 10^{-12} (b) 10^{-7} (c) 10^{-6} (d) 10^{-8}

99. A galvanometer coil has a resistance of 12 Ω and meter shows full scale deflection for a current of 3 mA. To convert galvanometer into a voltmeter of range 0 to 18 V,

(a) a resistance of 5988 Ω in series is required

(b) a resistance of 5988 Ω in parallel is required

(c) a resistance of 5.988 Ω in series is required

(d) a resistance of 5.988 Ω in parallel is required

100. Relation between voltage sensitivity (S_V) and current sensitivity (S_i) for a galvanometer of resistance G ohms is

(a) $\frac{S_i}{G} = S_V$ (b) $\frac{S_V}{G} = S_i$

(c) $S_i S_V = G$ (d) $\sqrt{S_i S_V} = G$

Special Format Questions

I. Assertion and Reason

Directions (Q. Nos. 101-105) *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.

101. Assertion Cyclotron is a device which is used to accelerate the positive ions.

Reason Cyclotron frequency depends upon the velocity.

102. Assertion If a proton and an α-particle enter a uniform magnetic field perpendicularly with the same speed, the time period of revolution of α-particle is double than that of proton.

Reason In a magnetic field, the period of revolution at a charged particle is directly proportional to the mass of the particle and inversely proportional to the charge of particle.

103. Assertion The ion cannot move with a speed beyond a certain limit in a cyclotron.

Reason As velocity increases, then time taken by ion increases.

104. Assertion The magnetic field produced by a current-carrying solenoid is independent of its length and cross-sectional area.

Reason The magnetic field inside the solenoid is uniform.

105. Assertion An electron and a proton enter a magnetic field with equal velocities, then the force experienced by the proton will be more than electron.

Reason The mass of proton is 1837 times more than that of electron.

II. Statement Based Questions (Type I)

■ **Directions** (Q. Nos. 106-110) *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.

106. Statement I When a charged particle moves in the region of a perpendicular magnetic field, its speed remains constant.

Statement II Force acting on the charged particle is given by $\mathbf{F} = q\,(\mathbf{v} \times \mathbf{B})$.

107. Statement I When a charged particle moves in a region of magnetic field such that its velocity is at some acute angle with direction of field, its trajectory is a helix.

Statement II Perpendicular component of velocity causes a rotating centripetal force and parallel component of velocity does not produces any force.

108. Statement I In cyclotron, frequency of applied voltage (to dees) is adjusted so that $\nu_{\text{applied voltage}} = \nu_{\text{cyclotron}} = qB/2\pi m$. This ensures acceleration of charged particle in each cycle.

Statement II Charged particles are moved inside 'dee' by magnetic field in semicircular paths and they arrive in gap between the 'dees' in a time interval of T sec, where $T = 2\pi m/Bq$.

109. Statement I Magnetic properties of iron like materials cannot be linked to intrinsic magnetic moment of electrons of its atoms.

Statement II The electron is an elementary particle, it does not spin around an axis and it does not possess any intrinsic magnetic moment.

110. Statement I If we increase the current sensitivity of a galvanometer by increasing number of turns, its voltage sensitivity also increases.

Statement II Resistance of a wire is directly proportional to its length.

Statement Based Questions (Type II)

111. Consider a moving charged particle in a region of magnetic field. Which of the following are correct?

I. If $\mathbf{v}$ is parallel to $\mathbf{B}$, then path of particle is spiral.
II. If $\mathbf{v}$ is perpendicular to $\mathbf{B}$, then path of particle is a circle.
III. If $\mathbf{v}$ has a component along $\mathbf{B}$, then path of particle is helical.
IV. If $\mathbf{v}$ is along $\mathbf{B}$, then path of particle is a circle.

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

112. An electron and a proton moving on a straight parallel paths with same velocity enter a semi-infinite region of uniform magnetic field perpendicular to velocity. Which of these are correct?

I. They will never come out of magnetic field region.
II. They will come out travelling along parallel paths.
III. They will come out same time.
IV. They will come out at different times.

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

113. A velocity selector; (a region of perpendicular electric and magnetic field)

I. Allows charged particles to pass straight when $v = E/B$.
II. Deflects particles in a direction perpendicular to both $\mathbf{v}$ and $\mathbf{B}$, when $v > E/B$.
III. Deflects particles in the direction of electric field when $v < E/B$.
IV. Deflects all particles in a direction perpendicular to both E and B.

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

114. Difference between Coulomb's force and Biot-Savart's force are

I. Electrostatic force is along the displacement vector joining the source and the field point but magnetic force is perpendicular to the plane containing the displacement vector and source.
II. There is an angle dependence in the Biot-Savart's law which is not present in Coulomb's law.
III. Biot-Savart's law can be expressed in vector form but Coulomb's law cannot be expressed in vector form.

IV. Biot-Savart's law is applicable in all medium but Coulomb's law is applicable only in medium which can be polarised.

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

115. Two coaxial solenoids 1 and 2 of the same length are set so that one is inside the other. The number of turns per unit length are n_1 and n_2. The current i_1 and i_2 are flowing in opposite directions. The magnetic field inside the inner coil is zero. This is possible when

I. $i_1 \neq i_2$ and $n_1 = n_2$
II. $i_1 = i_2$ and $n_1 \neq n_2$
III. $i_1 = i_2$ and $n_1 = n_2$
IV. $i_1 n_1 = i_2 n_2$

Which of the following statement(s) is/are correct?

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

116. The galvanometer cannot as such be used as an ammeter to measure the value of current in a given circuit. The following reasons are

I. galvanometer gives full scale deflection for a small current.
II. galvanometer has a large resistance.
III. a linear scale cannot be designed so that $I \propto \phi$.
IV. a galvanometer can give inaccurate values.

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

III. Matching Type

117. A charged particle with some initial velocity is projected in a region where non-zero electric and/or magnetic fields are present. In Column I, information about the existence of electric and/or magnetic field and direction of initial velocity of charged particle are given, while in Column II the probable path of the charged particle is mentioned. Match the entries of Column I with the entries of Column II.

Column I	Column II
A. $\mathbf{E} = 0$, $\mathbf{B} \neq 0$, and initial velocity is at any angle with **B**	1. Straight line
B. $\mathbf{E} \neq 0$, $\mathbf{B} = 0$ and initial velocity is at any angle with **E**	2. Parabola
C. $\mathbf{E} \neq 0$, $\mathbf{B} \neq 0$, $\mathbf{E} \parallel \mathbf{B}$ and initial velocity is $\perp$ to both	3. Circular
D. $\mathbf{E} \neq 0$, $\mathbf{B} \neq 0$, **E** perpendicular to **B** and **v** perpendicular to both **E** and **B**	4. Helical path with non-uniform pitch

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

118. Match the following parameters of a charged particle moving in cyclotron with their values.

Column I	Column II
A. Frequency of rotation of charged particle ν (Hz).	1. Bqv
B. Velocity of charged particle v (ms^{-1}).	2. $q^2B^2R^2/2m$
C. Kinetic energy of charged particle K (joule).	3. qBR/m
D. Force on charged particle when it is inside any of dees F (newton).	4. $\dfrac{Bq}{2\pi m}$

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

119. Match the following columns.

Column I	Column II
A. Lorentz force	1. $\oint \mathbf{E} \cdot d\mathbf{A} = \dfrac{q}{\varepsilon_0}$
B. Gauss' law	2. $d\mathbf{B} = \dfrac{\mu_0}{4\pi} = \dfrac{i\, d\mathbf{l} \times \mathbf{r}}{r^3}$
C. Biot-Savart's law	3. $\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$
D. Coulomb's law	4. $F = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{q_1 q_2}{r^2}$

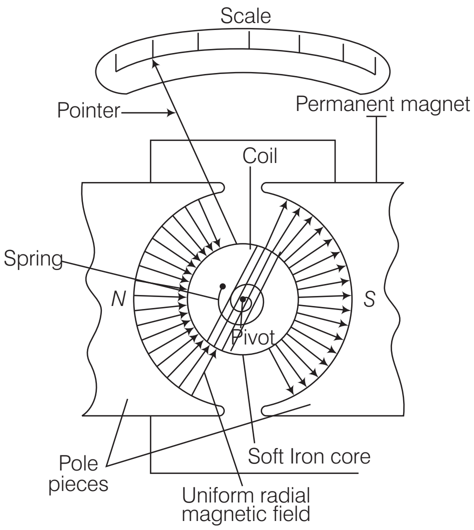
	A	B	C	D		A	B	C	D
(a)	3	1	2	4	(b)	1	2	4	3
(c)	2	3	1	4	(d)	4	1	2	3

120. For a current-carrying wire loop of N-turns, placed in region of a uniform magnetic field **B**, match Column I and Column II.

Column I	Column II
A. Torque on loop	1. **mB**
B. Torque on loop when **m** is either parallel or anti-parallel to **B**	2. NI**A**
C. Magnetic moment of loop	3. zero
D. Torque on loop when **m** is perpendicular to **B**	4. $\mathbf{m} \times \mathbf{B}$

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

121. Figure shows the construction details of a moving coil galvanometer.



Match the part with its function.

Column I	Column II
A. Soft iron core	1. produces deflecting torque
B. Pole pieces	2. produces restoring torque
C. Spring	3. produces radial field
D. Coil	4. increases field strength

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

IV. Passage Based Questions

■ **Directions** (Q. Nos. 122-124) *These questions are based on the following situation. Choose the correct options from those given below.*

An electron with a speed $v_0 << c$ moves in a circle of radius r_0 in a uniform magnetic field. The time required for one revolution of the electron is T_0. The speed of the electron is now doubled to $2v_0$.

122. The radius of the circle will change to

(a) $4r_0$ (b) $2r_0$ (c) r_0 (d) $r_0/2$

123. The time required for one revolution of the electron will change to

(a) $4T_0$ (b) $2T_0$ (c) T_0 (d) $T_0/2$

124. A charged particle is projected in a magnetic field $\mathbf{B} = (2\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) \times 10^2$ T. The acceleration of the particle is found to be $\mathbf{a} = (x\hat{\mathbf{i}} + 2\hat{\mathbf{j}})\text{ms}^{-2}$. Find the value of x.

(a) $4\ \text{ms}^{-2}$ (b) $-4\ \text{ms}^{-2}$
(c) $-2\ \text{ms}^{-2}$ (d) $2\ \text{ms}^{-2}$

■ **Directions** (Q. Nos. 125-126) *These questions are based on the following situation. Choose the correct options from those given below.*

The horizontal component of the earth's magnetic field at a certain place is 3.0×10^{-5} T and the direction of the field is from the geographic south to the north pole. A very long straight conductor is carrying a steady current of 1 A.

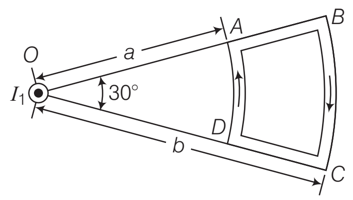
125. What is the force per unit length on it when it is placed on a horizontal table and the direction of current is east to west?

(a) $3 \times 10^{-5}\ \text{Nm}^{-1}$ (b) $5 \times 10^{-2}\ \text{Nm}^{-1}$
(c) $6 \times 10^{-1}\ \text{Nm}^{-1}$ (d) $8 \times 10^{-3}\ \text{Nm}^{-1}$

126. What is the force per unit length when the direction of the current is south to north?

(a) $5 \times 10^{-4}\ \text{Nm}^{-1}$ (b) Zero
(c) $6 \times 10^{-2}\ \text{Nm}^{-1}$ (d) $8 \times 10^{-3}\ \text{Nm}^{-1}$

■ **Directions** (Q. Nos. 127-128) *These questions are based on the following situation. Choose the correct options from those given below.*



The arc's BC (radius = b) and AD (radius = a) of loop are joined by the straight wires AB and CD. A steady current I is flowing in the loop. Angle made by AB and CD at the origin is 30°.Another straight thin wire with steady current I, flowing out of plane of the paper is kept at the origin.

127. The magnitude of the magnetic field B due to loop $ABCD$ at the origin O is

(a) zero (b) $\dfrac{\mu_0 I\,(b-a)}{24\,ab}$

(c) $\dfrac{\mu_0 I}{4\pi}\left(\dfrac{b-a}{ab}\right)$ (d) $\dfrac{\mu_0 I}{4\pi}\left[2(b-a)+\dfrac{\pi}{3}(a+b)\right]$

128. Due to presence of current I_1 at the origin

(a) the forces on AB and DC are zero

(b) the forces on AD and BC are zero

(c) the magnitude of the net force on the loop is given by $\dfrac{\mu_0 I I_1}{4\pi}\left\{2(b-a)+\dfrac{\pi}{3}(a+b)\right\}$

(d) the magnitude of the net force on the loop is given by $\dfrac{\mu_0 I I_1}{24 \cdot ab}(b-a)$

V. More than One Option Correct

129. Which of the following statements are correct?

(a) If a moving charged particle enters into a region of magnetic field from outside, it does not complete a circular path

(b) If a moving charged particle traces a helical path in a uniform magnetic field, the axis of the helix is parallel to the magnetic field

(c) The power associated with the force exerted by a magnetic field on a moving charged particle is always equal to zero

(d) If in a region a uniform magnetic field and a uniform electric field both exist, a charged particle moving in this region cannot trace a circular path

130. A charged particle moves in a uniform magnetic field. The velocity of the particle at some instant makes an acute angle with the magnetic field. The path of the particle will be

(a) a circle

(b) a helix with uniform pitch

(c) a helix with non-uniform pitch

(d) a helix with uniform radius

131. A proton is fired from origin with velocity $\mathbf{v} = v_0\hat{\mathbf{j}} + v_0\hat{\mathbf{k}}$ in a uniform magnetic field $\mathbf{B} = B_0\hat{\mathbf{j}}$.

(a) its z-coordinate can never be negative

(b) its x-coordinate can never be positive

(c) its x-and z-coordinates cannot be zero at the same time

(d) its y-coordinate will be proportional to its time of flight

132. Two circular coils of radii 5 cm and 10 cm carry equal currents of 2 A. The coils have 50 and 100 turns respectively and are placed in such a way that their planes as well as their centres coincide. Magnitude of magnetic field at the common centre of coils is

(a) $8\pi \times 10^{-4}$ T if currents in the coils are in same sense

(b) $4\pi \times 10^{-4}$ T if currents in the coils are in same sense

(c) zero if currents in the coils are in opposite sense

(d) $8\pi \times 10^{-4}$ T if currents in the coils are in opposite sense

NCERT & NCERT Exemplar Questions

NCERT

133. A circular coil of wire consisting of 100 turns, each of radius 8.0 cm carries a current of 0.40 A. What is the magnitude of the magnetic field B at the centre of the coil?

(a) 4 T (b) 3.1×10^{-4} T

(c) 2×10^{-3} T (d) 10^{-4} T

134. A long straight wire in the horizontal plane carries a current of 50 A in north to south direction. Give the magnitude and direction of B at a point 2.5 m east of the wire.

(a) 2×10^{-6} T, south (b) 3×10^{-6} T, down

(c) 4×10^{-6} T, up (d) 6 T, north

135. A horizontal overhead power line carries a current of 90 A in East to West direction. What are the magnitude and direction of the magnetic field due to the current 1.5 m below the line?

(a) 1.2×10^{-5} T, North (b) 1.2×10^{-5} T, South

(c) 4 T, vertically up (d) 4 T, vertically down

136. What is the magnitude of magnetic force per unit length on a wire carrying a current of 8 A and making an angle of 30° with the direction of a uniform magnetic field of 0.15 T?

(a) 0.4 Nm^{-1} (b) 0.6 Nm^{-1}

(c) 4 Nm^{-1} (d) 6 Nm^{-1}

137. A 3.0 cm wire carrying a current of 10 A is placed inside a solenoid perpendicular to its axis. The magnetic field inside the solenoid is given to be 0.27 T. What is the magnetic force on the wire?

(a) 7×10^{-2} N (b) 8.1×10^{-2} N

(c) 6.4×10^{-2} N (d) 4×10^{2} N

138. Two long and parallel straight wires A and B carrying currents of 8.0 A and 5.0 A in the same direction are separated by a distance of 4.0 cm. Estimate the force on a 10 cm section of wire A.

(a) 5×10^{-5} N repulsive (b) 5×10^{-5} N attractive

(c) 2×10^{-5} N repulsive (d) 2×10^{-5} N attractive

139. A closely wound solenoid 80 cm long has 5 layers of windings of 400 turns each. The diameter of the solenoid is 1.8 cm. If the current carried is 8.0 A, estimate the magnitude of B inside the solenoid near its centre.

(a) 2.5×10^{-2} T (b) 3.5×10^{-2} T

(c) 4.5×10^{-2} T (d) 5×10^{-2} T

140. A square coil of side 10 cm consists of 20 turns and carries a current of 12 A. The coil is suspended vertically and the normal to the plane of the coil makes an angle of 30° with the direction of a uniform horizontal magnetic field of magnitude 0.80 T. What is the magnitude of torque experienced by the coil?

(a) 1.96 Nm (b) 0.96 Nm (c) 2.0 Nm (d) 4 Nm

141. Two moving coil meters M_1 and M_2 having the following particulars :
$R_1 = 10\ \Omega,\ N_1 = 30,\ A_1 = 3.6 \times 10^{-3}\ \text{m}^2,\ B_1 = 0.25\ \text{T}$
$R_2 = 14\ \Omega,\ N_2 = 42,\ A_2 = 1.8 \times 10^{-3}\text{m}^2,\ B_2 = 0.50\ \text{T}$
(The spring constants are identical for the two meters). Determine the ratio of voltage sensitivity of M_2 and M_1.
(a) 4 (b) 5 (c) 6 (d) 1

142. In a chamber, a uniform magnetic field of 6.5 G (1G $= 10^{-4}$ T) is maintained. An electron is shot into the field with a speed of $4.8 \times 10^6\ \text{ms}^{-1}$ normal to the field explain why the path of the electron is a circle. Determine the radius of the circular orbit.
($e = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg)
(a) 2 cm (b) 8 cm (c) 6 cm (d) 4.2 cm

143. A circular coil of 30 turns and radius 8.0 cm carrying a current of 6.0 A is suspended vertically in a uniform horizontal magnetic field of magnitude 1.0 T. The field lines make an angle of 60° with the normal of the coil. Calculate the magnitude of the counter torque that must be applied to prevent the coil from turning.
(a) 4 Nm (b) 6 Nm (c) 3.1 Nm (d) 2.8 N m

NCERT Exemplar

144. Two charged particles traverse identical helical paths in a completely opposite sense in a uniform magnetic field $\mathbf{B} = B_0\hat{\mathbf{k}}$.
(a) They have equal z-components of momenta
(b) They must have equal charges
(c) They necessarily represent a particle, anti-particle pair
(d) The charge to mass ratio satisfy
$$\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$$

145. Biot-Savart, law indicates that the moving electrons (velocity v) produce a magnetic field **B** such that
(a) **B** is perpendicular to v
(b) **B** is parallel to v
(c) it obeys inverse cube law
(d) it is along the line joining the electron and point of observation

146. A current-carrying circular loop of radius R is placed in the x-y plane with centre at the origin. Half of the loop with $x > 0$ is now bent so that it now lies in the y-z plane.
(a) The magnitude of magnetic moment now diminishes
(b) The magnetic moment does not change
(c) The magnitude of **B** at $(0,0,z)$, $z > R$ increases
(d) The magnitude of **B** at $(0,0,z)$, $z >> R$ is unchanged

147. An electron is projected with uniform velocity along the axis of a current-carrying long solenoid. Which of the following is true?
(a) The electron will be accelerated along the axis
(b) The electron path will be circular about the axis
(c) The electron will experience a force at 45° to the axis and hence execute a helical path
(d) The electron will continue to move with uniform velocity along the axis of the solenoid

148. In a cyclotron, a charged particle
(a) undergoes acceleration all the time
(b) speeds up between the dees because of the magnetic field
(c) speeds up in a dee
(d) slows down within a dee and speeds up between dees

149. A circular current loop of magnetic moment M is in an arbitrary orientation in an external magnetic field **B.** The work done to rotate the loop by 30° about an axis perpendicular to its plane is
(a) MB (b) $\sqrt{3}\,\frac{MB}{2}$
(c) $\frac{MB}{2}$ (d) zero

150. The gyromagnetic ratio of an electron in an H-atom, according to Bohr model, is
(a) independent of which orbit it is in
(b) negative
(c) positive
(d) increase with the quantum number n

151. Consider a wire carrying a steady current, I placed in a uniform magnetic field **B** perpendicular to its length. Consider the charges inside the wire. It is known that magnetic forces do no work. This implies that,
(a) motion of charges inside the conductor is unaffected by **B**, since they do not absorb energy
(b) some charges inside the wire move to the surface as a result of **B**
(c) If the wire moves under the influence of **B**, no work is done by the force
(d) if the wire moves under the influence of **B**, no work is done by the magnetic force on the ions, assumed fixed within the wire.

152. Two identical current carrying coaxial loops, carry current I in an opposite sense. A simple amperian loop passes through both of them once. Calling the loop as C,
(a) $\oint \mathbf{B} \cdot d\mathbf{l} = m\mu_0 I$
(b) the value of $\oint \mathbf{B} \cdot d\mathbf{l} = \mp 2\mu_0 I$ is independent of sense of C
(c) there may be a point on C where, **B** and $d\mathbf{l}$ are perpendicular
(d) **B** vanishes everywhere on C

153. A cubical region of space is filled with some uniform electric and magnetic fields. An electron enters the cube across one of its faces with velocity v and a positron enters *via* opposite face with velocity $-v$.

At this instant,

(a) the electric forces on both the particles cause identical accelerations

(b) the magnetic forces on both the particles cause equal accelerations

(c) both particles gain or loose energy at the same rate

(d) the motion of the Centre of Mass (CM) is determined by **B** alone

154. A charged particle would continue to move with a constant velocity in a region wherein,

(a) $\mathbf{E} = 0, \mathbf{B} \neq 0$

(b) $\mathbf{E} \neq 0, \mathbf{B} \neq 0$

(c) $\mathbf{E} \neq 0, \mathbf{B} = 0$

(d) $\mathbf{E} = 0, \mathbf{B} = 0$

Answers

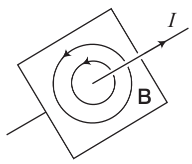
1.	(b)	**2.**	(c)	**3.**	(d)	**4.**	(d)	**5.**	(d)	**6.**	(c)	**7.**	(a)	**8.**	(c)	**9.**	(a)	**10.**	(a)	**11.**	(b)	**12.**	(b)	**13.**	(d)	**14.**	(a)	**15.**	(a)
16.	(b)	**17.**	(c)	**18.**	(d)	**19.**	(c)	**20.**	(b)	**21.**	(b)	**22.**	(d)	**23.**	(b)	**24.**	(b)	**25.**	(c)	**26.**	(c)	**27.**	(d)	**28.**	(d)	**29.**	(b)	**30.**	(a)
31.	(d)	**32.**	(c)	**33.**	(b)	**34.**	(b)	**35.**	(a)	**36.**	(c)	**37.**	(a)	**38.**	(b)	**39.**	(c)	**40.**	(c)	**41.**	(c)	**42.**	(c)	**43.**	(d)	**44.**	(c)	**45.**	(b)
46.	(c)	**47.**	(c)	**48.**	(a)	**49.**	(d)	**50.**	(d)	**51.**	(b)	**52.**	(a)	**53.**	(d)	**54.**	(a)	**55.**	(d)	**56.**	(d)	**57.**	(a)	**58.**	(a)	**59.**	(a)	**60.**	(c)
61.	(c)	**62.**	(c)	**63.**	(c)	**64.**	(d)	**65.**	(d)	**66.**	(a)	**67.**	(c)	**68.**	(a)	**69.**	(a)	**70.**	(c)	**71.**	(d)	**72.**	(d)	**73.**	(d)	**74.**	(c)	**75.**	(c)
76.	(d)	**77.**	(a)	**78.**	(d)	**79.**	(d)	**80.**	(a)	**81.**	(d)	**82.**	(b)	**83.**	(d)	**84.**	(a)	**85.**	(b)	**86.**	(a)	**87.**	(b)	**88.**	(b)	**89.**	(b)	**90.**	(a)
91.	(b)	**92.**	(b)	**93.**	(d)	**94.**	(d)	**95.**	(c)	**96.**	(c)	**97.**	(c)	**98.**	(c)	**99.**	(a)	**100.**	(a)	**101.**	(c)	**102.**	(b)	**103.**	(c)	**104.**	(b)	**105.**	(d)
106.	(a)	**107.**	(b)	**108.**	(c)	**109.**	(d)	**110.**	(d)	**111.**	(b)	**112.**	(c)	**113.**	(c)	**114.**	(a)	**115.**	(c)	**116.**	(c)	**117.**	(a)	**118.**	(d)	**119.**	(a)	**120.**	(c)
121.	(d)	**122.**	(b)	**123.**	(c)	**124.**	(b)	**125.**	(a)	**126.**	(b)	**127.**	(b)	**128.**	(b)	**129.**	(a,b,c,d)	**130.**	(b,d)	**131.**	(b, d)	**132.**	(a,c)	**133.**	(b)	**134.**	(c)	**135.**	(b)
136.	(b)	**137.**	(b)	**138.**	(c)	**139.**	(a)	**140.**	(b)	**141.**	(d)	**142.**	(d)	**143.**	(c)	**144.**	(d)	**145.**	(a)	**146.**	(a)	**147.**	(d)	**148.**	(a)	**149.**	(d)	**150.**	(b)

Hints *and* Explanations

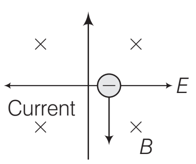
1. (*b*) For proton, $\mathbf{v} \perp \mathbf{B}$ and for electron $\mathbf{v} \parallel \mathbf{B}$. So, force on proton $= q\,(\mathbf{v} \times \mathbf{B}) = Bqv$ whereas, force on electron = 0.

2. (*c*) Direction of force can be found by left hand rule. As we know the direction of **F** is the direction of cross product of velocity **v** and magnetic field **B**, which is perpendicular to the plane containing **v** and **B**.

3. (*d*) The Oersted found that the alignment of the magnetic needle is tangential to an imaginary circle which has the straight current-carrying wire, as its centre has its plane perpendicular to the wire as shown in figure.



4. (*d*)



If an electron is travelling horizontally towards East and magnetic field in vertically downward, then according to left hand rule. So, force on electron is towards North.

5. (*d*) Magnetic field, *i.e.*, $B = \dfrac{F}{qv} = \dfrac{10^{-10}}{10^{-12} \times 10^{5}} = 10^{-3}\ \text{Wb m}^{-2}$

So, according to left hand rule, magnetic field acting along *Z*-axis.

6. (*c*) When a charged particle moves in the region of magnetic field, then force is perpendicular to the velocity and it produces a change of direction.

7. (*a*) Net force on the proton,

i.e., $F = Bqv\sin\theta$

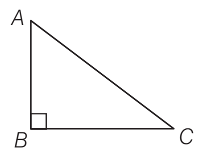
$= 1.5 \times 1.6 \times 10^{-19} \times 2 \times 10^{7} \times \sin 30° = 2.4 \times 10^{-12}$ N

8. (*c*) As the electric field is switched on, positive ion will start to move along positive *x*-direction and negative ion along negative *x*-direction. Current associated with motion of both types of ions is along positive *x*-direction. According to Fleming's left hand rule force on both types of ions will be along negative *y*-direction.

9. (*a*) The total number of mobile charge carriers in wire will be *nAl*. For a steady current I in this conducting wire, we may assume that each mobile carrier has an average drift velocity $\mathbf{v}_d$. In the presence of an external magnetic field **B**, the force on these carriers is given by

$$\mathbf{F} = (nAl)q\,(\mathbf{v}_d \times \mathbf{B})$$

10. (*a*) According to the question,



$$\mathbf{F}_{AB} + \mathbf{F}_{BC} + \mathbf{F}_{CA} = 0$$
$$\mathbf{F}_{BC} + \mathbf{F}_{CA} = 0 \qquad (\because \mathbf{F}_{AB} = 0)$$
$$\mathbf{F}_{CA} = -\mathbf{F}_{BC} = -\mathbf{F}$$

11. (*b*) When a current carrying closed loop is placed in a uniform magnetic field, $F_{\text{net}} = 0$, only torque acts.

12. (*b*) $r = \dfrac{mv}{qB} = \dfrac{9\times10^{-31}\,\text{kg}\times 3\times10^{7}\ \text{ms}^{-1}}{1.6\times10^{-19}\,\text{C}\times6\times10^{-4}\,\text{T}}$

$= 28\times10^{-2}\,\text{m} = 28$ cm

Frequency of an electron,

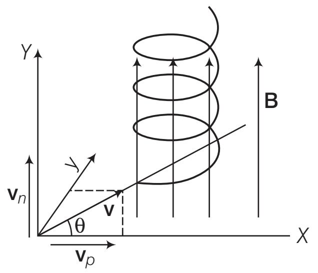
i.e., $\nu = v(2\pi r) \approx 20\times10^{6}\ \text{s}^{-1}$

$\approx 20\times10^{6}$ Hz $\approx$ 20 MHz

Amount of energy required

$$E = (1/2)mv^2 = (1/2)\,9\times10^{-31}\ \text{kg}\times9\times10^{14}\ \text{m}^2\text{s}^{-2}$$
$$= 40.5\times10^{-17}\,\text{J}$$
$$= 4\times10^{-16}\,\text{J} = 2.5\ \text{keV} \qquad (1\ \text{eV} = 1.6\times10^{-19}\ \text{J})$$

13. (*d*) When a particle moves perpendicular to the magnetic field. It has a tendency to perform circular motion in a plane perpendicular to the magnetic field. When this is coupled with the velocity parallel to the field, then resulting trajectory will be a helix along the magnetic field line as shown in figure.



14. (*a*) As we know that radius of circle,

$$r = \frac{mv}{Bq} = \frac{1}{2}\left(\frac{2mv^2}{Bqv}\right) \Rightarrow r = \frac{2E}{Bqv}$$

Energy is same. So, $r \propto 1/q$ but in case of deuteron and α-particle

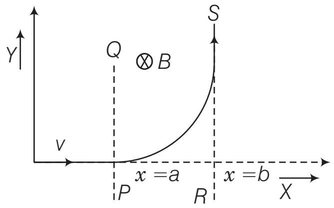
q is same and q for proton is least

$\therefore \qquad r_p > r_\alpha = r_d$

15. (*a*) Radius of path, $r = \dfrac{mv}{rB}$

Given, $r_a > r_b \Rightarrow \dfrac{m_a v_a}{qB} > \dfrac{m_b v_b}{qB} \Rightarrow m_a v_a > m_b v_b$

16. (*b*) The particle moves in a circular path of radius r in the magnetic field. It can just enter the region $x > b$ for $r \geq (b-a)$.



Now, $\quad r = \dfrac{mv}{qB} \geq (b-a)$

or $\quad v \geq \dfrac{q\,(b-a)B}{m} \Rightarrow v_{\min} = \dfrac{q\,(b-a)B}{m}$

17. (*c*) Radius of circular path followed by a particle,

$$r = \frac{mv}{Bq} = \frac{v}{\dfrac{Bq}{m}} = \frac{2\times10^{5}}{0.05\times2.5\times10^{7}} = 16\,\text{cm}$$

18. (*d*) As we know that frequency of proton,

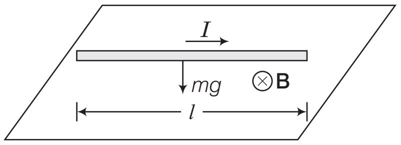
$$f = \frac{1}{T} = \frac{qB}{2\pi m} = \frac{1.6\times10^{-19}\times6.28\times10^{-4}}{2\times\dfrac{22}{7}\times1.67\times10^{-27}}$$
$$\approx 10^{-19-4+27} \approx 10^{4}\ \text{Hz}$$

19. (*c*) As, velocity **v** component is along magnetic field **B**. So, path is helical. Radius of a helix,

$$r = \frac{mv_\perp}{Bq} = \frac{1.67\times10^{-27}\times2\times10^{6}}{0.104\times1.6\times10^{-19}} \Rightarrow r = 0.2\ \text{m}$$

Time period, $T = \dfrac{2\pi m}{Bq} = 2\pi\times10^{-7}$ s

20. (*b*)



There is an upward force **F** of magnitude IlB. For mid-air suspension, this must be balanced by the force due to gravity.

$$mg = IlB \Rightarrow B = \frac{mg}{Il} = \frac{0.2\times9.8}{2\times1.5} = 0.65\ \text{T}$$

21. (*b*) The radius of circular path,

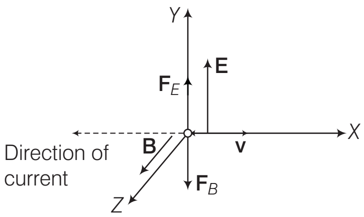
$$r = \frac{mv}{qB} \Rightarrow r \propto \frac{v}{B}$$

22. (*d*) $\because r = \dfrac{mv}{Bq} = \dfrac{\sqrt{2mK}}{Bq}$

$$\frac{r_p}{r_d} = \sqrt{\frac{m_pK_p}{m_dK_d}} \Rightarrow 1 = \frac{m_pK_p}{2m_pK_d}$$

$$K_p = 2K_d \Rightarrow K_p = 2\times50 = 100\ \text{keV}$$

23. (*b*)



When electric and magnetic fields are perpendicular to each other.

So, $\quad \mathbf{F}_E = q\mathbf{E} = qE\,\hat{\mathbf{j}},\ \mathbf{F}_B = q\mathbf{v}\times\mathbf{B}$

$= q(v\hat{\mathbf{i}}\times B\hat{\mathbf{k}}) = -qv\hat{\mathbf{j}} \qquad (\because\ \hat{\mathbf{i}}\times\hat{\mathbf{k}} = -\hat{\mathbf{j}})$

Therefore, force on electron is given by

$$\mathbf{F} = q(E - vB)\hat{\mathbf{j}}$$

24. (*b*) Velocity of a particle, $v = \frac{E}{B} = \frac{\sigma}{\varepsilon_0 B}$

$\therefore$ Time taken by electron to pass through the region,

$$t = \frac{l}{v} = \frac{l\varepsilon_0 B}{\sigma}$$

25. (*c*) The cyclotron is a machine to accelerate charged particles or ions to high energies. The cyclotron used both electric and magnetic fields in combination to increase the energy of charged particles.

26. (*c*) Frequency, $\nu = \frac{eB}{2\pi m}$

$\text{KE} = \frac{1}{2}mv^2$ and radius $R = \frac{mv}{eB}$

Here, velocity $v = \frac{\pi R}{T/2} = \frac{2\pi R}{T} = 2\pi R\nu$

$\therefore$ Radius, $R = \frac{m(2\pi R\nu)}{eB}$

Magnetic field, $B = \frac{2\pi m\nu}{e}$

Kinetic energy, $K = \frac{1}{2}m(v)^2 = 2m\pi^2\nu^2R^2$

27. (*d*) Radius in magnetic fields of circular orbit,

$$R = \frac{mV}{qB} = \frac{\sqrt{2mE}}{qB}$$

and total energy of a moving particle in a circular orbit,

$$E = \frac{q^2B^2R^2}{2m}$$

For a proton entering in a region of magnetic field,

$$E_1 = \frac{e^2 \times B^2 \times R^2}{2 \times m_P} \quad \ldots\text{(i)}$$

where, m_P is the mass of proton.

Similarly, for an α-particle moving in a uniform magnetic field

$$E_2 = \frac{(2e)^2 \times B^2 \times R^2}{2 \times (4m_P)} \quad (\because m_\alpha = 4m_P) \ldots\text{(ii)}$$

Dividing Eq. (ii) by Eq. (i), we get

$$\frac{E_2}{E_1} = \frac{(2e)^2 \times B^2 \times R^2}{2 \times (4m_P)} \times \frac{2 \times m_P}{e^2 \times B^2 \times R^2}$$

$$\frac{E_2}{E_1} = 1 \Rightarrow E_2 = E_1 = 1\,\text{MeV}$$

28. (*d*) Frequency of an electron

$$f = \frac{Bq}{2\pi m} = \frac{1 \times 1.6 \times 10^{-19}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 28\,\text{GHz}$$

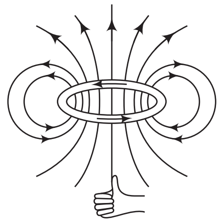
29. (*b*) $\because v = 3.2 \times 10^7\ \text{ms}^{-1} \Rightarrow B = 5 \times 10^{-4}\ \text{T}$

The frequency of electron,

$$\nu = \frac{qB}{2\pi m} = \frac{1.6 \times 10^{-19} \times 5 \times 10^{-4}}{2 \times 3.14 \times 9.1 \times 10^{-31}}$$

$$\nu = 1.4 \times 10^7\ \text{Hz} = 14\ \text{MHz}$$

30. (*a*)



Curl the palm of your right hand around the circular wire with the fingers pointing in the direction of the current. The right hand thumb gives the direction of the magnetic field.

31. (*d*) Since, the coil is tightly wound, we may take each circular element to have the same radius $R = 10$ cm $= 0.1$ m. The number of turns $N = 100$. The magnitude of the magnetic field is

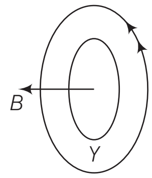
$$B = \frac{\mu_0 NI}{2R} = \frac{4\pi \times 10^{-7} \times 10^2 \times 1}{2 \times 10^{-1}}$$

$$= 2\pi \times 10^{-4} = 6.28 \times 10^{-4}\ \text{T}$$

32. (*c*) Magnetic field at the centre of the loop,

$$B = \frac{\mu_0 NI}{2r} = \frac{4\pi \times 10^{-7} \times 100 \times 0.4}{2 \times 8.0 \times 10^{-2}} = 3.1 \times 10^{-4}\ \text{T}$$

33. (*b*) The magnitude of magnetic field in current-carrying circular loop,



$$B = \frac{\mu_0 NI}{2R}$$

$$B_X = \frac{4\pi \times 10^{-7} \times 20 \times 16}{2 \times 0.16}$$

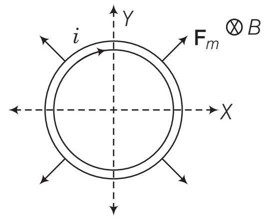
$$= 4\pi \times 10^{-4}\ \text{T}$$

$$B_Y = \frac{4\pi \times 10^{-7} \times 25 \times 18}{2 \times 0.1} = 9\pi \times 10^{-4}\ \text{T}$$

$$B_{\text{net}} = B_Y - B_X = 5\pi \times 10^{-4}\ \text{T}$$

$$= 1.57 \times 10^{-3}\ \text{T} \quad \text{(towards west)}$$

34. (*b*) Net force on a current-carrying loop in a uniform magnetic field is zero. Hence, the loop cannot translate. So, options (c) and (d) are wrong.



From Fleming's left hand rule, we can see that if magnetic field is perpendicular to paper inwards and current in the loop is clockwise (as shown), the magnetic force $\mathbf{F}_m$ on each element of the loop is radially outwards or the loops will have a tendency to expand.

35. (*a*) Magnetic field due to a straight current-carrying conductor

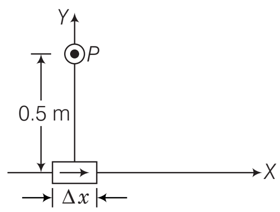
$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 35}{2 \times \pi \times 0.20} = 3.5 \times 10^{-5}\ \text{T}$$

36. (*c*) Vector notation of Biot-Savart's law,

$$d\mathbf{B} = \frac{\mu_0}{4\pi}\frac{I d\mathbf{l} \times \mathbf{r}}{r^3}$$

37. (*a*) The magnitude of magnetic field,

$$|d\mathbf{B}| = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}$$



i.e., $$|d\mathbf{B}| = \frac{10^{-7}\times 10\times 10^{-2}}{25\times 10^{-2}} = 4\times 10^{-8}\ \text{T}$$

As, $dl\times\mathbf{r} = \Delta x\hat{\mathbf{i}}\times y\hat{\mathbf{j}} = y\,\Delta x\,(\hat{\mathbf{i}}\times\hat{\mathbf{j}}) = y\,\Delta x\hat{\mathbf{k}}$

So, the direction of the field is in the + *Z*-direction.

38. (*b*) $|d\mathbf{B}| = \frac{\mu_0}{4\pi}\left|\frac{Id\mathbf{l}\times\mathbf{r}}{r^3}\right| = \frac{\mu_0}{4\pi}\times\frac{Idl\sin\theta}{r^2}$

If point lies on the conductor, then $\theta = 0°$ or $180°$ and $\sin\theta = 0$, then $dB = 0$. Hence, the magnetic field induction at any point on the conductor itself is zero.

39. (*c*) $B = \frac{\mu_0}{4\pi}\frac{\pi i}{R} = 10^{-7}\times\frac{22\times 12}{7\times 2\times 10^{-2}} = 1.9\times 10^{-4}\ \text{T}$

Thus, **B** is 1.9×10^{-4} T normal to the plane of the paper going into it.

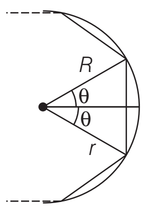
41. (*c*) Magnetic field at any point lying on the current-carrying straight conductor is zero.

Here, H_1 = magnetic field at *M* due to current in *PQ*.

H_2 = magnetic field at *M* due to *QR* + magnetic field at *M* due to *QS* + magnetic field at *M* due to *PQ*.

$$= 0 + \frac{H_1}{2} + H_1 = \frac{3}{2}H_1 \Rightarrow \frac{H_1}{H_2} = \frac{2}{3}$$

42. (*c*)



Angle subtended at centre by any of side $= \frac{2\pi}{n}$

$$\Rightarrow \quad 2\theta = \frac{2\pi}{n};\ \theta = \frac{\pi}{n}$$

Field due to one side,

$$B_1 = \frac{\mu_0 I}{4\pi r}(\sin\theta + \sin\theta)$$

But, $r = R\cos\theta = R\cos\frac{\pi}{n}$ and $\sin\theta = \sin\frac{\pi}{n}$

$$\therefore \quad B_1 = \frac{\mu_0 I}{4\pi R\cos\frac{\pi}{n}}\times 2\sin\frac{\pi}{n} = \frac{\mu_0 I}{2\pi R}\tan\frac{\pi}{n}$$

and so field on *n* sides at centre will add up to form net field

$$B_{\text{centre}} = \frac{\mu_0 nI}{2\pi R}\tan\frac{\pi}{n}.$$

43. (*d*) B at centre of a circle $= \frac{\mu_0 I}{2R}$

$$B \text{ at centre of a square} = 4\times\frac{\mu I}{4\pi\cdot\frac{l}{2}}(\sin 45° + \sin 45°)$$

$$= 4\sqrt{2}\frac{\mu_0 I}{2\pi l}$$

Now, $R = \frac{L}{2\pi}$ and $l = \frac{L}{4}$ (as $L = 2\pi R = 4l$)

where, L = length of wire

$$\therefore \quad B_A = \frac{\mu_0 I}{2\cdot\frac{L}{2\pi}} = \frac{\pi\mu_0 I}{L} = \pi\left(\frac{\mu_0 I}{L}\right)$$

$$B_B = 4\sqrt{2}\frac{\mu_0 I}{2\pi\left(\frac{L}{4}\right)} = \frac{8\sqrt{2}\mu_0 I}{\pi L} = \frac{8\sqrt{2}}{\pi}\left(\frac{\mu_0 I}{L}\right)$$

$$\therefore \quad B_A : B_B = \pi^2 : 8\sqrt{2}$$

44. (*c*) Magnetic field at centre of current-carrying coil,

$$B_c = \frac{\mu_0 I}{2r} \quad \ldots\text{(i)}$$

Magnetic field at axial point due to a current-carrying coil at distance of r,

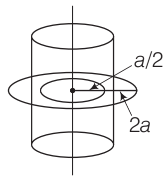
$$d = r$$

$$B_c = \frac{\mu_0 Ir^2}{2(r^2 + d^2)^{3/2}} \Rightarrow B_a = \frac{\mu_0 Ir^2}{2(2r^2)^{3/2}} \quad \ldots\text{(ii)}$$

Now, $$\frac{B_c}{B_a} = \frac{\mu_0 I}{2r}\times\frac{2(2r^2)^{3/2}}{\mu_0 Ir^2} = 2\sqrt{2}$$

$$B_c : B_a = 2\sqrt{2} : 1$$

45. (*b*) Consider two amperian loops of radius $a/2$ and $2a$ as shown in the diagram. Applying Ampere's circuital law for these loops, we get



$$\oint \mathbf{B}\cdot d\mathbf{L} = \mu_0 I_{\text{enclosed}}$$

For the smaller loop,

$$\Rightarrow \mathbf{B}\times 2\pi\frac{a}{2} = \mu_0\times\frac{I}{\pi a^2}\times\pi\left(\frac{a}{2}\right)^2 = \mu_0 I\times\frac{1}{4} = \frac{\mu_0 I}{4}$$

$$\Rightarrow \quad \mathbf{B}' = \frac{\mu_0 I}{4\pi a}, \text{ at distance } \frac{a}{2} \text{ from the axis of the wire.}$$

Similarly, for bigger amperian loop

$$\mathbf{B}'\times 2\pi\,(2a) = \mu_0 I$$

(total current enclosed by Amperian loop is 2.)

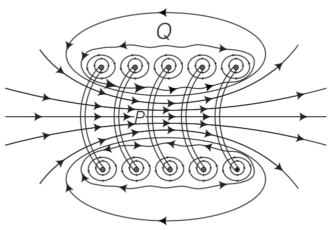
$$\Rightarrow \quad \mathbf{B}' = \frac{\mu_0 I}{4\pi a}$$

at distance $2a$ from the axis of the wire.

So, ratio of $\frac{\mathbf{B}}{\mathbf{B}'} = \frac{\mu_0 I}{4\pi a}\times\frac{4\pi a}{\mu_0 I} = 1$

46. (*c*) For a cylindrical conductor for $r < a$, $B \propto r$ and for $r > a$, $B \propto (1/r)$. So, graph (c) is correct.

47. (*c*)



48. (*a*) The number of turns per unit length is

$$n = \frac{500}{0.5} = 1000 \text{ turns/m}$$

The length $(l) = 0.5$ m and radius $(r) = 0.01$ m.

Thus, $l/a = 50$ *i.e.,* $l >> a$.

Hence, we can use the long solenoid formula, namely,

$$B = \mu_0 nI = 4\pi \times 10^{-7} \times 10^3 \times 5 = 6.28 \times 10^{-3} \text{ T}$$

49. (*d*) By the formula,

$$B = \mu_0 nI \quad \text{or} \quad 20 \times 10^{-3} = 4\pi \times 10^{-7} \times 2000 \times I$$

or $$I = \frac{20 \times 10^{-3}}{4\pi \times 10^{-7} \times 2000} \Rightarrow I \simeq 8 \text{ A}$$

50. (*d*) For toroid, applying Ampere's circuital law,

$$B\,(2\pi r) = \mu_0 NI \Rightarrow B = \frac{\mu_0 NI}{2\pi r}$$

where, B = magnetic field of a toroid

N = number of turns of toroidal coil

r = radius of toroid

51. (*b*) Mean radius, $r_m = \dfrac{0.25 + 0.26}{2} = 25.5 \times 10^{-2}$ m

$$n = \frac{N}{2\pi r_m} = \frac{3500}{2\pi \times 25.5 \times 10^{-2}}$$

Magnetic field of a toroid

$$B = \mu_0 nI = 4\pi \times 10^{-7} \times \frac{3500}{2\pi \times 25.5 \times 10^{-2}} \times 11 = 3 \times 10^{-2} \text{ T}$$

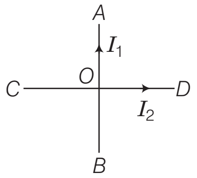
52. (*a*) The force acting per unit length,

$$\frac{F}{l} = \frac{\mu_0}{4\pi}\frac{2I_1 I_2}{d}$$

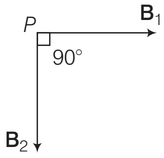
When $d = 1\text{m}, l = 1\text{m}, I_1 = I_2 = 1 \text{ A}$

Then, $F = 2 \times 10^{-7} \text{ Nm}^{-1}$

53. (*d*)



The point P is lying at a distance d along the Z-axis.



$$|\mathbf{B}_1| = \frac{\mu_0}{2\pi}\frac{I_1}{d} \text{ and } |\mathbf{B}_2| = \frac{\mu_0}{2\pi}\frac{I_2}{d}$$

$$B_{\text{net}} = \sqrt{B_1^2 + B_2^2} \Rightarrow B_{\text{net}} = \frac{\mu_0}{2\pi}\frac{1}{d}(I_1^2 + I_2^2)^{1/2}$$

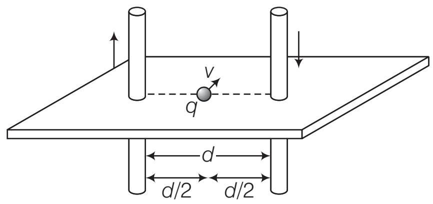
54. (*a*) $I_1 = 4 \text{ A}, I_2 = 5 \text{ A}, d = 4 \times 10^{-2} \text{ m}, l = 0.20$ m

Force on a current carrying wire,

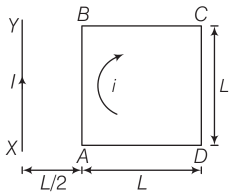
$$F = \frac{\mu_0 I_1 I_2 l}{2\pi d} = \frac{4\pi \times 10^{-7} \times 4 \times 5}{2 \times \pi \times 4 \times 10^{-2}} \times 0.20$$

$= 2 \times 10^{-5}$ N towards B

55. (*d*) According to given information, following figure can be drawn, which shows that direction of magnetic field is along the direction of motion of charge, so net force on it is zero.



56. (*d*) Consider the given figure,



$$F_{BA} = \frac{\mu_0 IiL}{2\pi\left(\frac{L}{2}\right)} \Rightarrow F_{CD} = \frac{\mu_0 IiL}{2\pi\left(\frac{3L}{2}\right)}$$

Therefore, net force on the loop $ABCD$ will be

$$F_{\text{loop}} = F_{BA} - F_{CD} = \frac{\mu_0 IiL}{2\pi}\left[\frac{1}{(L/2)} - \frac{1}{(3L/2)}\right]$$

$$F_{\text{loop}} = \frac{2\mu_0 iI}{3\pi}$$

57. (*a*) The force acting per unit length of a wire, $\dfrac{F}{l} = \dfrac{\mu_0 I_1 I_2}{2\pi d}$

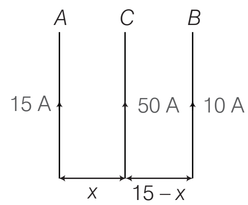
Also I_1 and I_2 are opposite directions.

$\therefore$ They repel each other, $F = 1.2 \text{ Nm}^{-1}$

58. (*a*) Current flows in same direction.

$\therefore$ Wires attract each other and $\dfrac{F}{l} = \dfrac{\mu_0 I^2}{2\pi d}$

59. (*a*) $\dfrac{F_{AC}}{l} = \dfrac{F_{BC}}{l}$



$$\frac{\mu_0}{4\pi} \cdot \frac{2 \times 15 \times 50}{x} = \frac{\mu_0}{4\pi} \times \frac{2 \times 50 \times 10}{15 - x}$$

$$\frac{15}{x} = \frac{10}{(15 - x)}$$

$$225 - 15x = 10x \Rightarrow 25x = 255 \quad \text{or} \quad x = 9 \text{ cm}$$

60. (*c*) Since, **B** is uniform only torque acts on a current-carrying loop.

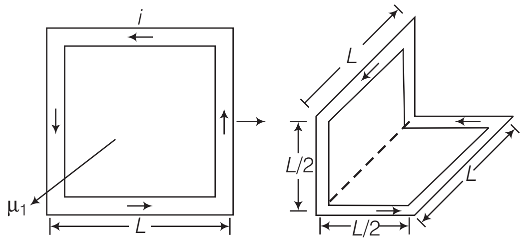
As, $\tau = \mathbf{M} \times \mathbf{B} \Rightarrow |\tau| = |\mathbf{M}||\mathbf{B}| \sin\theta$

For orientation shown in (b) $\theta = 0°$, $\tau = 0$ ($\because$ stable equilibrium)

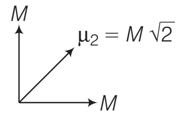
$\therefore$ and for (d) $\theta = \pi, \tau = 0$ ($\because$ unstable equilibrium)

61. (*c*) As we know, potential energy *i.e.,*
$U = -MB\cos\theta$, where θ = angle between normal to the plane of the coil and direction of magnetic field.

62. (*c*) As, we know that initial magnetic moment $= \mu_1 = iL^2$



$\mu_1 = iL^2$



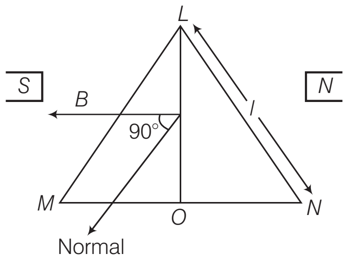
After folding the loop,

M = magnetic moment due to each part

$$= i\left(\frac{L}{2}\right) \times L = \frac{iL^2}{2} = \frac{\mu_1}{2}$$

$$\Rightarrow \quad \mu_2 = M\sqrt{2} = \frac{\mu_1}{2} \times \sqrt{2} = \frac{\mu_1}{\sqrt{2}}$$

63. (*c*) Torque acting on equilateral triangle in a magnetic field **B** is



$$\tau = \mathbf{M} \times \mathbf{B}, \tau = iAB\sin\theta \qquad (iA = \mathbf{M})$$

Area of ΔLMN,

$$A = \frac{\sqrt{3}}{4} l^2 \text{ and } \theta = 90° \quad (l = \text{sides of triangle})$$

Substituting the given values in the expression for torque, we have

$$\tau = i \times \frac{\sqrt{3}}{4} l^2 B \sin 90° = \frac{\sqrt{3}}{4} il^2 B \qquad (\because \sin 90° = 1)$$

Hence, $l = 2\left(\dfrac{\tau}{\sqrt{3}Bi}\right)^{1/2}$

64. (*d*) Torque on current loop in a field is $\tau = \mathbf{m} \times \mathbf{B}$.
where, m is magnetic moment of a current carrying loop B is magnetic field.

65. (*d*) For parallel **M** is stable and for anti-parallel is unstable.

66. (*a*) The torque acting on the coil $|\tau| = |\mathbf{m} \times \mathbf{B}| = mB\sin\theta$.
Here the circular coil is placed normal to the direction of magnetic field then the angle between the direction of magnetic moment ($\mathbf{m}$) and magnetic field ($\mathbf{B}$) is zero, then

$$\tau = mB\sin\theta = mB\sin 0 = 0 \Rightarrow \tau = 0$$

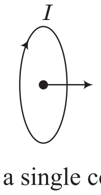
67. (*c*) For a loop at a point on its axis distant x from centre,

$$B = \frac{\mu_0 IR^2}{2(x^2 + R^2)^{3/2}}$$

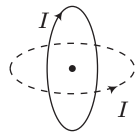
For $x >> R$, $B = \dfrac{\mu_0 R^2 I}{2x^3} \Rightarrow B = \dfrac{\mu_0 IA}{2\pi x^3}$

Hence, $\mathbf{B} \simeq \dfrac{\mu_0 \mathbf{m}}{2\pi x^3} = \dfrac{\mu_0}{4\pi} \times \dfrac{2\mathbf{m}}{x^3}$

68. (*a*)



For a single coil, magnetic field, $B_s = \dfrac{\mu_0 I}{2R}$ T ...(i)



For two coils magnetic field,

$$B_T = \sqrt{B_1^2 + B_2^2} = \sqrt{2}\frac{\mu_0 I}{2R} \qquad \text{...(ii)}$$

On comparing Eq. (i) and Eq. (ii), we get

$$\frac{B_S}{B_T} = \frac{1}{\sqrt{2}}$$

69. (*a*) Magnetic moment of a current-carrying loop is

$$\mathbf{m} = NI\mathbf{A}$$

where, N is number of turns, I is current flowing on a loop and A is area of cross-section of loop.

70. (*c*) Here, $N = 150$, $R = 12\text{ cm} = 12 \times 10^{-2}$ m, $I = 2$A

$$B = \frac{\mu_0 NI}{2R} = \frac{2\pi \times 10^{-7} \times 150 \times 2}{12 \times 10^{-2}}$$

$$= 1.57 \times 10^{-3} \text{ T} = 15.7 \times 10^{-4} \text{ T} = 15.7 \text{ G}$$

71. (*d*) Each segment experiences a force, so it tends to assume a circular shape.

72. (*d*) Work done $= \mathbf{MB}(1 - \cos\theta), \theta = 0°$ so work done is zero.

73. (*d*) Magnetic field at the centre of circular loop,

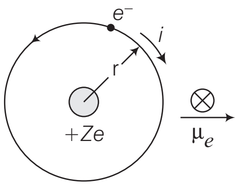
$$B = \frac{\mu_0}{4\pi}\frac{2\pi I}{r} = \frac{\mu_0 I}{2r} \Rightarrow I = \frac{2Br}{\mu_0}$$

Also, $A = \pi r^2$ or $r = (A/\pi)^{1/2}$

Magnetic moment, $M = IA = \dfrac{2Br}{\mu_0} A = \dfrac{2BA}{\mu_0} \times \left(\dfrac{A}{\pi}\right)^{1/2}$

$$= \frac{2BA^{3/2}}{\mu_0 \pi^{1/2}}$$

74. (*c*) The uniform circular motion of the electron constitutes a current in anti-clockwise. The direction of the magnetic moment is into the plane of the paper and is indicated separately by ⊗.



75. (*c*) T is the time period of revolution. Let r be the orbital radius of the electron, and v the orbital speed. Then,

$$T = \frac{2\pi r}{v}, I = \frac{2}{T}$$

On substituting, we have $I = ev/2\pi r$.

76. (*d*) Magnetic field on a current-carrying in a circular orbit

i.e., $B = \frac{\mu_0 I}{2R}$

$$\therefore \quad I = \frac{B \times 2R}{\mu_0} = \frac{12.56 \times 2 \times 5.2 \times 10^{-11}}{4\pi \times 10^{-7}} = 1.04 \times 10^{-3} \text{ A}$$

77. (*a*) For $n = 1$, for an H_2 atom, $\mu_{l\ \min} = \frac{e}{4\pi m_e} h$

$$= \frac{1.60 \times 10^{-19} \times 6.63 \times 10^{-34}}{4 \times 3.14 \times 9.11 \times 10^{-31}} = 9.27 \times 10^{-24} \text{ Am}^2$$

where, the subscript min stands for minimum. This value is called the Bohr magneton.

78. (*d*) There will be a magnetic moment, usually denoted by μ_i associated with this circulating current.

Its magnitude is $\mu_i = I\pi r^2 = evr/2$.

Multiplying and dividing the right hand side of the above expression by the electron mass m_e,

We have $\quad \mu_l = \frac{e}{2m_e}(m_e vr) = \frac{e}{2m_e} l$

Here, l is the magnitude of the angular momentum of the electron about the central nucleus (orbital angular momentum). Vectorially,

$$\mu_l = -\frac{e}{2m_e} l$$

The negative sign indicates that the angular momentum of the electron is opposite in direction to the magnetic moment.

79. (*d*) A moving coil galvanometer is a sensitive instrument which is used to measure a deflection when a current flows through its coil.

80. (*a*) When a current flows through the coil, a torque acts on it. This torque is given by $\tau = NIAB$

where, the symbols have their usual meaning. Since, the field is radial by design, we have taken $\sin\theta = 1$ in the above expression for the torque. The magnetic torque $NIAB$ tends to rotate the coil.

A spring S_P provides a counter torque $k\phi$ that balances the magnetic torque $NIAB;$ resulting in a steady angular deflection ϕ. In equilibrium $k\phi = NIAB$

where, k is the torsional constant of the spring, *i.e.,* the restoring torque per unit twist. The deflection ϕ is indicated on the scale by a pointer attached to the spring. We have

$$\phi = \left(\frac{NAB}{k}\right) I$$

81. (*d*) Uniform field is made radial by cutting pole pieces radially.

82. (*b*) The deflection in a moving coil galvanometer,

$\phi = \frac{NAB}{k} \cdot I \quad$ or $\quad \phi \propto N$, where N is number of turns in a coil, B is magnetic field, A is area of cross-section.

83. (*d*) The deflecting torque acting on the coil

$$\tau_{\text{deflection}} = NIAB$$

86. (*a*) Current sensitivity of the galvanometer deflection per unit ampere

$$\Rightarrow \quad \frac{\phi}{I} = \frac{NBA}{k}$$

87. (*b*) Current sensitivity of all galvanometer

$$\frac{\phi}{I} = S_i = \frac{NBA}{k}$$

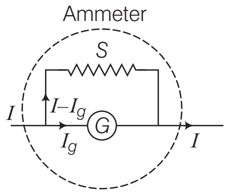
Hence, to increase S_i, k must be decreased.

88. (*b*) Spring constant, $k = 10^{-8} \frac{\text{Nm}}{\text{rad}}$

$N = 100, A = 1 \text{ cm}^2 = (1 \times 10^{-2})^2 \text{ m}^2 = 1 \times 10^{-4} \text{ m}^2$ $B = 5$ T,

$$\therefore \quad S_i = \frac{NBA}{k} = \frac{100 \times 5 \times 1 \times 10^{-4}}{10^{-8}} = 5 \times 10^6 \text{ A}^{-1}$$

89. (*b*) As potential is same for parallel combination.



For ammeter, $S\ (I - I_g) = GI_g$

Shunt resistance, $S = \frac{G\, I_g}{I - I_g}$

$$= \frac{15 \times 4 \times 10^{-3}}{6 - 4 \times 10^{-3}} = 10 \text{ m}\Omega$$

90. (*a*) Minimum current measured by $A \to 0.3$ mA

by $B \to 0.5$ mA

91. (*b*) According to ammeter circuit, we get $(I - I_g) S = I_g G$

where, G is resistance of galvanometer.

92. (*b*) To convert a galvanometer into ammeter, a low resistance is connected in parallel with the coil of galvanometer.

93. (*d*) $R = \frac{R_G r_s}{R_G + r_s}$

Here, $R_G = 70\ \Omega$, $r_s = 0.03\ \Omega$

$$\therefore \quad R = \frac{70 \times 0.03}{70 + 0.03} = 0.02998 = 0.03\ \Omega$$

94. (*d*) $\quad S_V = \frac{S_i}{R} \quad \Rightarrow \quad S_V' = \frac{1.5 S_i}{2R} = \frac{3}{4} S_V$

% decrease in voltage sensitivity $= \frac{1 - 3/4}{1} \times 100 = 25\%$

$$= (1/4)\, S_V$$

95. (*c*) Voltage sensitivity is deflection per unit voltage

$$\frac{\phi}{V} = \frac{NBA}{kR} = \left(\frac{NBA}{k}\right) \times \frac{1}{R}$$

96. (*c*) To convert a galvanometer into voltmeter, a high resistance in series is to be connected with galvanometer.

97. (*c*) For voltmeter circuit,

$$(I - I_g) \cdot R_L = I_g \, (G + S)$$

where, G and S, are resistance of galvanometer and shunt.

98. (*c*) $G = 12 \ \Omega$ and $I_g = 2.5 \times 10^{-3}$ A

For ammeter, $S = \dfrac{GI_g}{I - I_g} = \dfrac{12 \times 2.5 \times 10^{-3}}{7.5 - (2.5 \times 10^{-3})}$

$\Rightarrow \quad S = 4 \times 10^{-3} \ \Omega \quad \Rightarrow \quad \dfrac{1}{R_{\text{ammeter}}} = \dfrac{1}{G} + \dfrac{1}{S}$

$\Rightarrow \quad R_a = \dfrac{SG}{S + G} = 4.0 \times 10^{-3} \ \Omega$

For a galvanometer as voltmeter,

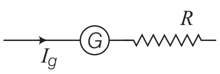
$$R = \frac{V}{I_g} - G = \frac{10.0}{2 \cdot 5 \times 10^{-3}} - 12 = 3988 \ \Omega$$

$\therefore \quad R_V$ = Voltmeter's resistance

$R_V = R + G = 4000 \ \Omega = 4 \times 10^3 \ \Omega$

Ratio, $\dfrac{R_a}{R_V} = \dfrac{4 \times 10^{-3}}{4 \times 10^3} = 10^{-6}$

99. (*a*)



For voltmeter circuit, we get

As, $\quad I_g \, (R + G) = V$

So, $\quad R = \dfrac{V}{I_g} - G = \dfrac{18}{3 \times 10^{-3}} - 12 = 5988 \ \Omega$ in series

100. (*a*) As, we know current sensitivity $S_i = \dfrac{NBA}{k}$

and voltage sensitivity, $S_V = \dfrac{NBA}{kR}$

$\Rightarrow \quad \dfrac{S_i}{S_V} = R \text{ (or } G) \quad \Rightarrow \quad \dfrac{S_i}{G} = S_V$

101. (*c*) Cyclotron is utilised to accelerate the positive ion.

Cyclotron frequency is given by $\nu = \dfrac{Be}{2\pi m}$.

It means cyclotron frequency does not depend upon velocity.

102. (*b*) Time period, $T = \dfrac{2\pi m}{Bq}$ as $\left(\dfrac{m}{q}\right)_\alpha = 2\left(\dfrac{m}{q}\right)_p \Rightarrow T_\alpha = 2T_p$

Also, $\quad T \propto m$

But, $\quad T_\alpha = 4T_p$ which is not the case.

103. (*c*) Time taken is independent of velocity and radius of path. However, maximum velocity will be given by

$$v_{\max} = \frac{qBR}{m}$$

where, R is radius of Dee's.

104. (*b*) The magnetic field due to solenoid having n number of turns/metre and carrying current I is

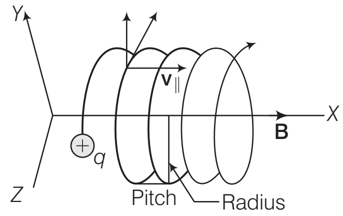
$$B = \frac{\mu_0 nI}{2} (\cos\alpha - \cos\beta)$$

It is obvious that magnetic field is independent of length and area. Also magnetic field is uniform inside the solenoid.

105. (*d*) The force experienced by a charged particle in a magnetic field is given by $F = q(v \times B)$, which is independent of mass. As qv and B are same for both the electron and proton, both will experience same force.

106. (*a*) When a charged particle moves in region of a perpendicular magnetic field, the magnetic force is perpendicular to the velocity of the particle. So, no work is done and no change in the magnitude of the velocity.

107. (*b*) If velocity has component along **B**, this component remains unchanged as the motion along the magnetic field will not be affected by the magnetic field. The motion in a plane perpendicular to **B** is as before a circular one, thereby producing a helical motion.



108. (*c*) Charged particle covers semicircular path in $T/2$ s.

$$T = \frac{2\pi m}{Bq}$$

where, B is magnetic field and m is mass of electron.

109. (*d*) Any charge in uniform circular motion would have an associated magnetic moment. This dipole moment is labelled as the orbital magnetic moment. Hence, the subscript l in μ_l. Besides the orbital moment, the electron has an intrinsic magnetic moment, which has the same numerical value. It is called the spin magnetic moment. But we hasten to add that it is not as though the electron is spinning. The electron is an elementary particle and it does not have an axis to spin around like a top or our Earth. Nevertheless it does possess this intrinsic magnetic moment. The microscopic roots of magnetism in iron and other materials can be traced back to this intrinsic spin magnetic moment.

110. (*d*) Current sensitivity, $S_i = \dfrac{NBA}{k}$

and voltage sensitivity, $S_V = \dfrac{NBA}{kR}$

So, when S_i is increased by increasing number of turns N, length of wire used also increases and so, R increases. Hence, S_V may remain same or decrease whereas S_i increases.

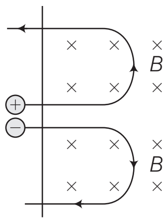
111. (*b*) If $\mathbf{v} \perp \mathbf{B}$, then path is a circular motion and if **v** has a component along **B**, then path will be helical.

112. (*c*) Radius of a circle

$$r = \frac{mv}{Bq} \Rightarrow r \propto m \Rightarrow v_e < v_p$$

and time taken to complete one revolution

$$T = \frac{2\pi m}{Bq} \quad \Rightarrow \quad T \propto m$$



But, mass of electron $(m_e) <$ mass of proton (m_p)

So, $\quad T_e < T_p$

113. (*c*) In a velocity selector, where F_e and F_B are electric and magnetic field,

Case I $F_e = F_B \Rightarrow v = E/B$
Case II $F_e < F_B \Rightarrow v > E/B$
Case III $F_e > F_B \Rightarrow v < E/B$

114. (*a*) *Difference between Coulomb's force and Biot-Savart's forces are*

I. The electrostatic field is along the displacement vector joining the source and the field point. The magnetic field is perpendicular to the plane containing the displacement vector r and the current element Idl.

II. There is an angle dependence in the Biot-Savart's law which is not present in the electrostatic case. In the magnetic field at any point in the direction of Idl is zero. Along this line, $\theta = 0$, $\sin\theta = 0$, then $|d\mathbf{B}| = 0$.

115. (*c*) As two coaxial solenoids 1 and 2 of the same length are set to be inside the other. So, net magnetic field,

i.e., $B_{net} = B_1 - B_2 \Rightarrow B_1 - B_2 = 0$

$B_1 = B_2 \Rightarrow B \propto ni$

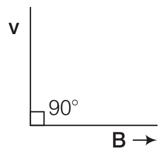
So, $n_1 i_1 = n_2 i_2$ or $n_1 = n_2$ and $i_1 = i_2$

116. (*c*) I Galvanometer is a very sensitive device, it gives a full scale deflection for a current of the order of μA.
II For measuring currents, the galvanometer has to be connected in series and as it has a large resistance, this will change the value of the current in the circuit.

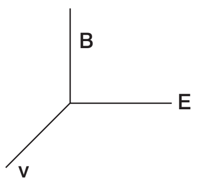
117. (*a*) A. Since, $\mathbf{E} = 0$ and $\mathbf{B} \neq 0$ so path will be straight line. If velocity is parallel to $\mathbf{B}$, or path will be circular if $v \perp B$, or path will be helical (with uniform pitch) if $\mathbf{v}$ is at same other angle to $\mathbf{B}$.
Hence, $A \rightarrow 1, 3$

B. Since, $\mathbf{E} \neq 0$ and $\mathbf{B} = 0$. So, path will be straight line parellel to $\mathbf{E}$ or parabola otherwise.
Hence, $B \rightarrow 1, 2$

C. $\mathbf{E} \neq 0, \mathbf{B} \neq 0, \mathbf{E} \parallel \mathbf{B}$
Helical path with non-uniform pitch.
Hence, $C \rightarrow 4$



D. Straight line path if $\mathbf{v} \times \mathbf{B} = \mathbf{E}$
Hence, $D \rightarrow 1$



119. (*a*) A. Lorentz force $\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$

B. Gauss' law, $\oint \mathbf{E} \cdot d\mathbf{A} = q/\varepsilon_0$

C. Biot-Savart's law, $d\mathbf{B} = \dfrac{\mu_0}{4\pi} = \dfrac{id\mathbf{l} \times \mathbf{r}}{r^3}$

D. Coulomb's law, $F = \dfrac{1}{4\pi\varepsilon_0} \dfrac{q_1 q_2}{r^2}$

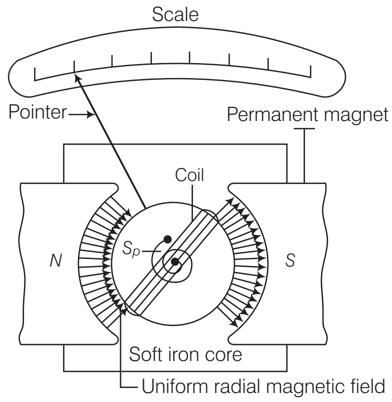
120. (*c*) A. Torque on loop, $\tau = \mathbf{m} \times \mathbf{B}$
where, $\mathbf{m}$ is magnetic moment of a current-carrying loop and $\mathbf{B}$ is magnetic field.

B. Torque on loop when m is either parallel or anti-parallel to $\mathbf{B}$, *i.e.,* $\tau = \mathbf{m} \times \mathbf{B}$ vanishes.

C. Magnetic moment of loop, $m = NI\mathbf{A}$, where I is current and A is area of cross-section of wire.

D. Torque on loop when m is perpendicular to $\mathbf{B}$.
$\tau = \mathbf{m} \times \mathbf{B} = mB \sin 90° = mB$

121. (*d*)



A. Core increases field strength.
B. Pole pieces produce radial field.
C. Spring produce restoring torque.
D. Coil produces deflecting torque.

122. (*b*) $r_0 = \dfrac{mv}{qB} \Rightarrow r' = \dfrac{m(2v_0)}{qB} = 2r_0$

123. (*c*) $T = \dfrac{2\pi m}{qB} \rightarrow$ independent of velocity.

124. (*b*) As $F \perp B$
Hence, $a \perp B$

$\therefore \quad \mathbf{a} \cdot \mathbf{B} = 0 \Rightarrow (x\hat{\mathbf{i}} + 2\hat{\mathbf{j}}) \cdot (2\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) = 0$

$2x + 8 = 0 \Rightarrow x = -4 \text{ ms}^{-2}$

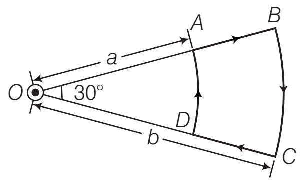
125. (*a*) Force acting on a horizontal table $F = IlB\sin\theta$
So, the force per unit length is

$$f = \frac{F}{l} = IB\sin\theta$$

When the current is flowing from East to West, then
$\theta = 90°$, so $f = IB\sin 90° = 1 \times 3 \times 10^{-5} \times 1 = 3 \times 10^{-5}$ Nm^{-1}

126. (*b*) When the current is flowing from South to North, then $\theta = 0°$, So, $f = IB\sin 0° \Rightarrow f = 0$
Hence, there is no force on the conductor.

127. (*b*)



Net magnetic field at O, $B_{AB} + B_{BC} + B_{CD} + B_{DA}$

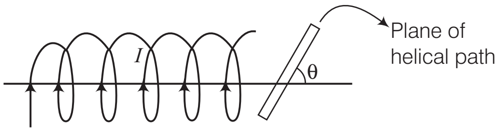
$$\Rightarrow \quad B = 0 + \frac{\mu_0 I}{4a} \times \frac{\pi}{6\pi} + 0 - \frac{\mu_0 I}{4b} \times \frac{\pi}{6\pi} = \frac{\mu_0 I}{24\,ab}(b-a)$$

128. (*b*) As, *AD* and *BC* are parallel to the field of I_1. So, force on them is zero.

129. (*a,b,c,d*) Options (a) and (b) are theoretical facts. As in case of moving charged particle in magnetic field $\mathbf{F}_{mag} \perp \mathbf{v}$, hence power associated will be zero (option (c) is correct).

If both the electric and magnetic fields exist : If $\mathbf{B} \parallel \mathbf{E}$, the path of the charged particle will be helical. If $\mathbf{B} \parallel \mathbf{E}$, the radius of the charged particle will not be constant. Hence, the path will not be circular (option (d) is correct).

130. (*b,d*) If a particle moves in a magnetic field in helical path, the plane of the helical path will be inclined at an acute angle with the magnetic field.



Hence, options (b) and (d) are correct.

131. (*b, d*) Velocity of proton makes an angle of 45° with the direction of magnetic field. Therefore, the path of the proton is a helix. The plane of the circle of this helix is the plane formed by negative *X* and positive *Z*-axis. Therefore, *x*-coordinate can never be positive. Further, *x* and *z*-coordinates will become zero simultaneously after every pitch and *y*-coordinate of the proton at any time *t* is

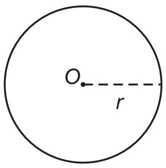
$$y = v_0 t, \quad i.e., \quad y \propto t$$

132. (*a,c*) Using $B = \frac{\mu_0 NI}{2R} \Rightarrow |\mathbf{B}_1| = |\mathbf{B}_2| = 4\pi \times 10^{-4}$ T

If current in same sense, $B_{net} = 8\pi \times 10^{-4}$ T

If current in opposite sense, $B_{net} = 0$

133. (*b*) Here, $n = 100$, $r = 8\text{ cm} = 8 \times 10^{-2}$ m



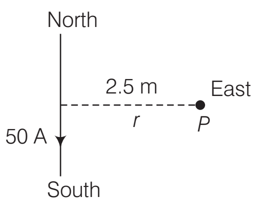
and $\qquad I = 0.40$ A

The magnetic field *B* at the centre,

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi In}{r} = \frac{10^{-7} \times 2 \times 3.14 \times 0.4 \times 100}{8 \times 10^{-2}} = 3.1 \times 10^{-4}$$

T

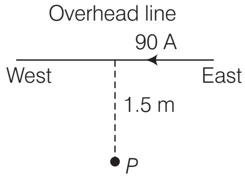
134. (*c*) Given, $I = 50$ A and $r = 2.5$ m



The magnitude of magnetic field,

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2I}{r} = 10^{-7} \cdot \frac{2 \times 50}{2.5} = 4 \times 10^{-6} \text{ T, upward direction}$$

135. (*b*)

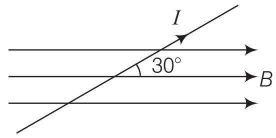


The magnitude of magnetic field,

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2I}{r} = \frac{10^{-7} \times 2 \times 90}{1.5} = 1.2 \times 10^{-5} \text{ T}$$

The direction of *B* will be perpendicularly upward.

136. (*b*) According to the question, $I = 8$ A, $\theta = 30°$, $B = 0.15$ T, $l = 1$ m

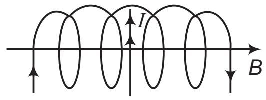


The magnitude of magnetic force

$$\mathbf{F} = I(\boldsymbol{l} \times \mathbf{B}) = I\,l\,B\sin\theta$$

$$= 8 \times 1 \times 0.15 \times \sin 30° = \frac{8 \times 0.15}{2} = 0.6 \text{ Nm}^{-1}$$

137. (*b*)



Here, the angle between the magnetic field and the direction of flow of current is 90°.

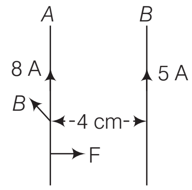
Given, $l = 3\text{ cm} = 3 \times 10^{-2}$m, $I = 10$ A, $B = 0.27$ T,

The magnitude of magnetic force on the wire,

$$F = IlB \sin 90° = 10 \times 3 \times 10^{-2} \times 0.27 \times \sin 90°$$

$$= 8.1 \times 10^{-2} \text{ N}$$

138. (*c*) Given, $I_1 = 8$ A, $I_2 = 5$ A and $r = 4\text{ cm} = 0.04$ m



Force per unit length on two parallel wire carrying-current

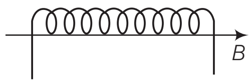
$$F = \frac{\mu_0}{4\pi} \cdot \frac{2I_1 \cdot I_2}{r} = \frac{10^{-7} \times 2 \times 8 \times 5}{0.04} = 2 \times 10^{-4} \text{ N}$$

The force on *A* of length 10 cm is $F' = F \times 0.1$

$(\because 1\text{m} = 100\text{ cm})$

$$\Rightarrow \quad F' = 2 \times 10^{-4} \times 0.1 = 2 \times 10^{-5} \text{ N}$$

139. (*a*)



$\therefore$ The total number of turns, $N = 400 \times 5 = 2000$

and number of turns/length, $n = \frac{2000}{0.8} = 2500$

The magnitude of magnetic field inside the solenoid

$$B = \mu_0 nI = 4 \times 3.14 \times 10^{-7} \times 2500 \times 8 = 2.5 \times 10^{-2}\ \text{T}$$

The direction of magnetic field is along the axis of solenoid.

140. (*b*) The magnitude of torque experienced by the coil,

$$\tau = NI\,AB \sin\theta$$
$$= 20 \times 12 \times (10 \times 10^{-2})^2 \times 0.80 \times \sin 30°$$
$$\tau = 2.4 \times 0.80 \sin 30° = \frac{2.4 \times 0.80}{2} = 0.96\ \text{Nm}$$

141. (*d*) Using the formula of voltage sensitivity,

$$V = \frac{NAB}{kR}$$

$$\therefore \frac{V_{s_2}}{V_{s_1}} = \frac{n_2 B_2 A_2 . k_1 R_1}{k_2 . R_2 . n_1 B_1 A_1} = \frac{42 \times 0.50 \times 1.8 \times 10^{-3} \times k \times 10}{k \times 14 \times 30 \times 0.25 \times 3.6 \times 10^{-3}}$$

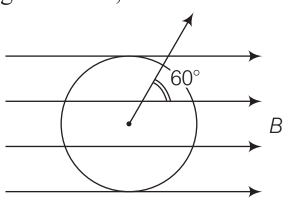
$= 1$

142. (*d*) $r = \frac{mv}{Bq}$ [Here, $\mathbf{F} = q(\mathbf{v} \times \mathbf{B}) = e(\mathbf{v} \times \mathbf{B}) = e\mathbf{V}B \sin 90°$]

$$evB \sin 90° = \frac{mv^2}{r}$$

$$\Rightarrow \quad r = \frac{mv}{eB \times 1} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \quad 10^{-4}}$$
$$= 4.2 \times 10^{-2}\ \text{m} = 4.2\ \text{cm}$$

143. (*c*) Magnitude of torque acting on the current-carrying coil due to the magnetic field,



$$\tau = nIAB \sin\theta$$
$$= 30 \times 6 \times \pi (0.08)^2 \times 1 \times \sin 60°$$
$$= 30 \times 6 \times 3.14 \times 0.08 \times 0.08 \times \frac{\sqrt{3}}{2} = 3.133\ \text{Nm}$$

144. (*d*) For given pitch, *d* corresponds to charged particle, we have

$$\frac{q}{m} = \frac{2\pi v \cos\theta}{qB} = \text{constant} \quad \Rightarrow \quad \left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$$

Note Consider *e* in place of *q* in solution.

145. (*a*) Magnetic field associated with moving charge

$$\mathbf{B} = \frac{\mu}{4\pi} q \frac{\mathbf{v} \times \mathbf{r}}{r^2}$$

So, $B \perp v$

147. (*d*) $F = qvB \sin\theta = 0$ as $\theta = 0$ or π

148. (*a*) The charged particle undergoes acceleration as

(i) speeds up between the dees because of the oscillating electric field and

(ii) speed remains the same inside the dees because of the magnetic field but direction undergoes change continuously.

149. (*d*) The rotation of the loop by 30° about an axis perpendicular to its plane make no change in the angle made by magnetic moment with the direction of magnetic field, therefore, the work done to rotate the loop is zero.

150. (*b*) If L is the magnitude of the angular momentum of the electron about the central nucleus (orbital angular momentum). Vectorially,

$$\mu_l = -\frac{e}{2m_e} L$$

where, μ_l is the magnetic moment.

The negative sign indicates that the angular momentum of the electron is opposite in direction of the magnetic moment.

151. (*b,d*) Magnetic forces on a wire carrying a steady current, I placed in a uniform magnetic field B, perpendicular to its length is given by

$$F = IlB$$

The direction of force is given by Fleming's left hand rule and F is perpendicular to the direction of magnetic field **B**. Therefore, work done by the magnetic force on the ions is zero.

152. (*b,c*) Applying the Ampere's circuital law, we have

$$\oint_c \mathbf{B} \cdot d\mathbf{l} = \mu_0 (I - I) = 0 \text{ (because current is in opposite sense.)}$$

Also, there may be a point on C where **B** and d**l** are perpendicular and hence, $\oint_c \mathbf{B} \cdot d\mathbf{l} = 0$

153. (*b,c,d*) The magnetic force $\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$ on charged particle is either zero or **F** is perpendicular to **v** (or component of **v**) which in turn revolves particles on circular path with uniform speed. In both the cases, particles have equal accelerations.

Both the particles gain or loss energy at the same rate as both are subjected to the same electric force ($\mathbf{F} = q\mathbf{E}$) in opposite direction.

Since, there is no change of the Centre of Mass (CM) of the particles , therefore the motion of the Centre of Mass (CM) is determined by **B** alone.

154. (*a,b,d*) Here, force on charged particle due to electric field $\mathbf{F}_E = q\mathbf{E}$.

Force on charged particle due to magnetic field,

$$\mathbf{F}_m = q(\mathbf{v} \times \mathbf{B})$$

Now, $F_E = 0$ if $E = 0$ and $F_m = 0$ if $\sin\theta = 0$ or $\theta° = 0°$ or $180°$

Hence, $B \neq 0$.

Also, $E = 0$ and $B = 0$ and the resultant force $q\mathbf{E} + q(\mathbf{v} \times \mathbf{B}) = 0$. In this case, $E \neq 0$ and $B \neq 0$.