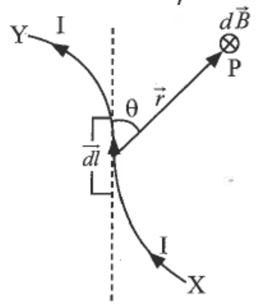
CHAPTER : 4

MOVING CHARGES AND MAGNETISM

STUDY NOTES

- **Oersted observation:** A compass needle suffers a deflection when it is placed near a wire carrying an electric current. When the direction of current is reversed, the direction of deflection of the needle also reverses. This conclusively proves that a current carrying conductor produces a magnetic field around it. This is called magnetic effect of current.
- **Biot-Savart law:** According to this law, the magnetic field due to a current carrying element $\vec{dl}$ carrying current I at a point P at distance r from it is given by

$$dB = \frac{\mu_o}{4\pi} \cdot \frac{I\, dl\, \sin\theta}{r^2}$$



In vector notation, $\vec{dB} = \frac{\mu_o I}{4\pi} \cdot \frac{\vec{dl} \times \vec{r}}{r^3}$

- **Magnetic field due to straight current carrying conductor.** The magnetic field at a point at perpendicular distance 'a' from a straight conductor carrying current I is given by

$B = \frac{\mu_o I}{4\pi a} (\sin \phi_1 + \sin \phi_2)$

Where ϕ_1 and ϕ_2 are the angles which the perpendicular from the observation point to the conductor makes with the lines joining the ends of the conductor to the observation point.
- The magnetic field due to a straight conductor of infinite length is given by

$$B = \frac{\mu_o I}{4\pi a}$$

- **Rules for finding the direction of magnetic field due to straight current carrying conductor.**
  (i) **Right hand thumb rule:** If we hold the straight conductor in the grip of our right hand in such a way that the extended thumb points in the direction of current, then the direction of curl of fingers will give the direction of the magnetic field.
  (ii) **Maxwell's cork screw rule:** If a right-handed screw be rotated along a wire so that it advances in the direction of current, then the direction in which the thumb rotates gives the direction of the magnetic field.
- **Magnetic field of a circular current loop:** The magnetic field of a circular current loop of radius a carrying current I is:
  (i) At the centre of the loop : $B = \frac{\mu_o I}{2a}$.
  (ii) At an axial point at distance r from the centre :

$$B = \frac{\mu_o I a^2}{2(r^2 + a^2)^{3/2}}$$

- **Rules for finding the direction of magnetic field due to circular current loop.**
  - (i) **Right hand thumb rule :** If we curl the fingers of our right hand around the circular wire with the fingers pointing in the direction of the current, then the extended thumb gives the direction of the magnetic field.
  - (ii) **Clock rule :** This rule gives the polarity of any face of the circular current loop. If the current round any face of the coil is in anticlockwise direction, it behaves like a north pole. If the current flows in the clockwise direction, it behaves like a south pole.
- **Ampere's circuital law:** The line integral of the magnetic field $\vec{B}$ around any closed path is equal to μ_0 times the total current I enclosed by the closed path.

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I$$

- **Magnetic field of a straight solenoid:** A solenoid is a long-insulated wire wound in the form of a helix. It has a large length as compared to its diameter. The magnetic field of a straight solenoid carrying current I and having n turns per unit length is given by
  - (i) $B = n\mu_0 I$ (at a point inside the solenoid)
  - (ii) $B = \frac{1}{2} n\mu_0 I$ (at a point at either ends)
- **Magnetic field of a toroidal solenoid:** A solenoid bent into the form of a closed ring is called a toroidal solenoid. The magnetic field inside the toroidal solenoid has a constant magnitude and tangential direction. It is given by

  $B = n\mu_0 I$

  Where I is the current in the windings and n is the number of turns per unit length. The field lines are concentric circles.
- **Force on a charge moving in a magnetic field:** A charge q moving with velocity $\vec{v}$ at an angle θ with the magnetic field $\vec{B}$ experiences the magnetic Lorentz force,

  $F = qvB\sin\theta$

  The direction of this force is perpendicular to both $\vec{v}$ and $\vec{B}$, and work done by it is zero.
- **Rules for finding the direction of force a charge moving perpendicular to a magnetic field.**
  - (i) **Fleming's left hand rule:** Stretch the thumb and the first two fingers of the left hand mutually perpendicular to each other. If the forefinger points in the direction of the magnetic field, central finger in the direction of current, then the thumb gives the direction of force on the charged particle.
  - (ii) **Right hand palm rule:** Open the right hand and place it so that tips of the fingers point in the direction of the field $\vec{B}$ and thumb in the direction of velocity $\vec{v}$ of positive charge, then the palm faces towards the force $\vec{F}$.
- **Lorentz force:** The total force, called Lorentz force, acting on a charge q moving with velocity $\vec{v}$ in an electric field $\vec{E}$ and magnetic field $\vec{B}$ is

  $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$
- **Motion of charge inside an electric field:** If a potential difference is applied between two parallel plates separated by distance d, then electric field set up between the plates is $E = V/d$

  The charge q of mass m experiences the electric force, $F_e = qE$

  Acceleration produced in the charge, $a = qE/m$

  The moving charge follows a parabolic path inside the electric field
- **Cyclotron:** It is a device used to accelerate charged particles like protons, deutrons, α-particles, etc. to very high energies. Here charged particles move along a spiral path under the action of a perpendicular magnetic field and gain energy as they cross an alternating electric field again and again.
- **Cyclotron frequency:** In a cyclotron, the frequency of the applied alternating electric field is equal to the frequency of revolution of the charged particle. This frequency is called cyclotron frequency.

It is given by,

$f_c = qB/2\pi m$

where m is the mass and q is the charge of the positive ion. The cyclotron frequency is independent of both the velocity of the particle and the radius of its orbit.

- **Maximum energy gained by positive ions:** If v_0 and r_0 are the maximum velocities and maximum radius of the circular path of the positive ions in a cyclotron then

$$\frac{mv_0^2}{r_0} = qv_0 B \quad or \quad v_0 = \frac{qBr_0}{m}$$

$\therefore$ Maximum kinetic energy $= \frac{1}{2}mv_0^2 = \frac{q^2B^2r_0^2}{2m}$

If V is the accelerating potential of the high frequency oscillator and the charged particle completes n revolutions before leaving the dees, then

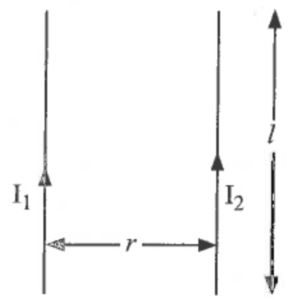
Maximum kinetic energy $= 2nqV$

- **Force on a current carrying conductor in a magnetic field:** A conductor of length l carrying current I held in a magnetic field $\vec{B}$ at an angle θ with it, experiences a force given by

$\vec{F} = \mathrm{I}\,(\vec{l} \times \vec{B})$

- **Force between two parallel infinitely long current carrying conductors:** The force per unit length between two long parallel conductors carrying currents I_1 and I_2, and separated by distance r is given by

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



The force is attractive when the currents are in the same direction and repulsive when the currents are in opposite directions.

- **SI unit of current is ampere.** One ampere is that strength of current which, when flowing in two parallel infinitely long conductors of negligible cross-section placed in vacuum at a distance of 1 m from each other, produces between them a force of 2×10^{-7} newton per metre length.
- **Torque on current carrying coil in a magnetic field:** A rectangular coil of area A, carrying current I and capable of rotation about an axis perpendicular to the field $\vec{B}$ experiences a torque,

$$\tau = NIBA \sin\theta = m\ B \sin\theta$$

where N = number of turns in the coil, $m = NIA$ = magnetic dipole moment, θ = angle which the normal to the plane of the coil makes with the field $\vec{B}$.

In vector rotation, $\vec{\tau} = \vec{m} \times \vec{B}$

Torque is minimum when the plane of the coil is perpendicular to the magnetic field (θ = 0°).
Torque is maximum when the plane of the coil is parallel to the magnetic field (θ = 90°).

$$\tau_{max} = NIBA$$

- **Moving coil galvanometer:** It is a device used to detect current in a circuit. It is based on the principle that a current carrying coil placed in a magnetic field experiences a torque, the magnitude of which depends on the strength of current. It consists of a coil of wire of area A and N turns carrying current I to be measured. It is suspended in a radial magnetic field so that its plane always remains parallel to $\vec{B}$ by a suspension fibre of torsion constant k. In equilibrium position,

  Restoring torque = Deflecting torque

  $$\text{or } k\,\alpha = NIBA \quad \text{or } \alpha = \frac{NBA}{k}.I$$

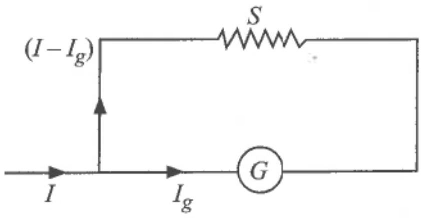
- **Current sensitivity of a galvanometer:** It is the deflection produced in a galvanometer when unit current flows through it.

  $$\text{Current sensitivity} = \frac{\alpha}{I} = NBA/k$$

- **Voltage sensitivity of a galvanometer:** It is the deflection produced in a galvanometer when unit potential difference is applied across in ends.

  $$\text{Voltage sensitivity} = \frac{\alpha}{V} = \frac{\alpha}{IR} = NBA/kR$$

- **Conversion of a Galvanometer into an Ammeter:** A galvanometer can be converted into an ammeter by connecting a low resistance into its parallel. If G is the resistance of a galvanometer and it gives full scale deflection for current I_g then required low resistance S, connected in its parallel for converting it into an ammeter of range I is given by



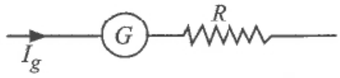
$$I_g \times G = (I - I_g) \times S$$

$$S = \left(\frac{I_g}{I - I_g}\right)G$$

The resistance in ideal ammeter is zero.

- **Conversion of a Galvanometer into a Voltmeter:** A galvanometer can be converted into a voltmeter by connecting a high resistance into its series. If a galvanometer of resistance G show full scale deflection for current I_g then required high resistance R, connected in series for converting it into a voltmeter of range V is given by

$$V = I_g\,(G + R) \Rightarrow R = \frac{V}{I_g} - G$$



QUESTION BANK

MULTIPLE CHOICE QUESTIONS

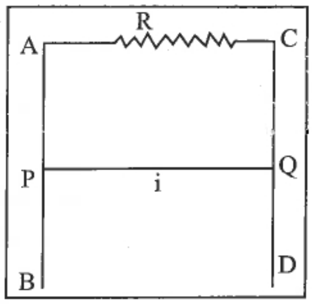
1. A proton has a velocity $\vec{v} = (3\hat{i} + 2\hat{j}) \times 10^6$ m/s and it experiences a force $\vec{F} = -(1.28 \times 10^{-3}\hat{k})$ N. When its velocity is along the z-axis, it experiences a force along the x-axis. What is the magnetic field?
   (a) $(-0.27\hat{j})$ T (b) $(-0.27\hat{j})$ G (c) $(0.27\hat{j})$T (d) $(-0.27\hat{i})$ T

2. A conductor of length l is placed perpendicular to a horizontal magnetic field B suddenly. Suddenly a certain amount of charges is passed through it, when it is found to jump to a height h. The amount of charge that passes through the conductor is

(a) $\frac{m\sqrt{gh}}{Bl}$ (b) $\frac{m\sqrt{2gh}}{Bl}$

(c) $\frac{m\sqrt{gh}}{2Bl}$ (d) none of these

3. A conductor PQ of length l and mass m can slide, without friction, but with an ideal electrical contact, along two vertical conductors AB and CD connected through a resistor R. A uniform magnetic field B is applied perpendicular to the plane of the paper. Terminal velocity is :



(a) $\frac{mg}{B^2l^2}R$ (b) $\frac{mg}{B^2l}R$

(c) $\frac{B^2l^2}{mg}R$ (d) insufficient data

4. An electron and a proton possessing equal moment are injected to a region at right angles to a uniform magnetic field. The ratio of their radii of curvature while moving inside the magnetic field is

(a) 1:1 (b) 1:4 (c) 4:1 (d) 1:2

5. A solid conducting sphere of radius R and total charge q rotates about its diametric axis with constant angular speed ω. The magnetic moment of the sphere is:

(a) $\frac{1}{3}qR^2\omega$ (b) $\frac{1}{5}qR^2\omega$ (c) $\frac{2}{3}qR^2\omega$ (d) $\frac{2}{5}qR^2\omega$

6. The magnetic field at a distance x on the axis of a circular coil of radius R is 1/64 th of that at the centre, the value of x is :

(a) $\frac{R}{\sqrt{15}}$ (b) $\frac{2R}{\sqrt{15}}$ (c) $R\sqrt{15}$ (d) $R\sqrt{3}$

7. A charged particle moving in a uniform magnetic field penetrates layer of lead and thereby loses one half of its kinetic energy. How does the radius of curvature of its path change?

(a) Directly as the square root of the kinetic energy of the particle

(b) Directly as the kinetic energy of the particle

(c) Inversely as the square root of the kinetic energy of the particle

(d) Inversely as the kinetic energy of the particle

8. A uniform electric field and a uniform magnetic field are acting along the same direction in a certain region. If an electron is projected along the direction of the fields with a certain velocity, then

(a) its velocity will decrease

(b) its velocity will increase

(c) it will turn towards right of direction of motion

(d) it will turn towards left of direction of motion.

9. A particle of mass M and charge Q moving with velocity v describes a circular path of radius R, when subjected to a uniform transverse magnetic field of induction B. The work done by the field, when the particle completes one full circle is

(a) $\left(\frac{Mv^2}{R}\right)\times 2\pi R$ (b) $BQ\ (2\pi R)$ (c) 0 (d) $BQv(2\pi R)$

10. A charged particle moves through a magnetic field perpendicular to its direction. Then

(a) kinetic energy changes but the momentum is constant

(b) the momentum changes but the kinetic energy is constant

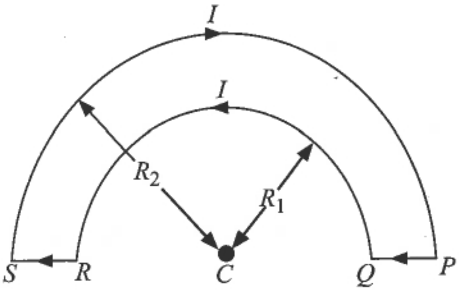
(c) both momentum and kinetic energy of the particle are not constant
(d) both momentum and kinetic energy of the particle are constant.

11. In a region, steady and uniform electric and magnetic fields are present. These two fields are parallel to each other. A charged particle is released in the region. The path of the particle will be
(a) ellipse (b) circle (c) helix (d) straight line.

12. Two particles X and Y having equal charges, after being accelerated through the same potential difference, enter a region of uniform magnetic field and describe circular paths of radii R_1 and R_2 respectively. What will be the ratio of their masses?
(a) $\left(\frac{R_2}{R_1}\right)^2$ (b) $\left(\frac{R_1}{R_2}\right)$ (c) $\left(\frac{R_1}{R_2}\right)^2$ (d) $\left(\frac{R_2}{R_1}\right)$

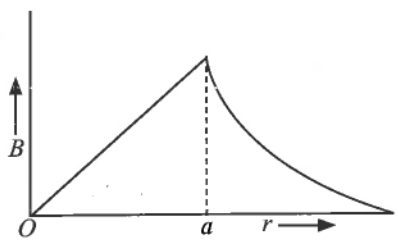
13. A wire of certain length is bent to form a circular coil of a single turn. If the same wire is bent into a coil of smaller radius so as to have two turns, then magnetic field produced at the centre by the same value of current is
(a) one quarter of its value in first case
(b) one half of its value in first case
(c) two times its value in first case
(d) four times its value in first case

14. The wire loop PQRSP formed by joining two semi-circular wires of radii R_1 and R_2 carries a current I as shown. The magnitude of the magnetic field at the centre C is



(a) $\frac{\mu_0 I}{2}\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$ (b) $\frac{\mu_0 I}{4}\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$ (c) $\frac{\mu_0 I}{2}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ (d) $\frac{\mu_0 I}{4}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

15. The magnetic field due to a straight conductor of uniform cross-section of radius a and carrying a steady current is represented by

(a)


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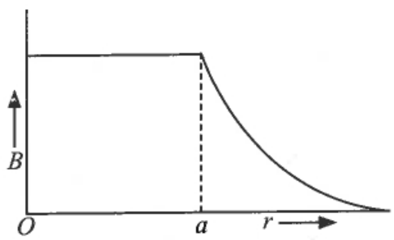

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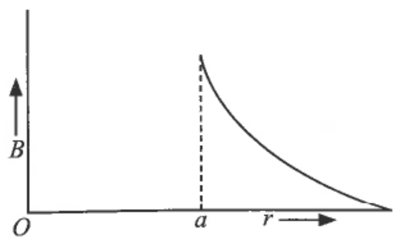

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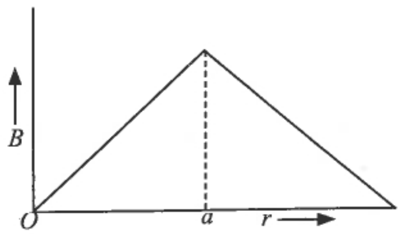


16. A long straight wire of radius r carries a steady current I. The current is uniformly distributed across its cross section. The ratio of the magnetic field at $r/2$ and $2r$ is

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

17. A galvanometer of resistance G can measure 1, A current. If a shunt S is used to convert it into an ammeter to measure 10 A current, the ratio of G and S is:

(a) $\frac{1}{9}$ (b) $\frac{9}{1}$ (c) 10 (d) $\frac{1}{10}$

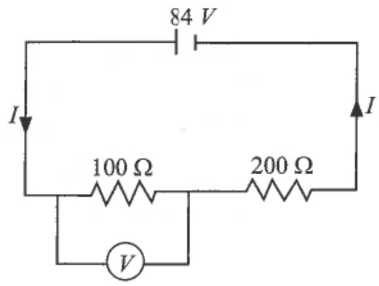
18. Magnetic field at the centre of a square of side 'a' carrying current I is:

(a) $2\sqrt{2}\frac{\mu_0 I}{\pi a}$ (b) $\frac{\mu_0 I}{\pi a}\frac{1}{2\sqrt{2}}$ (c) $\frac{\mu_0 I}{\pi a}\left(\frac{1}{2}+\frac{1}{\sqrt{2}}\right)$ (d) $\frac{\mu_0 I}{\pi a}\left(\frac{1}{2}-\frac{1}{\sqrt{2}}\right)$

19. Torque acting on a 40 turn coil of 100 cm^2 area carrying a current of 10 A held with its axis at right angles to a uniform magnetic field of 0.2 T is:

(a) 0.008 Nm (b) 0.8 Nm (c) 0.8 Nm^{-1} (d) 0.08 Nm^{-1}

20. In an electronics lab a student used a voltmeter V of resistance 400 Ω to measure the potential difference across a 100 Ω resistor in the circuit shown. What will be the reading on the voltmeter he/she will get?



(a) 24 V
(b) 26 V
(c) 42 V
(d) 2.4 V

21. A straight wire of length l carrying a current I stays suspended horizontally in mid air in a region where there is a uniform magnetic field $\vec{B}$. Magnitude of the magnetic field in terms of linear mass density λ is:

(a) $\frac{\lambda g}{I}$ (b) $\frac{\lambda g}{\sqrt{2}I}$ (c) $\frac{\sqrt{g}I}{2}$ (d) $\frac{\sqrt{2}gI}{\lambda}$

22. A proton, a deuteron and an α-particle having the same kinetic energy are moving in circular trajectories in a constant magnetic field. If r_p, r_d and r_α denote respectively the radii of the trajectories of these particles, then

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

23. 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) $\frac{qbB}{m}$ (b) $\frac{q(b-a)B}{m}$ (c) $\frac{qaB}{m}$ (d) $\frac{q(b+a)B}{2m}$

24. 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 degrees about an axis perpendicular to its plane is

(a) $\frac{MB}{2}$ (b) MB (c) zero (d) √3 MB

25. 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 helical path
(d) The electron will continue to move with uniform velocity along the axis of the solenoid.

26. A hollow cylindrical conductor of radii a and b carries a current I uniformly spread over its cross section. Prove that the magnetic field B for points inside the body of the conductor at a distance r from the axis of the cylinder is given by

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

27. If 2% of the main current is to the passed through the galvanometer of resistance G, the resistance of shunt required is

(a) $\frac{G}{49}$ (b) $\frac{G}{50}$ (c) 49 G (d) 50 G

28. 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

29. A current I ampere flows along an infinitely long straight thin walled tube, then the magnetic induction at any point inside the tube is

(a) infinite (b) zero (c) $\frac{\mu_0}{2\pi} \times \frac{2I}{r} T$ (d) $\frac{2I}{r} T$

30. A long wire carries a steady current. It is bent into a circle of one turn and the magnetic field at the centre of the coil is B. It is then bent into a circular loop of n turns .

The magnetic field at the centre of the coil is

(a) nB (b) $2nB$ (c) n^2B (d) $2n^2B$

31. A long solenoid has 200 turns per cm and carries a current I. The magnetic field at its centre is 6.28×10^{-2} Wb m^{-2}. Another long solenoid has 100 turns per cm and it carries a current $\frac{I}{3}$. The value of the magnetic field at its centre is

(a) 1.05×10^{-3} Wbm^{-2}

(b) 1.05×10^{-4} Wbm^{-2}

(c) 1.05×10^{-2} Wbm^{-2}

(d) 1.05×10^{-5} Wbm^{-2}

32. A current I flows along the length of an infinitely long, straight thin walled pipe. Then

(a) the magnetic field at all points inside the pipe is the same, but not zero

(b) the magnetic field is zero only on the axis of the pipe

(c) the magnetic field is different at different points inside the pipe

(d) the magnetic field at any point inside the pipe is zero

33. A long insulated copper wire is closely wound as a spiral of N turns. The spiral has inner radius a and outer radius b. The spiral lies in the X-Y plane and a steady current I flows through the wire. The Z-component of the magnetic field at the centre of the spiral is

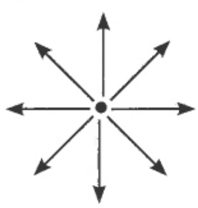
(a) $\frac{\mu_0 NI}{2(b-a)} ln\left(\frac{b}{a}\right)$

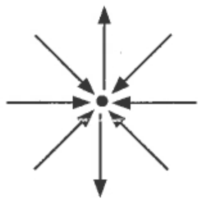
(b) $\frac{\mu_0 NI}{2(b-a)} ln\left(\frac{b+a}{b-a}\right)$

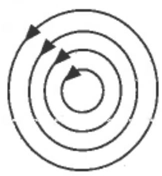
(c) $\frac{\mu_0 NI}{4b} ln\left(\frac{b}{a}\right)$

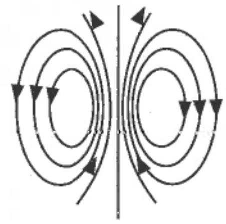
(d) $\frac{\mu_0 NI}{8b} ln\left(\frac{b+a}{b-a}\right)$

34. Which of the field patterns given below is valid for electric field as well as for magnetic field?

(a) 

(b) 

(c) 

(d) 

35. A coil in the shape of an equilateral triangle of side 'l' is suspended between the pole pieces of a permanent magnet such that overline $\vec{B}$ 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) $\frac{2}{\sqrt{3}}\left(\frac{\tau}{Bi}\right)$ (b) $2\left(\frac{\tau}{\sqrt{3}Bi}\right)^{\frac{1}{2}}$ (c) $\frac{2}{\sqrt{3}}\left(\frac{\tau}{Bi}\right)^{\frac{1}{2}}$ (d) $\frac{1}{\sqrt{3}}\left(\frac{\tau}{Bi}\right)$

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

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

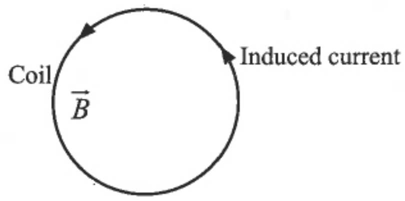
37. A charged particle of mass m and charge q travels on circular path of radius r that is perpendicular to a magnetic field B. The time taken by the particle to complete one revolution is:

(a) $\frac{2\pi q^2 B}{m}$ (b) $\frac{2\pi mq}{B}$ (c) $\frac{2\pi m}{qB}$ (d) $\frac{2\pi qB}{m}$

38. A proton moving with a velocity 3×10^5 m/s enters a magnetic field of 0.3 T at an angle of 30° with the field. The radius of curvature of its path will be

(a) 0.02 cm (b) 0.5 cm (c) 2 cm (d) 1.25 cm

39. A coil is placed in a magnetic field B as shown below:



(a) Outward and decreasing with time
(b) Parallel to the plane of coil and decreasing with time
(c) Outward and increasing with time
(d) Parallel to the plane of coil and increasing with time

40. A current of 1.5 A is flowing through a triangle of side 9 cm each. The magnetic field at the centroid of the triangle is :

(Assume that the current is flowing in the clockwise direction.)

(a) 3×10^{-7} T, outside the plane of triangle (b) $2\sqrt{3} \times 10^{-7}$ T, outside the plane of triangle
(c) $2\sqrt{3} \times 10^{-5}$ T, inside the plane of triangle (d) 3×10^{-5} T, inside the plane of triangle

41. A positively charged particle projected towards east is deflected towards north by a magnetic field. The field may be:

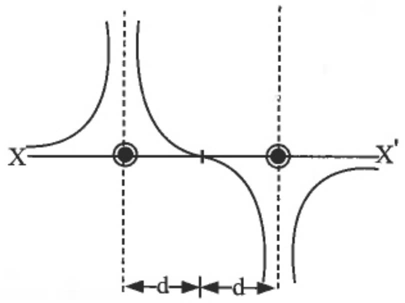
(a) towards west (b) towards south (c) upwards (d) downward

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

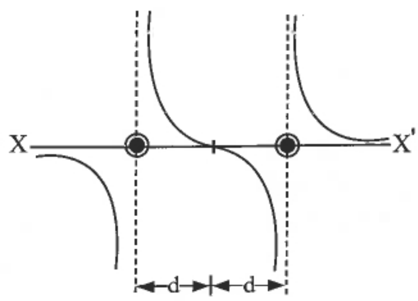
(a) 25 keV (b) 100 keV (c) 200 keV (d) 50 keV

43. A student placed two long parallel wires at a distance 2d apart. The wires carry steady equal currents flowing out of the plane of the paper as shown. He plotted the variation of the magnetic field B along the line XX'. Which one of the following graphs he will obtain?

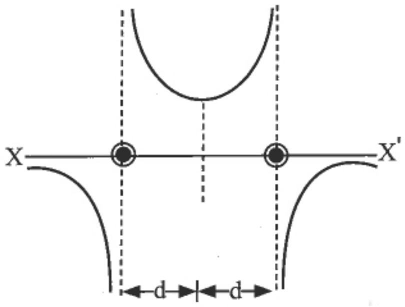
(a)



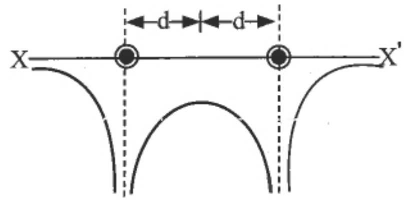
(b)



(c)



(d)



44. 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 to form a square of side 'a'. If B_A and B_B are the values of magnetic fields at the centres of the circle and square respectively, then the ratio B_A/B_B is :

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

45. Two ions of masses 4 amu and 16 amu have charges +2e and +3e respectively. These ions pass through the region of constant perpendicular magnetic field. The kinetic energy of both ions is same. Then:

(a) lighter ion will be deflected less than heavier ion

(b) lighter ion will be deflected more than heavier ion

(c) both ions will be deflected equally

(d) no ion will be deflected

46. A particle of charge q and mass m is moving with a velocity $-v\hat{i}$ $(v \neq 0)$ towards a large screen placed in the Y-Z plane at a distance d. If there is a magnetic field $\vec{B} = B_o\hat{k}$, the maximum value of v for which the particle will not hit the screen is:

(a) $\frac{2qdB_0}{m}$ (b) $\frac{2qdB_0}{3m}$ (c) $\frac{qdB_0}{2m}$ (d) $\frac{qdB_0}{m}$

47. Magnetic fields at two points on the axis of a circular coil at a distance of 0.05 m and 0.2 m from the centre are in the ratio 8: 1. The radius of coil is

(a) 0.15 m (b) 0.2 m (c) 1 m (d) 0. 1m

48. The ratio of magnetic field at the centre of a current carrying circular coil to its magnetic moment is x. If the current and radius both are doubled the new ratio will become:

(a) $2x$ (b) $4x$ (c) $x/4$ (d) $x/8$

49. A particle of specific charge (charge/mass) α starts moving from the origin under the action of an electric field $\vec{E} = E_0\hat{i}$ and magnetic field $\vec{B} = B_0\hat{k}$. Its velocity at $(x_0, 0, 0)$ is $(4\hat{i} + 3\hat{j})$. The value of x_0 is:

(a) $\frac{13}{2}\frac{\alpha E_0}{B_0}$ (b) $\frac{16\alpha B_0}{E_0}$ (c) $\frac{25}{2\alpha E_0}$ (d) $\frac{5}{\alpha B_0}$

50. A magnetic needle is kept in a non-uniform magnetic field. It experiences a

(a) a force and a torque (b) a force but not a torque

(c) a torque but not a force (d) neither a force nor a torque

51. Magnetic moment of an electron in nth orbit of hydrogen atom is

(a) $\frac{neh}{\pi m}$ (b) $\frac{neh}{4\pi m}$ (c) $\frac{meh}{2\pi m}$ (d) $\frac{meh}{4\pi m}$

52. A large metal sheet carries an electric current along its surface. Current per unit length is λ. Magnetic field near the metal sheet is:

(a) $\frac{\mu_0\lambda}{2}$ (b) $\mu_0\lambda$ (c) $\frac{\mu_0\lambda}{2\pi}$ (d) $\frac{\mu_0}{2\lambda\pi}$

53. A rigid circular loop of radius r and mass m lies in the x-y plane on a flat table and has a current i flowing in it. At this particular place, the earth's magnetic field is $\vec{B} = B_x\hat{i} + B_z\hat{k}$ The value of i so that one edge of the loop lifts from the table is:

(a) $\dfrac{mg}{\pi r\sqrt{B_x^2 + B_z^2}}$ (b) $\dfrac{mg}{\pi r B_z}$ (c) $\dfrac{mg}{\pi r B_x}$ (d) $\dfrac{mg}{\pi r\sqrt{B_x B_z}}$

54. Deuteron in a cyclotron describes a circle of radius 32 cm just before emerging from the cyclotron. The frequency of the applied alternating voltage is 10 MHz. Then the magnetic field is:

(a) 1 T (b) 1.25 T (c) 0.5 T (d) 1.30 T

55. A particle of mass m and charge Q moving with a velocity v enters a region of uniform magnetic field of induction B. Then its path in the region is

(a) always circular (b) circular if $v.B = 0$
(c) circular if $v \times B = 0$ (d) none of these.

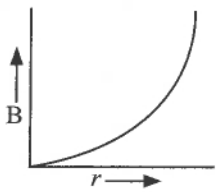
56. The magnitude of the magnetic field at the centre of an equilateral triangular loop of side 1 m which is carrying a current of 10 A is :
Take $\mu_0 = 4\pi \times 10^{-7}$ NA^{-2}

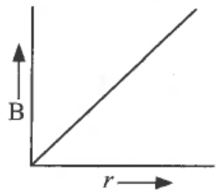
(a) 3 μT (b) 18 μT (c) 9 μT (d) 1μT

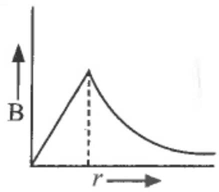
57. A square loop is carrying a steady current I and the magnitude of its magnetic dipole moment is m. If this square loop is changed to a circular loop and it carries the same current, the magnitude of the magnetic dipole moment of circular loop will be:

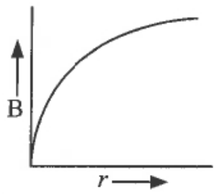
(a) $\dfrac{m}{\pi}$ (b) $\dfrac{3m}{\pi}$ (c) $\dfrac{2m}{\pi}$ (d) $\dfrac{4m}{\pi}$

58. A thick current carrying cable of radius R carries current I uniformly distributed across its cross-section. The variation of magnetic field B due to the cable with the distance r from the axis of the cable is represented by

(a)


(b)


(c)


(d)


59. A long solenoid of 50 cm length having 100 turns carries a current of 2.5 A. The magnetic field at the centre of solenoid is
Take $\mu_o = 4\pi \times 10^{-7}$ NA^{-2}

(a) 3.14×10^{-4} (b) 6.28×10^{-5} (c) 3.14×10^{-5} (d) 6.28×10^{-4}

60. Two similar coils of radius R are lying concentrically with their planes at right angles to each other. The currents flowing in them are I and 2I, respectively. The resultant magnetic field induction at the centre will be

(a) $\dfrac{\sqrt{5}\mu_o I}{2R}$ (b) $\dfrac{3\mu_o I}{2R}$ (c) $\dfrac{\mu_o I}{2R}$ (d) $\dfrac{\mu_o I}{R}$

61. If a long hollow copper pipe carries a current, then magnetic field is produced

(a) inside the pipe only (b) outside the pipe only
(c) both inside and outside the pipe (d) no where

62. A particle of mass m, charge q and kinetic energy T enters a transverse uniform magnetic field of induction B. After 3 s, the kinetic energy of the particle will be

(a) 3 T (b) 2 T (c) 4 T (d) T

63. To convert a galvanometer to ammeter, a shunt S is to be connected with the galvanometer G. The effective resistance of the ammeter then is

(a) $GS/(G + S)$ (b) $G + S$ (c) $(G + S)/GS$ (d) None of these

64. A galvanometer can be converted into a voltmeter by connecting a

(a) high resistance in series. (b) high resistance in parallel.
(c) low resistance in parallel. (d) low resistance in series.

65. The deflecting torque acting on the coil of a galvanometer is
(a) inversely proportional to number of turns.
(b) inversely proportional to current flowing.
(c) inversely proportional to area of the coil.
(d) directly proportional to the magnetic field strength.

66. A rectangular coil (Dimension 5 cm × 2.5 cm) with 100 turns, carrying a current of 3 A in the clock-wise direction, is kept centered at the origin and in the X-Z plane. A magnetic field of 1 T is applied along X-axis. If the coil is tilted through 45° about Z-axis, then the torque on the coil is:
(a) 0.38 Nm (b) 0.55 Nm (c) 0.42 Nm (d) 0.27 Nm

67. A conducting rod of mass m and length l is placed over a smooth horizontal surface. A uniform magnetic field B is acting perpendicular to the rod. Charge q is suddenly passed through the rod and it acquires an initial velocity v on the surface, then q is equal to :
(a) $\frac{2mv}{Bl}$ (b) $\frac{Bl}{2mv}$ (c) $\frac{mv}{Bl}$ (d) $\frac{Blv}{2m}$

68. Two parallel wires carrying equal currents in opposite directions are placed at $x = \pm a$ parallel to y-axis with $z = 0$. Magnetic field at origin O is B_1 and at P (2a, 0, 0) is B_2. Then the ratio B_1/B_2 is :
(a) -3 (b) $\frac{-1}{2}$ (c) $\frac{-1}{3}$ (d) 2

69. A conducting rod of length l and mass m is moving down a smooth inclined plane of inclination θ with constant velocity v. A current i is flowing in the conductor in a direction perpendicular to paper inwards. A vertically upward magnetic field $\vec{B}$ exists in space. Then magnitude of magnetic field $\vec{B}$ is:
(a) $\frac{mg}{il}\sin\theta$ (b) $\frac{mg}{il}\cos\theta$ (c) $\frac{mg}{il}\tan\theta$ (d) $\frac{mg}{il\sin\theta}$

70. Which of the following represents dimensions of $\frac{B^2R^2C^2}{2\mu_0}$
(a) ML^{-1} (b) MLT^{-1} (c) ML^2T^{-2} (d) MLT^2

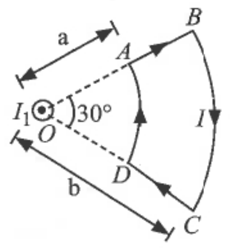
71. A charge q moves with a velocity 2m/s along X-axis in a uniform magnetic field $\vec{B} = (\hat{i} + 2\hat{j} + 3\hat{k})$ tesla.
(a) Charge will experience a force in z – y plane
(b) Charge will experience a force along – y axis
(c) Charge will experience a force along – z axis
(d) Charge will experience a force along – z axis

72. If a current is passed through a spring, then the spring will
(a) expand (b) remain same (c) compress (d) none of these

73. If an ammeter is to be used in place of voltmeter, then we must connect with the ammeter
(a) a low resistance in parallel
(b) a high resistance in parallel
(c) a high resistance in series
(d) a low resistance in series.

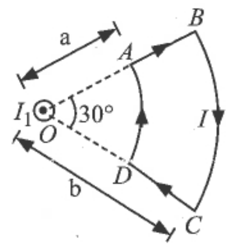
74. A current I flows in an infinitely long wire with cross-section in the form of a semicircular ring of radius R. The magnitude of the magnetic induction along its axis is
(a) $\frac{\mu_0 I}{\pi^2 R}$ (b) $\frac{\mu_0 I}{2\pi^2 R}$ (c) $\frac{\mu_0 I}{2\pi R}$ (d) $\frac{\mu_0 I}{8\pi R}$

75. A current loop was arranged in a manner as shown in figure below. The magnitude of the magnetic field (loop ABCD at the origin O) is



(a) zero
(b) $\frac{\mu_0 I(b-a)}{24ab}$
(c) $\frac{\mu_0 I}{4\pi}\left[\frac{b-a}{ab}\right]$
(d) $\frac{\mu_0 I}{4\pi}\left[2(b-a)+\frac{\pi}{3}(a+b)\right]$

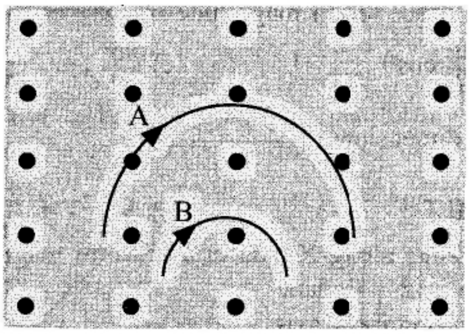
76. Due to the presence of the current I_1 at the origin



(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 $\frac{\mu_0 I_1}{4\pi}\left[2(b-a)+\frac{\pi}{3}(a+b)\right]$
(d) The magnitude of the net force on the loop is given by $\frac{\mu_0 I I_1}{24ab}(b-a)$

77. A positive charge q is distributed over a circular ring of radius a. It is placed in a horizontal plane and is rotated about its axis at a uniform angular speed ω. A horizontal magnetic field B exists in the space. The torque acting on the ring due to magnetic force is
(a) $\frac{1}{2}q\omega a^2 B$ (b) $\frac{1}{2}q\omega aB$ (c) $\frac{1}{2}q\omega^2 aB$ (d) $q\omega^2 aB$

78. Two particles A and B of masses m_A and m_B respectively and having the same charge are moving in a plane. A uniform magnetic field exists perpendicular to this plane. The speeds of the particles are v_A and v_B respectively and the trajectories are as shown in the figure. Then



(a) $m_A v_A < m_B v_B$ (b) $m_A v_A > m_B v_B$
(c) $m_A < m_B$, and $v_A < v_B$ (d) $m_A = m_B$ and $v_A = v_B$

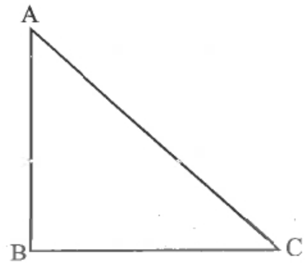
79. Two long conductors, separated by a distance d carry currents I_1 and I_2 in the same direction. They exert a force F on each other. Now the current in one of them is increased to two times and its direction is reversed. The distance is also increased to 3d. The new value of force between them is
(a) –2F (b) F/3 (c) –2F/3 (d) –F/3

80. Mixed He^+ and O^{2+} ions (mass of He^+ = 4 amu and that of O^{2+} = 16 amu) beam passes a region of constant perpendicular magnetic field. If kinetic energy of all the ions is same, then
(a) He^+ ions will be deflected more than those of O^{2+}
(b) He^+ ions will be deflected less than those of O^{2+}
(c) all the ions will be deflected equally
(d) no ions will be deflected

81. An electron is moving in a region of electric field and magnetic field, it will gain energy from
(a) electric field (b) magnetic field (c) both of these (d) none of these.

82. When deuterium and helium are subjected to an accelerating field simultaneously, then
(a) both acquire same energy
(b) deuterium accelerates faster
(c) helium accelerates faster
(d) neither of them is accelerated

83. A current carrying closed loop in the form of a right angle isosceles triangle ABC is placed in a uniform magnetic field acting along AB. If the magnetic force on the arm BC is F, the force on the arm AC is



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

84. An electron is projected along the axis of a circular conductor carrying some current. Electron will experience force

(a) along the axis.
(b) perpendicular to the axis.
(c) at an angle of 4° with axis
(d) no force experienced

85. An electron enters into a magnetic field at an angle of 60°, its path will be

(a) straight line (b) circle (c) parabola (d) helix

86. An electron moves in a circular path of radius 15 cm in a magnetic field of 4 gauss. What is the velocity of electron in this field?

(a) 1.07×10^7 m/s (b) 1.07×10^5 m/s (c) 1.07 m/s (d) 1.07×10^9 m/s

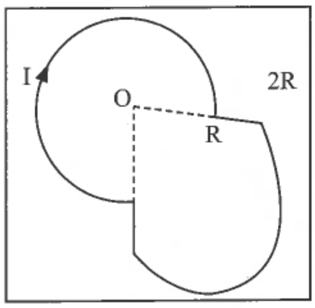
87. A beam of ions enters normally into a uniform magnetic field of 4×10^{-2} tesla with velocity of 2×10^5 m/s. If the specific charge of the ion is 5×10^7 C/kg, then the radius of the circular path described will be

(a) 0.10 m (b) 0.06 m (c) 0.20 m (d) 0.25 m

88. A galvanometer of resistance 25 Ω is shunted by a 2.5 Ω wire. The part of total current that flows through the galvanometer is given as

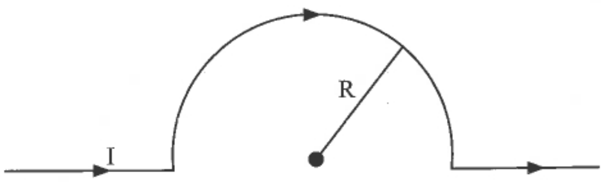
(a) $\frac{I}{I_0} = \frac{1}{11}$ (b) $\frac{I}{I_0} = \frac{2}{11}$ (c) $\frac{I}{I_0} = \frac{3}{11}$ (d) $\frac{I}{I_0} = \frac{4}{11}$

89. A current I is flowing through the loop as shown in figure. The magnetic field at centre O is



(a) $\frac{7\mu_0 I}{16R}$ (b) $\frac{7\mu_0 I}{16\pi R}$ (c) $\frac{5\mu_0 I}{16R}$ (d) $\frac{5\mu_0 I}{16\pi R}$

90. What is the magnetic field at the centre O?



(a) $\frac{\mu_0 I}{4\pi R}$ (b) $\frac{\mu_0 I}{4R}$ (c) $\frac{\mu_0 I}{4\pi R}(2\pi + 1)$ (d) $\frac{\mu_0 I}{2R}$

91. Electron is moving perpendicular to z-axis; the magnetic field B, is present along the z-axis; the radius of circular path is a. Angular momentum is given by:

(a) eB_0a^2 (b) 0 (c) $e^2B_0^2a^2$ (d) eB_0a

92. Electron beam is allowed to pass normally through mutually perpendicular magnetic and electric fields. If magnetic field induction and electric field strength are 0.0004 Wb/m^2 and 3000 V/m respectively and beam suffers no deflection, then velocity of electron is

(a) 7.5×10^6 m/s (b) 7.5×10^2 m/s (c) 7.5×10^4 m/s (d) 1.2×10^6 m/s.

93. An α-particle crosses a space without any deflection. If electric field $E = 8 \times 10^6$ V/m and magnetic particle is field B = 1.6 T, the velocity of particle is

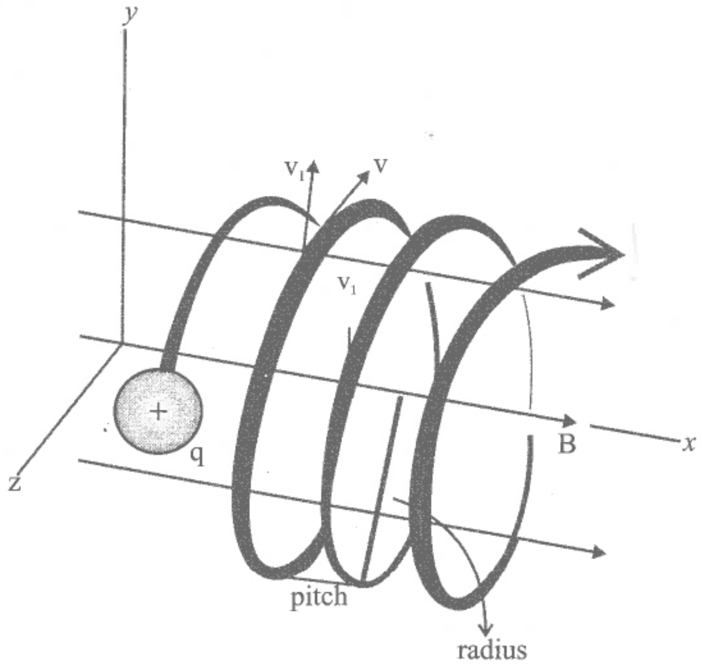
(a) 2.5×10^6 m/s (b) 5×10^6 m/s (c) 8×10^6 m/s (d) 5×10^6 m/s

94. What is the magnitude of magnetic force per until length of a wire carrying a current of 5 A and making an angle of 30° with direction of a uniform magnetic field of 0.1 T?

(a) 0.25 Nm (b) 0.45 Nm (c) 0.35 Nm (d) 0.55 Nm.

INPUT TEXT BASED MCQs

1. *We shall consider motion of a charged particle in a uniform magnetic field. First consider the case of v perpendicular to B. The perpendicular force, q v × B, acts as a centripetal force and produces a circular motion perpendicular to the magnetic field. The particle will describe a circle if v and B are perpendicular to each other. If velocity has a 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 as shown in figure below.*



(i) The radius of the charge particle, (when v is perpendicular to B) placed in a uniform magnetic field is given by

(a) $R = mv/qB$ (b) $R = qB/mv$ (c) $R = Bqm/v$ (d) $R = vq/mB$

(ii) An electron, proton, He^+ and Li^{++} are projected with the same velocity perpendicular to a uniform magnetic field. Which one will experience maximum magnetic force?

(a) Electron (b) Proton (c) He^+ (d) Li^{++}

(iii) Two charged particles A and B having the same charge, mass and speed enter into a magnetic field in such a way that the initial path of A makes an angle of 30° and that of B makes an angle of 90° with the field. Then the trajectory of

(a) B will have smaller radius of curvature than that of A

(b) both will have the same curvature

(c) A will have smaller radius of curvature than that of B

(d) both will move along the direction of their original velocities.

(iv) What will be the frequency of the particle?

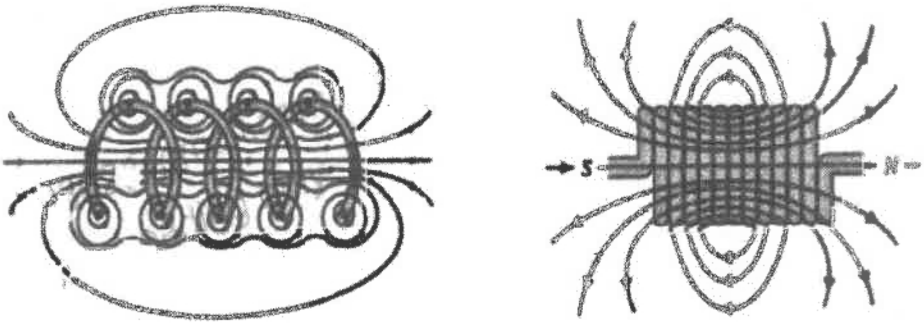
(a) m / qB (b) $qB/2\pi m$ (c) $2\pi R/ v \cos\theta$ (d) $2\pi R/ v \sin\theta$

(v) The magnetic field in a certain region of space is given by $B = 8.35\times10^{-2}\hat{i}$ T. A proton is shot into the field with velocity $\vec{v} = (2\times10^5\hat{i} + 4\ 10^5\hat{j})$ m/s. The proton follows a helical path in the field. The distance moved by proton in the *x*-direction during the period of one revolution in the *yz*-plane will be

(Mass of proton $=1.67\times10^{-27}$ kg)

(a) 0.053 m (b) 0.136 m (c) 0.157 m (d) 0.236 m

2. *We shall discuss a long solenoid. By long solenoid we mean that the solenoid's length is large compared to its radius. It consists of a long wire wound in the form of a helix where the neighbouring turns are closely spaced. So each turn can be regarded as a circular loop. The net magnetic field is the vector sum of the fields due to all the turns. Enamelled wires are used for winding so that turns are insulated from each other. Figure below shows the magnetic field lines of a solenoid carrying a steady current I. We see that if the turns are closely spaced, the resulting magnetic field inside the solenoid becomes fairly uniform, provided that the length of the solenoid is much greater than its diameter. For an "ideal" solenoid, which is infinitely long with turns tightly packed, the magnetic field inside the solenoid is uniform and parallel to the axis, and vanishes outside the solenoid.*



(i) A long solenoid has 800 turns per metre length of solenoid. A current of 1.6 A flows through it. The magnetic induction at the end of the solenoid on its axis is

(a) 16×10^{-4} T (b) 8×10^{-4} T (c) 32×10^{-4} T (d) 4×10^{-4} T

(ii) The magnetic field (B) inside a long solenoid having n turns per unit length and carrying current I when iron core is kept in it is (μ_0 = permeability of vacuum, 1 = magnetic susceptibility)

(a) $\mu_0 n I(1 - \chi)$ (b) $\mu_0 n I\chi$ (c) $\mu_0 n I^2(1 + \chi)$ (d) $\mu_0\ nI(1 + \chi)$

(iii) Choose the correct statement in the following.

(a) The magnetic field inside the solenoid is less than that of outside.

(b) The magnetic field inside an ideal solenoid is not at all uniform.

(c) The magnetic field at the centre, inside an ideal solenoid is atmost twice that the ends.

(d) The magnetic field at the centre, inside an ideal solenoid is almost half of that at the ends.

(iv) A solenoid of length l and having n turns carries a current I is in the anticlockwise direction. The magnetic field is

(a) $\mu_0 nI$ (b) $\mu_0 \frac{nI}{l^2}$

(c) along the axis of solenoid (d) perpendicular to the axis of coil

(v) The magnitude of the magnetic field inside a long solenoid is increased by

(a) decreasing its radius (b) decreasing the current through it

(c) increasing its area of cross-section (d) introducing a medium of higher permeability

3. Two current-carrying conductors placed near each other will exert magnetic forces on each other. Ampere studied the nature of this magnetic force and its dependence on the product of magnitude of currents in both the conductors, on the shape and size of conductors as well as the distances between the conductors. Using Fleming's left hand rule, it is observed that currents flowing in the same direction attract each other and currents flowing in the opposite directions repel each other. Thus, force per unit length acting on a conductor of infinite length is given by

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

(i) A vertical wire carries a current in upward direction. An electron beam sent horizontally towards the wire will be deflected

(a) towards right (b) towards left (c) upwards (d) downwards

(ii) A current carrying, straight wire is kept along axis of a circular loop carrying a current. The straight wire

(a) will exert an inward force on the circular loop. (b) will exert an outward force on the circular loop.

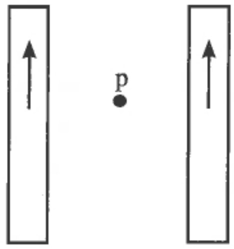
(c) will not exert any force on the circular loop. (d) will exert a force on the circular loop parallel to itself.

(iii) A proton beam is going from north to south and electron beam is going from south to north. Neglecting the earth's magnetic field, the electron beam will be deflected

(a) towards the proton beam (b) away from the proton beam

(c) upwards (d) downwards

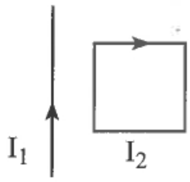
(iv) Two long sttraight wire are set parallel to each other. Each carries a current i in the same direction and the separation between them is $2r$. The intensity of the magnetic field midway between them is



(a) $\mu_0 i/r$ (b) $4\mu_0 i/r$

(c) zero (d) $\mu_0 i/4r$

(v) Consider the situation shown in figure. The straight wire is fixed but the loop can move under magnetic force. The loop will



(a) remain stationary (b) move towards the wire

(c) move away from the wire (d) rotate about the wire.

ANSWERS

1. (a)	**2.** (b)	**3.** (a)	**4.** (a)	**5.** (b)	**6.** (c)	**7.** (a)	**8.** (a)	**9.** (c)	**10.** (b)
11. (d)	**12.** (c)	**13.** (d)	**14.** (d)	**15.** (a)	**16.** (b)	**17.** (b)	**18.** (a)	**19.** (b)	**20.** (a)
21. (a)	**22.** (a)	**23.** (b)	**24.** (b)	**25.** (d)	**26.** (a)	**27.** (a)	**28.** (a)	**29.** (b)	**30.** (c)
31. (c)	**32.** (c)	**33.** (a)	**34.** (c)	**35.** (b)	**36.** (d)	**37.** (c)	**38.** (b)	**39.** (a)	**40.** (d)
41. (d)	**42.** (b)	**43.** (b)	**44.** (b)	**45.** (a)	**46.** (d)	**47.** (d)	**48.** (d)	**49.** (c)	**50.** (a)
51. (b)	**52.** (a)	**53.** (c)	**54.** (d)	**55.** (c)	**56.** (a)	**57.** (d)	**58.** (c)	**59.** (d)	**60.** (a)
61. (b)	**62.** (d)	**63.** (a)	**64.** (a)	**65.** (d)	**66.** (d)	**67.** (c)	**68.** (a)	**69.** (c)	**70.** (a)
71. (a)	**72.** (c)	**73.** (c)	**74.** (a)	**75.** (b)	**76.** (b)	**77.** (a)	**78.** (b)	**79.** (c)	**80.** (c)
81. (a)	**82.** (d)	**83.** (b)	**84.** (d)	**85.** (d)	**86.** (a)	**87.** (a)	**88.** (a)	**89.** (a)	**90.** (b)
91. (a)	**92.** (a)	**93.** (b)	**94.** (a)						

Input Text Based MCQs

1. (i) (a), (ii) (d), (iii) (a), (iv) (b), (v) (c) **2.** (i) (b), (ii) (d), (iii) (c), (iv) (c), (v) (d)

3. (i) (c), (ii) (c), (iii) (a), (iv) (c), (v) (b)