

EXERCISE

EXERCISE (S-1)

HCV Worked out Examples(Chapter No. 35 - Q. No. 1,2,3,4,5,6,7,8,9,10)

- Two long, straight wires, each carrying a current of 10 A, are placed along the X- and Y-axes respectively. The currents point along the positive directions of the axes. Find the magnetic field at the points
(a) (1 m, 2 m), (b) (-1 m, 2 m), (c) (-1 m, -2 m) and (d) (1 m, -2 m).
- A circular loop of radius 4.0 cm is placed in a horizontal plane and carries an electric current of 5.0 A in the clockwise direction as seen from above. Find the magnetic field
(a) At a point 3.0 cm above the centre of the loop.
(b) At a point 3.0 cm below the centre of the loop.
- Two concentric circular coils X and Y of radii 16 cm and 10 cm, respectively, lie in the same vertical plane containing the north to south direction. Coil X has 20 turns and carries a current of 16A; coil Y has 25 turns and carries a current of 18 A. The sense of the current in X is anticlockwise, and clockwise in Y, for an observer looking at the coils facing west. Give the magnitude and direction of the net magnetic field due to the coils at their centre. **[NCERT]**
- For a circular coil of radius R and N turns carrying current I, the magnitude of the magnetic field at a point on its axis at a distance x from its centre is given by,

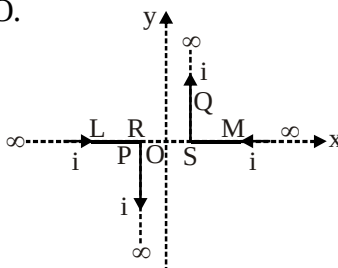
$$B = \frac{\mu_0 I R^2 N}{2(x^2 + R^2)^{3/2}}$$

- Show that this reduces to the familiar result for field at the centre of the coil.
- Consider two parallel co-axial circular coils of equal radius R, and number of turns N, carrying equal currents in the same direction, and separated by a distance R. How that the field on the axis around the mid-point between the coils is uniform over a distance that is small as compared to R, and is given

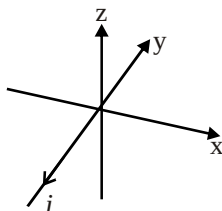
$$\text{by, } B = 0.72 \frac{\mu_0 N I}{R}, \text{ approximately.}$$

[Such an arrangement to produce a nearly uniform magnetic field over a small region is known as Helmholtz coils] **[NCERT]**

- A current element $\Delta \ell = \Delta x \hat{i} - \Delta y \hat{j}$ carries 10A current. It is placed at origin. Calculate magnetic field at point 'P' which is at position vector $\vec{r} = (\hat{i} + \hat{j})m$ with respect to origin. (where $\Delta x = \Delta y = 1mm$)
- A circular loop of radius r carries a current i. How should a long, straight wire carrying a current 4i be placed in the plane of the circle so that the magnetic field at the centre becomes zero ?
- A pair of stationary and infinitely long bent wires are placed in the x-y plane as shown in figure. The wires carry currents of $i = 10A$ each as shown. The segments L and M are along the x-axis. The segment P and Q are parallel to the y-axis such that $OS = OR = 0.02 m$. Find the magnitude and direction of the magnetic induction at the origin O.



8. A long straight wire carries a current of 10 A directed along the negative y-axis as shown in figure. A uniform magnetic field B_0 of magnitude 10^{-6} T is directed parallel to the x-axis. What is the resultant magnetic field at the following points?

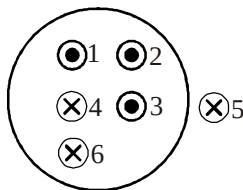


- (a) $x = 0$, $z = 2$ m ; (b) $x = 2$ m, $z = 0$; (c) $x = 0$, $z = -0.5$ m
9. Two circular coils A and B of radius $\frac{5}{\sqrt{2}}$ cm and 5 cm respectively carry current 5 Amp and $\frac{5}{\sqrt{2}}$ Amp respectively. The plane of B is perpendicular to plane of A and their centres coincide. Find the magnetic field at the centre.

HCV Exercises (Chapter No. 35 - Q. No. 2 to 25, 32 to 37, 41 to 46)

HCV Worked out Examples(Chapter No. 35 - Q. No. 11, 12, 13, 14)

10. Six wires of current $I_1 = 1$ A, $I_2 = 2$ A, $I_3 = 3$ A, $I_4 = 1$ A, $I_5 = 5$ A and $I_6 = 4$ A cut the page perpendicularly at the points 1, 2, 3, 4, 5 and 6 respectively as shown in the figure. Find the value of the integral $\oint \vec{B} \cdot d\vec{l}$ around the closed path.



11. A thin but long, hollow, cylindrical tube of radius r carries a current i along its length. Find the magnitude of the magnetic field at a distance $r/3$ from the surface
(a) Inside the tube (b) Outside the tube.
12. A long, cylindrical tube of inner and outer radii a and b carries a current with uniform current density j over its cross-section. Find the magnitude of the magnetic field at a point
(a) Just inside the tube (b) Just outside the tube
13. A toroid has a core (non-ferromagnetic) of inner radius 25 cm and outer radius 26 cm, around which 3500 turns of a wire are wound. If the current in the wire is 11 A, what is the magnetic field
(a) outside the toroid, (b) inside the core of the toroid, and
(c) in the empty space surrounded by the toroid. [NCERT]
14. A magnetic field of 100 G ($1\text{G} = 10^{-4}$ T) is required which is uniform in a region of linear dimension about 10 cm and area of cross-section about 10^{-3} m². The maximum current carrying capacity of a given coil of wire is 15 A and the number of turns per unit length that can be wound round a core is at most 1000 turns m⁻¹. Suggest some appropriate design particular of a solenoid for the required purpose. Assume the core is not ferromagnetic. [NCERT]

HCV Exercises (Chapter No. 35 - Q No.47 to 61)

HCV Worked out Examples(Chapter No. 34 - Q. No. 1,4,5,6,7,8,11)

HCV Worked out Examples(Chapter No. 35 - Q. No. 15)

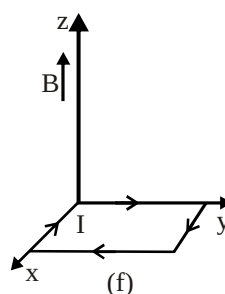
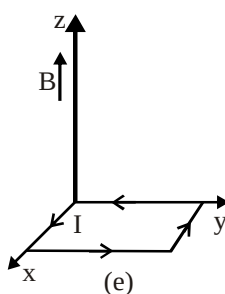
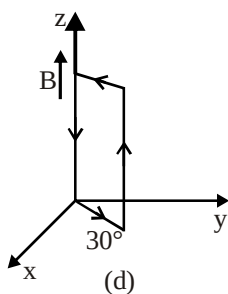
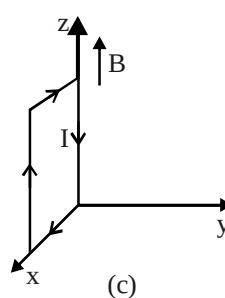
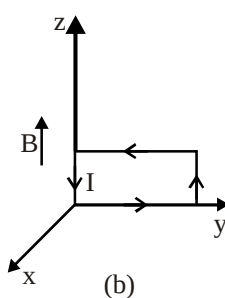
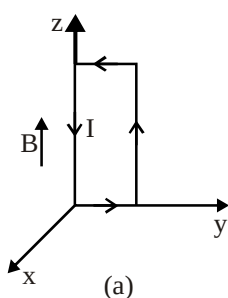
15. A charged particle (charge q , mass m) has velocity v_0 at origin in $+x$ direction. In space there is a uniform magnetic field B in $-z$ direction. Find the y coordinate of particle when it crosses y axis.
16. A beam of protons with a velocity 4×10^5 m/s enters a uniform magnetic field of 0.3 T at an angle of 60° to the magnetic field. Find the radius of the helical path taken by the proton beam. Also find the pitch of the helix (which is the distance travelled by a proton in the beam parallel to the magnetic field during one period of rotation).
17. An electron emitted by a heated cathode and accelerated through a potential difference of 2.0 kV, enters a region with uniform magnetic field of 0.15 T. Determine the trajectory of the electron if the field (a) is transverse to its initial velocity, (b) makes an angle of 30° with the initial velocity. [NCERT]
18. In a chamber, a uniform magnetic field of 6.5 G ($1 \text{ G} = 10^{-4} \text{ T}$) is maintained. An electron is shot into the field with a speed of $4.8 \times 10^6 \text{ m s}^{-1}$ normal to the field. Explain why the path of the electron is a circle. Determine the radius of the circular orbit. ($e = 1.6 \times 10^{-19} \text{ C}$, $m_e = 9.1 \times 10^{-31} \text{ kg}$) [NCERT]
19. Answer the following questions :
 - (a) A magnetic field that varies in magnitude from point to point but has a constant direction (east to west) is set up in a chamber. A charged particle enters the chamber and travels undeflected along a straight path with constant speed. What can you say about the initial velocity of the particle ?
 - (b) A charged particle enters an environment of a strong and non-uniform magnetic field varying from point to point both in magnitude and direction and comes out of it following a complicated trajectory. Would its final speed equal the initial speed if it suffered no collisions with the environment?
 - (c) An electron travelling west to east enters a chamber having a uniform electrostatic field in north to south direction. Specify the direction in which a uniform magnetic field should be set up to prevent the electron from deflecting from its straight line path.
20. A magnetic field set up using Helmholtz coils is uniform in a small region and has a magnitude of 0.75 T. In the same region, a uniform electrostatic field is maintained in a direction normal to the common axis of the coils. A narrow beam of (single species) charged particles all accelerated through 15 kV enters this region in a direction perpendicular to both the axis of the coils and the electrostatic field. If the beam remains undeflected when the electrostatic field is $9.0 \times 10^5 \text{ V m}^{-1}$, make a simple guess as to what the beam contains. Why is the answer not unique? [NCERT]
21. In question no. 20, obtain the frequency of revolution of the electron in its circular orbit. Does the answer depend on the speed of the electron? Explain.

HCV Exercises (Chapter No. 35 - Q. No. 38)

HCV Exercises (Chapter No. 34 - Q. No. 1 to 7 & 28 to 52)

HCV Worked out Examples(Chapter No. 34 - Q. No. 2,3,9,10)

22. A straight horizontal conducting rod of length 0.45 m and mass 60g is suspended by two vertical wires at its ends. A current of 5.0 A is set up in the rod through the wires. [NCERT]
 (a) What magnetic field should be set up normal to the conductor in order that the tension in the wires is zero?
 (b) What will be the total tension in the wires if the direction of current is reversed keeping the magnetic field same as before ? [Ignore the mass of the wires). $g = 9.8 \text{ ms}^{-2}$.
23. A uniform magnetic field of 1.5 T exists in a cylindrical region of radius 10.0 cm, its direction parallel to the axis along east to west. A wire carrying current of 7.0 A in the north to south direction passes through this region. What is the magnitude and direction of the force on the wire if, [NCERT]
 (a) the wire intersects the axis.
 (b) the wire is turned from N-S to northeast-northwest direction,
 (c) the wire in the N-S direction is lowered from the axis by a distance of 6.0 cm ?
24. (a) 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. [NCERT]
 (b) Would your answer change, if the circular coil in (a) were replaced by a planar coil of some irregular shape that encloses the same area? (All other particulars are also unaltered.)
25. A uniform magnetic field of 3000 G is established along the positive z-direction. A rectangular loop of sides 10 cm and 5 cm carries a current of 12A. What is the torque on the loop in the different cases shown in figure. What is the force on each case ? Which case corresponds to stable equilibrium? [NCERT]



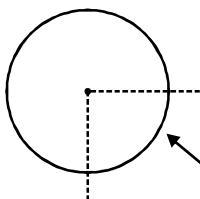
26. A circular coil of 20 turns and radius 10 cm is placed in a uniform magnetic field of 0.10 T normal to the plane of the coil. If the current in the coil is 5.0 A, what is the [NCERT]
- (a) total, torque on the coil,
 (b) total force on the coil,
 (c) average force on each electron in the coil due to the magnetic field ?
 (The coil is made of copper wire of cross-sectional area 10^{-5} m^2 , and the free electron density in copper is given to be about 10^{29} m^{-3} .)
27. Two moving coil meters. M_1 and M_2 have the following particulars: [NCERT]
- $R_1 = 10 \Omega$, $N_1 = 30$,
 $A_1 = 3.6 \times 10^{-3} \text{ m}^2$, $B_1 = 0.25 \text{ T}$
 $R_2 = 14 \Omega$, $N_2 = 42$, $A_2 = 1.8 \times 10^{-3} \text{ m}^2$, $B_2 = 0.50 \text{ T}$
 (The spring constants are identical for the two meters). Determine the ratio of
 (a) current sensitivity and
 (b) voltage sensitivity of M_2 and M_1 .

HCV Exercises (Chapter No. 34 - Q. No. 8 to 27 & 53 to 61)

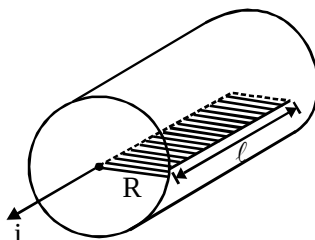
HCV Exercises (Chapter No. 35 - Q. No. 26 to 31, 39, 40)

EXERCISE (S-2)

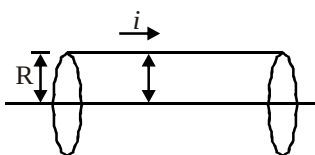
1. A long thin walled pipe of radius R carries a current I along its length. The current density is uniform over the circumference of the pipe. The magnetic field at the center of the pipe due to quarter portion of the pipe shown, is



2. Find the flux passing through the shaded rectangular plane which passes through the axis due to the long straight current carrying conductor having a current i . Given length $\ell = 1\text{m}$, current $I = 2\text{A}$, Radius $R = 5\text{cm}$. If answer is $n \frac{\mu_0 \ell^2 I^2}{16\pi}$ (in weber). Write value of n .

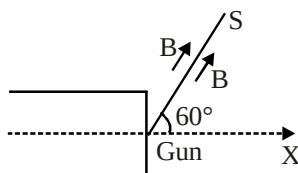


3. A cylindrical conductor of radius R carries a current along its length. The current density J , however, it is not uniform over the cross section of the conductor but is a function of the radius according to $J = br$, where b is a constant. Find an expression for the magnetic field B .

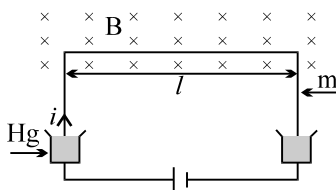


(a) at $r_1 < R$ & (b) at distance $r_2 > R$, measured from the axis

4. An electron gun G emits electron of energy 2keV traveling in the (+)ve x -direction. The electron are required to hit the spot S where $GS = 0.1\text{m}$ & the line GS makes an angle of 60° with the x -axis, as shown in the fig. A uniform magnetic field $\vec{B}$ parallel to GS exists in the region outside to electron gun. Find the minimum value of B needed to make the electron hit S .

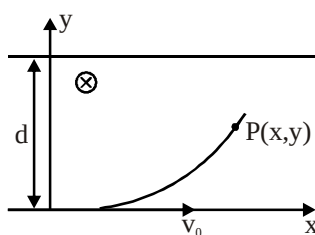


5. A U-shaped wire of mass m and length l is immersed with its two ends in mercury (see figure). The wire is in a homogeneous field of magnetic induction $\mathbf{B}$. If a charge, that is, a current pulse $q = \int i dt$, is sent through the wire, the wire will jump up.



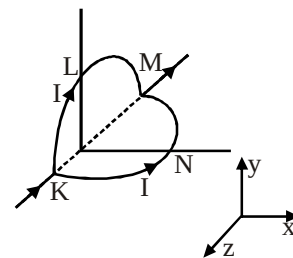
Calculate, from the height h that the wire reaches, the size of the charge or current pulse, assuming that the time of the current pulse is very small in comparison with the time of flight. Make use of the fact that impulse of force equals $\int F dt$, which equals mv . Evaluate q for $B = 0.1 \text{ Wb/m}^2$, $m = 10 \text{ gm}$, $l = 20 \text{ cm}$ & $h = 3 \text{ meters}$. [$g = 10 \text{ m/s}^2$]

6. A particle of mass $1 \times 10^{-26} \text{ kg}$ and charge $+1.6 \times 10^{-19} \text{ C}$ travelling with a velocity $1.28 \times 10^6 \text{ m/s}$ in the $+x$ direction enters a region in which a uniform electric field $\mathbf{E}$ and a uniform magnetic field of induction $\mathbf{B}$ are present such that $E_x = E_y = 0$, $E_z = -102.4 \text{ kV/m}$ and $B_x = B_z = 0$, $B_y = 8 \times 10^{-2} \text{ weber/m}^2$. The particle enters this region at the origin at time $t = 0$. Determine the location (x , y and z coordinates) of the particle at $t = 5 \times 10^{-6} \text{ s}$. If the electric field is switched off at this instant (with the magnetic field still present), what will be the position of the particle at $t = 7.45 \times 10^{-6} \text{ s}$?
7. A non-uniform magnetic field $\vec{B} = B_0 \left(1 + \frac{y}{d}\right) (\hat{k})$ is present in region of space in between $y = 0$ and $y = d$. The lines are shown in the diagram. A particle of mass ' m ' and positive charge ' q ' is moving. Given an initial velocity $\vec{v} = v_0 \hat{i}$. Find the components of velocity of the particle when it leaves the field.

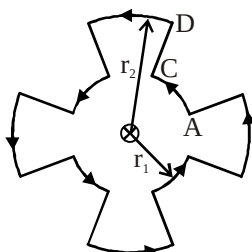


8. Two coils each of 100 turns are held such that one lies in the vertical plane with their centres coinciding. The radius of the vertical coil is 20 cm and that of the horizontal coil is 30 cm. How would you neutralize the magnetic field of the earth at their common centre? What is the current to be passed through each coil? Horizontal component of earth's magnetic induction = $3.49 \times 10^{-5} \text{ T}$ and angle of dip = 30° .
9. An infinite wire, placed along z -axis, has current I_1 in positive z -direction. A conducting rod placed in xy plane parallel to y -axis has current I_2 in positive y -direction. The ends of the rod subtend $+30^\circ$ and -60° at the origin with positive x -direction. The rod is at a distance a from the origin. Find net force on the rod.

10. A circular loop of radius R is bent along a diameter and given a shape as shown in the figure. One of the semicircles (KNM) lies in the $x-z$ plane and the other one (KLM) in the $y-z$ plane with their centers at the origin. Current I is flowing through each of the semicircles as shown in figure.

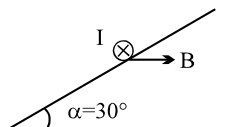


- (i) A particle of charge q is released at the origin with a velocity $\mathbf{v} = -v_0 \hat{i}$. Find the instantaneous force $\mathbf{f}$ on the particle. Assume that space is gravity free.
- (ii) If an external uniform magnetic field $B \hat{j}$ is applied, determine the forces F_1 and F_2 on the semicircles KLM and KNM due to this field and the net force F on the loop.
11. A current of 10A flows around a closed path in a circuit which is in the horizontal plane as shown in the figure. The circuit consists of eight alternating arcs of radii $r_1 = 0.08$ m and $r_2 = 0.12$ m. Each arc subtends the same angle at the centre.

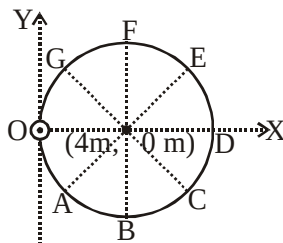


- (a) Find the magnetic field produced by this circuit at the centre.
- (b) An infinitely long straight wire carrying a current of 10A is passing through the centre of the above circuit vertically with the direction of the current being into the plane of the circuit. What is the force acting on the wire at the centre due to the current in the circuit? What is the force acting on the arc AC and the straight segment CD due to the current at the centre?
12. A particle of charge $+q$ and mass m moving under the influence of a uniform electric field $E \hat{i}$ and a magnetic field $B \hat{k}$ enters in I quadrant of a coordinate system at a point $(0, a)$ with initial velocity $v \hat{i}$ and leaves the quadrant at a point $(2a, 0)$ with velocity $-2v \hat{j}$. Find
- (a) Magnitude of electric field
- (b) Rate of work done by the electric field at point $(0, a)$
- (c) Rate of work done by both the fields at $(2a, 0)$.
13. Electric charge q is uniformly distributed over a rod of length l . The rod is placed parallel to a long wire carrying a current i . The separation between the rod and the wire is a . Find the force needed to move the rod along its length with a uniform velocity v .
14. There exists a uniform magnetic and electric field of magnitude 1 T and 1 V/m respectively along positive y -axis. A charged particle of mass 1 kg and charge 1 C moving with velocity 1 m/sec along x -axis is at origin at $t = 0$. If the coordinates of particle at time p seconds is given as (X, Y, Z) in meter, then find the value of $(XY + YZ + ZX) \frac{5}{\pi^2}$.

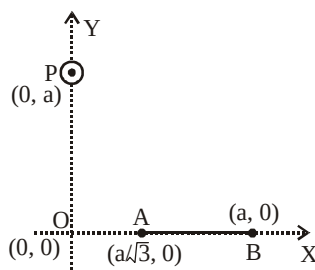
15. A proton beam passes without deviation through a region of space where there are uniform transverse mutually perpendicular electric and magnetic field with E and B . Then the beam strikes a grounded target. Find the force imparted by the beam on the target if the beam current is equal to I .
16. The figure shows a conductor of weight 1.0 N and length $L = 0.5\text{ m}$ placed on a rough inclined plane making an angle 30° with the horizontal so that conductor is perpendicular to a uniform horizontal magnetic field of induction $B = 0.10\text{ T}$. The coefficient of static friction between the conductor and the plane is 0.1 . A current of $I = 10\text{ A}$ flows through the conductor inside the plane of this paper as shown. What is the force needed to be applied parallel to the inclined plane to sustaining the conductor at rest?



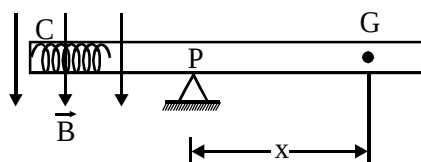
17. An infinite uniform current carrying wire is kept along z -axis, carrying current I_0 in the direction of the positive z -axis. OABCDEFG represents a circle (where all the points are equally spaced), whose centre at point $(4\text{ m}, 0\text{ m})$ and radius 4 m as shown in the figure. If $\int_{DEF} \vec{B} \cdot d\vec{\ell} = \frac{\mu_0 I_0}{k}$ in S.I. unit, then find the value of k .



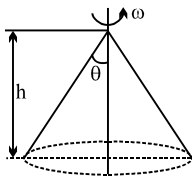
18. An infinite current carrying conductor, parallel to z -axis is situated at point P as shown in the figure. Value of $\int_A^B \vec{B} \cdot d\vec{\ell}$ is given by $\alpha \frac{\mu_0 i}{96}$, then fill the value of α in OMR sheet ?



19. A rod of length ℓ and total charge 'q' which is uniformly distributed is rotating with angular velocity ω about an axis passing through the centre of rod and perpendicular to rod. Find the magnitude of magnetic dipole moment (in $\text{Amp} \cdot \text{m}^2$) of rod. (Take : $q = 4C$, $\omega = 6\text{ rad/s}$ and $\ell = 2\text{ m}$.)
20. A uniform wooden bar of mass $\frac{\pi}{100}\text{ kg}$ and radius of cross-section 10 cm carries a light coil C of 100 turns. The bar is smoothly pivoted at P. If the coil carries a current 2 A and subjected to an external magnetic field 10^{-2} T , the bar remains in equilibrium. Find the distance x (in cm) of the C.M. of the rod from the pivot.

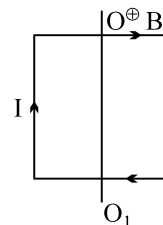


21. Q charge is uniformly distributed over the same surface of a right circular cone of semi-vertical angle θ and height h . The cone is uniformly rotated about its axis at angular velocity ω . Calculate associated magnetic dipole moment.



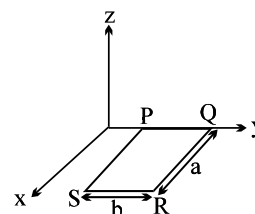
22. A stationary, circular wall clock has a face with a radius of 15cm. Six turns of wire are wound around its perimeter, the wire carries a current 2.0 A in the clockwise direction. The clock is located, where there is a constant, uniform external magnetic field of 70 mT (but the clock still keeps perfect time) at exactly 1:00 pm, the hour hand of the clock points in the direction of the external magnetic field (a) After how many minutes will the minute hand point in the direction of the torque on the winding due to the magnetic field? (b) What is the magnitude of this torque.

23. A square current carrying loop made of thin wire and having a mass $m=10\text{g}$ can rotate without friction with respect to the vertical axis OO_1 , passing through the centre of the loop at right angles to two opposite sides of the loop. The loop is placed in a homogeneous magnetic field with an induction $B = 10^{-1}\text{ T}$ directed at right angles to the plane of the drawing. A current $I = 2\text{ A}$ is flowing in the loop. Find the period of small oscillations that the loop performs about its position of stable equilibrium.



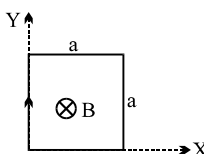
24. 3 infinitely long thin wires each carrying current i in the same direction, are in the x-y plane of a gravity free space. The central wire is along the y-axis while the other two are along $x = \pm d$.
- Find the locus of the points for which the magnetic field B is zero.
 - If the central wire is displaced along the z-direction by a small amount & released, show that it will execute simple harmonic motion. If the linear density of the wires is λ , find the frequency of oscillation.

25. A rectangular loop PQRS made from a uniform wire has length a , width b and mass m . It is free to rotate about the arm PQ, which remains hinged along a horizontal line taken as the y-axis (see figure). Take the vertically upward direction as the z-axis. A uniform magnetic field $\vec{B} = (3\hat{i} + 4\hat{k})B_0$ exists in the region. The loop is held in the x-y plane and a current I is passed through it. The loop is now released and is found to stay in the horizontal position in equilibrium.

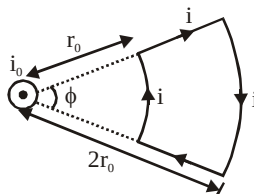


- What is the direction of the current I in PQ?
- Find the magnetic force on the arm RS.
- Find the expression for I in terms of B_0 , a , b and m .

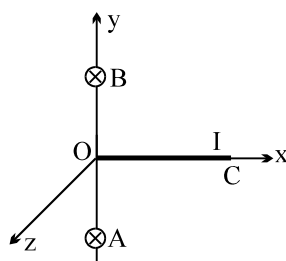
26. A rectangular loop of wire is oriented with the left corner at the origin, one edge along X-axis and the other edge along Y-axis as shown in the figure. A magnetic field is into the page and has a magnitude that is given by $\beta = \alpha y$ where α is constant. Find the total magnetic force on the loop if it carries current i .



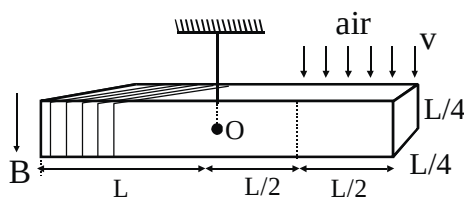
27. A closed loop carrying a current i is placed so that its plane is perpendicular to the long straight conductor which carries a current i_0 as shown in the figure. The torque acting on the current loop is $\alpha \mu_0 \text{ N-m}$. Then find the value of α . (Given $i = 2 \text{ A}$, $i_0 = 2 \text{ A}$, $r_0 = 2\pi \text{ m}$, $\phi = 60^\circ$)



28. A straight segment OC (of length L meter) of a circuit carrying a current I amp is placed along the x -axis. Two infinitely long straight wires A and B, each extending from $z = -\infty$ to $+\infty$, are fixed at $y = -a$ metre and $y = +a$ metre respectively, as shown in the figure. If the wires A and B each carry a current I amp into plane of the paper. Obtain the expression for the force acting on the segment OC. What will be the force OC if current in the wire B is reversed?



29. A non conducting non-magnetic rod having square cross-section of side $L/4$ is suspended from a rigid support as shown in the figure. A light and small coil of 600 turns is wrapped tightly at the left end of the rod where uniform magnetic field B exists in vertically downward direction. Air of density ρ hits the half of the right part of the rod with velocity v as shown in the figure. What should be the current (in mA) in the coil so that rod remains horizontal? [Assume air particles come to rest after colliding with the rod] [Take : $\rho = 1.05 \text{ kg/m}^3$, $v = 10 \text{ m/s}$, $B = 1 \text{ T}$, $L = 2 \text{ m}$]

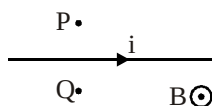


EXERCISE (O-1)

1. A horizontal overhead power line carries a current of 90 A in east to west direction. What is the magnitude and direction of the magnetic field due to the current 1.5 m below the line?

(A) 1.2×10^{-5} T, towards south (B) 1.2×10^{-5} T, towards north
(C) 2.5×10^{-5} T, towards south (D) 2.5×10^{-5} T, towards north

2. A long, straight wire carrying a current of 1.0 A is placed horizontally in a uniform magnetic field $B = 1.0 \times 10^{-5}$ T pointing vertically upward (figure). The magnitude of the resultant magnetic field at the points P and Q, both situated at a distance of 2.0 cm from the wire in the same horizontal plane are respectively



(A) zero, $20 \mu\text{T}$ (B) $20 \mu\text{T}$, zero (C) zero, zero (D) $20 \mu\text{T}$, $20 \mu\text{T}$

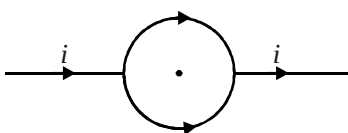
3. Two parallel wires carry equal currents of 10 A along the same direction and are separated by a distance of 2.0 cm. Find the magnetic field at a point which is 2.0 cm away from each of these wires.

(A) 3.4×10^{-4} T in a direction parallel to the plane of the wires and perpendicular to the wires
(B) 1.7×10^{-4} T in a direction parallel to the plane of the wires and parallel to the wires
(C) 1.7×10^{-4} T in a direction parallel to the plane of the wires and perpendicular to the wires
(D) 3.4×10^{-4} T in a direction parallel to the plane of the wires and parallel to the wires

4. Consider a 10 cm long piece of a wire which carries a current of 10 A. Find the magnitude of the magnetic field due to the piece at a point which makes an equilateral triangle with the ends of the piece.

(A) Zero (B) $5.5 \mu\text{T}$ (C) $7.5 \mu\text{T}$ (D) $11.5 \mu\text{T}$

5. A conducting circular loop of radius a is connected to two long, straight wires. The straight wires carry a current i as shown in figure. Find the magnetic field B at the centre of the loop.



(A) zero (B) $\frac{\mu_0 I}{2a}$ (C) $\frac{\mu_0 I}{a}$ (D) $\frac{\mu_0 I}{a} + \frac{\mu_0 I}{2\pi a}$

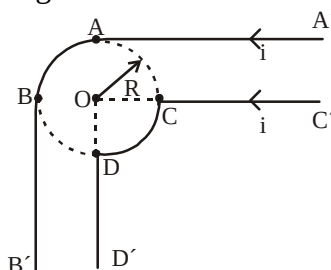
6. A piece of wire carrying a current of 6.00 A is bent in the form of a circular arc of radius 10.0 cm, and it subtends an angle of 120° at the centre. Find the magnetic field B due to this piece of wire at the centre.

(A) zero (B) 1.26×10^{-5} T (C) 5×10^{-5} T (D) 7.2×10^{-5} T

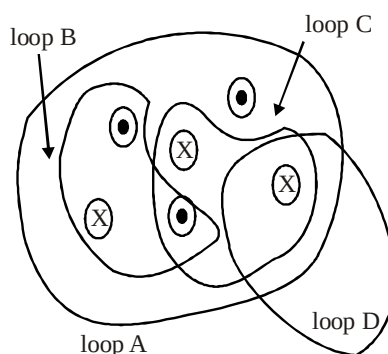
7. A charge of 3.14×10^{-6} C is distributed uniformly over a circular ring of radius 20.0 cm. The ring rotates about its axis with an angular velocity of 60.0 rad/s. Find the ratio of the electric field to the magnetic field at a point on the axis at a distance of 5.00 cm from the centre.

(A) zero (B) 0.5×10^{15} m/s (C) 1.88×10^{15} m/s (D) 5.88×10^{15} m/s

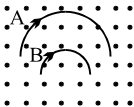
8. All straight wires are very long. Both AB and CD are area of the same circle, both subtending right angles at the centre O. Then the magnetic field at O is

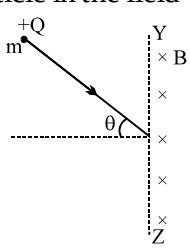


- (A) $\frac{\mu_0 i}{4\pi R}$ (B) $\frac{\mu_0 i}{4\pi R} \sqrt{2}$ (C) $\frac{\mu_0 i}{2\pi R}$ (D) $\frac{\mu_0 i}{2\pi R} (\pi + 1)$
9. An equilateral triangular loop of wire of side ℓ carries a current i . The magnetic field produced at the circumcenter of the loop is
- (A) $\frac{\mu_0}{4\pi} \frac{3\sqrt{3}i}{\ell}$ (B) $\frac{\mu_0}{4\pi} \frac{9i}{\ell}$ (C) $\frac{\mu_0}{4\pi} \frac{18i}{\ell}$ (D) $\frac{\mu_0}{4\pi} \frac{6i}{\ell}$
10. Consider six wires coming into or out of the page, all with the same current. Rank the line integral of the magnetic field (from most positive to most negative) taken counterclockwise around each loop shown.

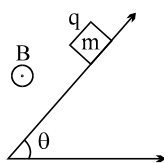


- (A) $B > C > D > A$ (B) $B > C = D > A$ (C) $B > A > C = D$ (D) $C > B = D > A$
11. **Statement-1** : Ampere law can be used to find magnetic field due to finite length of a straight current carrying wire.
Statement-2 : The magnetic field due to finite length of a straight current carrying wire is symmetric about the wire.
 (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
 (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
 (C) Statement-1 is true, statement-2 is false.
 (D) Statement-1 is false, statement-2 is true.
12. A long, cylindrical wire of radius b carries a current i distributed uniformly over its cross-section. Find the magnitude of the magnetic field at a point inside the wire at a distance a from the axis.
- (A) zero (B) $\frac{\mu_0 i b}{2\pi a^2}$ (C) $\frac{\mu_0 i a^2}{2\pi b^3}$ (D) $\frac{\mu_0 i a}{2\pi b^2}$

13. A copper wire of diameter 1.6 mm carries a current of 20 A. Find the maximum magnitude of the magnetic field $\vec{B}$ due to this current.
(A) 5.0 mT (B) 10 mT (C) 15 mT (D) 15.5 mT
14. 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) zero (B) $8\pi \times 10^{-3}$ T (C) $15\pi \times 10^{-3}$ T (D) $\pi \times 10^{-3}$ T
15. A circular loop of radius 20 cm carries a current of 10 A. An electron crosses the plane of the loop with a speed of 2.0×10^6 m/s. The direction of motion makes an angle of 30° with the axis of the circle and passes through its centre. Find the magnitude of the magnetic force on the electron at the instant it crosses the plane.
(A) zero (B) $\pi \times 10^{-19}$ N (C) $16\pi \times 10^{-19}$ N (D) $32\pi \times 10^{-19}$ N
16. A charged particle enters a non-uniform uni-directional field such that initial velocity is parallel to magnetic field, then the radius of curvature of its path is (in standard notation) :
(A) mV/qB (B) 0 (C) ∞ (D) qB/mV
17. A charge particle moves in a uniform magnetic field such that initial velocity is perpendicular to the magnetic field. No other force acts on the particle.
(A) the motion is uniform rectilinear
(B) the motion can be non uniform circular motion
(C) the motion can be uniform circular motion
(D) the motion must be uniform circular motion.
18. A tightly-wound, long solenoid carries a current of 2.00 A. An electron is found to execute a uniform circular motion inside the solenoid with a frequency of 1.00×10^8 rev/s. Find the number of turns per metre in the solenoid.
(A) 500 Turns/m (B) 1020 Turns/m (C) 1232 Turns/m (D) 1420 Turns/m
19. An electron is moving along positive x-axis. A uniform electric field exists towards negative y-axis. What should be the direction of magnetic field of suitable magnitude so that net force of electron is zero
(A) positive z- axis (B) negative z-axis (C) positive y-axis (D) negative y-axis
20. Two protons move parallel to each other, keeping distance r between them, both moving with same velocity $\vec{V}$. Then the ratio of the electric and magnetic force of interaction between them is
(A) c^2/V^2 (B) $2c^2/V^2$ (C) $c^2/2V^2$ (D) None
21. An electron having kinetic energy T is moving in a circular orbit of radius R perpendicular to a uniform magnetic induction $\vec{B}$. If kinetic energy is doubled and magnetic induction tripled, the radius will become
(A) $\frac{3R}{2}$ (B) $\sqrt{\frac{3}{2}}R$ (C) $\sqrt{\frac{2}{9}}R$ (D) $\sqrt{\frac{4}{3}}R$
22. 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 $v_A = v_B$

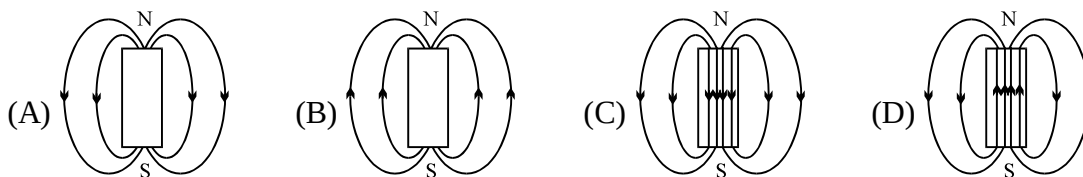
23. A charged particle moves in a magnetic field $\vec{B} = 10\hat{i}$ with initial velocity $\vec{u} = 5\hat{i} + 4\hat{j}$. The path of the particle will be
(A) straight line (B) circle (C) helical (D) none
24. An electron makes 3×10^5 revolutions per second in a circle of radius 0.5 angstrom. Find the magnetic field B at the centre of the circle.
(A) 6×10^{-10} T (B) 12×10^{-10} T (C) 18×10^{-10} T (D) 24×10^{-10} T
25. Electrons moving with different speeds enter a uniform magnetic field in a direction perpendicular to the field. They will move along circular paths.
(A) of same radius
(B) with larger radii for the faster electrons
(C) with smaller radii for the faster electrons
(D) either (B) or (C) depending on the magnitude of the magnetic field
26. In the previous question, time periods of rotation will be :
(A) same for all electrons
(B) greater for the faster electrons
(C) smaller for the faster electrons
(D) either (B) or (C) depending on the magnitude of the magnetic field
27. 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) $q b B/m$ (B) $q(b - a) B/m$ (C) $q a B/m$ (D) $q(b + a) B/2m$
28. A particle having charge of 1 C, mass 1 kg and speed 1 m/s enters a uniform magnetic field, having magnetic induction of 1 T, at an angle $\theta = 30^\circ$ between velocity vector and magnetic induction. The pitch of its helical path is (in meters)
(A) $\frac{\sqrt{3}\pi}{2}$ (B) $\sqrt{3}\pi$ (C) $\frac{\pi}{2}$ (D) π
29. A particle with charge +Q and mass m enters a magnetic field of magnitude B, existing only to the right of the boundary YZ. The direction of the motion of the particle is perpendicular to the direction of B. Let $T = 2\pi \frac{m}{QB}$. The time spent by the particle in the field will be
- 
- (A) $T\theta$ (B) $2T\theta$ (C) $T \left(\frac{\pi + 2\theta}{2\pi} \right)$ (D) $T \left(\frac{\pi - 2\theta}{2\pi} \right)$
30. In the previous question, if the particle has -Q charge, the time spent by the particle in the field will be
(A) $T\theta$ (B) $2T\theta$ (C) $T \left(\frac{\pi + 2\theta}{2\pi} \right)$ (D) $T \left(\frac{\pi - 2\theta}{2\pi} \right)$

31. A block of mass m & charge q is released on a long smooth inclined plane magnetic field B is constant, uniform, horizontal and parallel to surface as shown. Find the time from start when block loses contact with the surface.



- (A) $\frac{m \cos \theta}{qB}$ (B) $\frac{m \operatorname{cosec} \theta}{qB}$ (C) $\frac{m \cot \theta}{qB}$ (D) none
32. 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.
33. In given figure, X and Y are two long straight parallel conductors each carrying a current of 2 A. The force on each conductor is F newtons. When the current in each is changed to 1 A and reversed in direction, the force on each is now
- | | | |
|--------------------------------------|-------------------------------------|--|
| (A) $F/4$ and unchanged in direction | (B) $F/2$ and reversed in direction | $\begin{array}{c} \text{X} \\ \xrightarrow{2\text{A}} \end{array}$ |
| (C) $F/2$ and unchanged in direction | (D) $F/4$ and reversed in direction | $\begin{array}{c} \xrightarrow{2\text{A}} \\ \text{Y} \end{array}$ |
34. 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) 2×10^{-5} N ; attractive force normal to B towards A.
(B) 2×10^{-5} N ; attractive force normal to A towards B.
(C) 5×10^{-5} N ; attractive force normal to A towards B.
(D) 5×10^{-5} N ; attractive force normal to B towards A.
35. 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 magnitude of magnetic force on the wire?
(A) zero (B) 3.5×10^{-2} N (C) 8.1×10^{-2} N (D) 12.1×10^{-2} N
36. 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) zero (B) 1 N m^{-1} (C) 3.2 N m^{-1} (D) 0.6 N m^{-1}
37. The wires which connected the battery of an automobile to its starting motor carry a current of 300 A (for a short time). What is the force per unit length between the wires if they are 70 cm long and 1.5 cm apart? Is the force attractive or repulsive ?
(A) 1.2 N m^{-1} ; repulsive (B) 1.2 N m^{-1} ; attractive
(C) 3.5 N m^{-1} ; repulsive (D) 3.5 N m^{-1} ; attractive
38. A solenoid 60 cm long and of radius 4.0 cm has 3 layers of windings of 300 turns each. A 2.0 cm long wire of mass 2.5 g lies inside the solenoid (near its centre) normal to its axis ; both the wire and the axis of the solenoid are in the horizontal plane. The wire is connected through two leads parallel to the axis of the solenoid to an external battery which supplies a current of 6.0 A in the wire. What value of current (with appropriate sense of circulation) in the windings of the solenoid can support the weight of the wire? $g = 9.8 \text{ ms}^{-2}$.
(A) zero (B) 108 A (C) 200 A (D) 458 A

39. The magnetic field lines due to a bar magnet are correctly shown in



40. A wire of mass 100 g carrying a current of 2A towards increasing x is in the form of $y = x^2$ ($-2\text{m} \leq x \leq +2\text{m}$). This wire is placed in a magnetic field $B = -0.02\hat{k}$ Tesla & gravity free region. The acceleration of the wire (in m/s^2) is :-

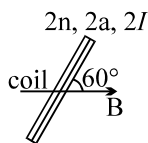
- (A) $-1.6\hat{j}$ (B) $-3.2\hat{j}$ (C) $1.6\hat{j}$ (D) $2.4\hat{j}$

41. A circular loop of radius R carries a current I . Another circular loop of radius r ($r \ll R$) carries a current i and is placed at the centre of the larger loop. The planes of the two circles are at right angle to each other. Find the torque acting on the smaller loop.

- (A) zero (B) $\frac{\mu_0 \pi i I r^2}{4R}$ (C) $\frac{\mu_0 \pi i I r^2}{2R}$ (D) $\frac{\mu_0 \pi i I r^2}{R}$

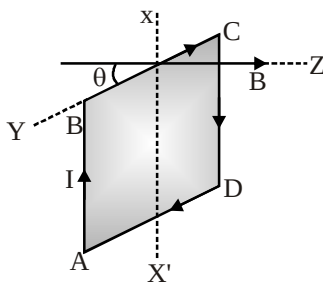
42. A particle of charge q and mass m moves in a circular orbit of radius r with angular speed ω . The ratio of the magnitude of its magnetic moment to that of its angular momentum depends on
(A) ω and q (B) ω , q and m (C) q and m (D) ω and m

43. A rectangular coil PQ has $2n$ turns, an area $2a$ and carries a current $2I$, (refer figure). The plane of the coil is at 60° to a horizontal uniform magnetic field of flux density B . The torque on the coil due to magnetic force is



- (A) $BnaI \sin 60^\circ$ (B) $8BnaI \cos 60^\circ$ (C) $4naI B \sin 60^\circ$ (D) none

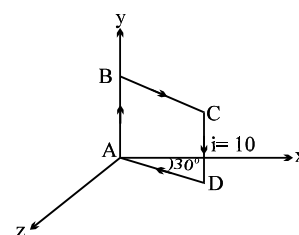
44. The square loop ABCD, carrying a current I , is placed in a uniform magnetic field B , as shown. The loop can rotate about the axis XX' . The plane of the loop makes an angle θ ($\theta < 90^\circ$) with the direction of B . Through what angle will the loop rotate by itself before the torque on it becomes zero



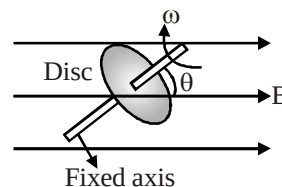
- (A) θ (B) $90^\circ - \theta$ (C) $90^\circ + \theta$ (D) $180^\circ - \theta$

45. Figure shows a square current carrying loop ABCD of side 10 cm and current $i = 10\text{A}$. The magnetic moment $\vec{M}$ of the loop is

- (A) $(0.05)(\hat{i} - \sqrt{3}\hat{k})\text{A} - \text{m}^2$ (B) $(0.05)(\hat{j} + \hat{k})\text{A} - \text{m}^2$
(C) $(0.05)(\sqrt{3}\hat{i} + \hat{k})\text{A} - \text{m}^2$ (D) $(\hat{i} + \hat{k})\text{A} - \text{m}^2$



46. A disc of radius r and carrying positive charge q is rotating with an angular speed ω in a uniform magnetic field B about a fixed axis as shown in figure, such that angle made by axis of disc with magnetic field is θ . Torque applied by axis on the disc is

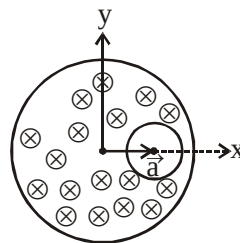


- (A) $\frac{q\omega r^2 B \sin \theta}{2}$, clockwise
(B) $\frac{q\omega r^2 B \sin \theta}{4}$, anticlockwise
(C) $\frac{q\omega r^2 B \sin \theta}{2}$, anticlockwise
(D) $\frac{q\omega r^2 B \sin \theta}{4}$, clockwise
47. A square coil of side 10 cm consists of 20 turns and carries a current of 12 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) zero (B) 2.32 Nm (C) 1.56 Nm (D) 0.96 N m

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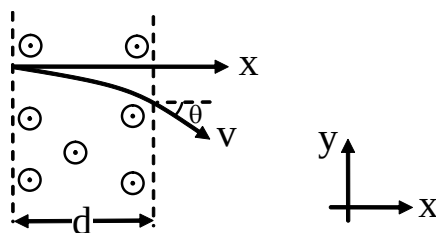
48. Consider three quantities $x = E/B$, $y = \sqrt{1/\mu_0 \epsilon_0}$ and $z = \frac{l}{CR}$. Here, l is the length of a wire, C is a capacitance and R is a resistance. All other symbols have standard meanings.
(A) x, y have the same dimensions (B) y, z have the same dimensions
(C) z, x have the same dimensions (D) none of the three pairs have the same dimensions.
49. The magnetic lines of force due to a straight current carrying wire will be:
(A) circular for finite length of wire (B) circular for semi-infinite wire
(C) circular for infinite wire (D) Parabolic for finite wire
50. A current I flows along the length of an infinitely long, straight, solid pipe. Then correct statement(s)-
(A) The magnetic field is zero only on the axis of the pipe
(B) The magnetic field is different at different points inside the pipe
(C) The magnetic field is maximum on surface
(D) The magnetic field at all points inside the pipe is the same, but not zero

51. Figure shows cross-section view of a infinite cylindrical wire with a cylindrical cavity, current density is uniform $\hat{j} = -j_0 \hat{k}$ as shown in figure.



- (A) Field inside cavity is uniform
(B) Field inside cavity is along $\vec{a}$
(C) Field inside cavity is perpendicular to $\vec{a}$
(D) If an electron is projected with velocity $v_0 \hat{j}$ it will move undeviated before colliding with cavity wall

52. A particle of charge q is projected with a momentum $\vec{p} = p\hat{i}$ in the given region of magnetic field $\vec{B} = B\hat{k}$. It emerges from the magnetic field after deviating through an angle $\theta = 30^\circ$.



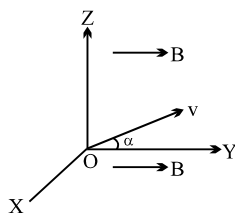
- (A) The value of $\vec{p}$ is $2qBd$
 (B) The value of $\vec{p}$ is qBd
 (C) Maximum change in momentum takes place for $d \geq \frac{p}{qB}$
 (D) Maximum change in momentum takes place for $d \geq \frac{p}{2qB}$
53. Two charged particles traverse *identical* helical paths in a completely opposite sense in a uniform magnetic field $\vec{B} = B_0\hat{k}$
 (A) They have equal z-components of momenta.
 (B) They must have equal charges.
 (C) They necessarily represent a particle-antiparticle pair.
 (D) The charge to mass ratio satisfy : $\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$
54. Current flows through uniform, square frames as shown. In which case is the magnetic field at the centre of the frame not zero?
- (A)

(B)

(C)

(D)
55. A long straight wire carries a current along the x-axis. Consider the points A(0, 1, 0), B(0, 1, 1), C(1, 0, 1) and D(1, 1, 1). Which of the following pairs of points will have magnetic fields of the same magnitude?
 (A) A and B (B) A and C (C) B and C (D) B and D
56. Two identical charged particles enter a uniform magnetic field with same speed but at angles 30° and 60° with field. Let a, b and c be the ratio of their time periods, radii and pitches of the helical paths than
 (A) $abc = 1$ (B) $a/bc > 1$ (C) $abc < 1$ (D) $a = bc$
57. An electron is moving along the positive X-axis. You want to apply a magnetic field for a short time so that the electron may reverse its direction and move parallel to the negative X-axis. This can be done by applying the magnetic field along
 (A) Y-axis (B) Z-axis (C) Y-axis only (D) Z-axis only

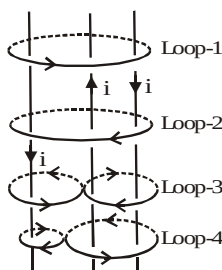
58. In a region of space, a uniform magnetic field B exists in the y -direction. A proton is fired from the origin, with its initial velocity v making a small angle α with the y -direction in the yz plane. In the subsequent motion of the proton,



- (A) its x -coordinate can never be positive
(B) its x - and z -coordinates cannot both be zero at the same time
(C) its z -coordinate can never be negative
(D) its y -coordinate will be proportional to the square of its time of flight

MATRIX MATCH TYPE

59. Three wires are carrying same constant current i in different directions. Four loops enclosing the wires in different manners are shown. The direction of $d\vec{\ell}$ is shown in figure.



Column I

- (A) Along closed loop-1
(B) Along closed loop-2
(C) Along closed loop-3
(D) Along closed loop-4

Column II

- (P) $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 i$
(Q) $\oint \vec{B} \cdot d\vec{\ell} = -\mu_0 i$
(R) $\oint \vec{B} \cdot d\vec{\ell} = 0$
(S) Net work done by the magnetic force to move a unit charge along the loop is zero

60. **Column I** (Magnetic moment of)

- (A) a uniformly charged ring rotating uniformly about its axis
(B) a charged particle rotating uniformly about a point
(C) a uniformly charged disk rotating uniformly about its axis
(D) a uniformly charged spherical shell rotating uniformly about one of its diameter
(E) a uniformly charged sphere rotating uniformly about one of its diameter

Column II

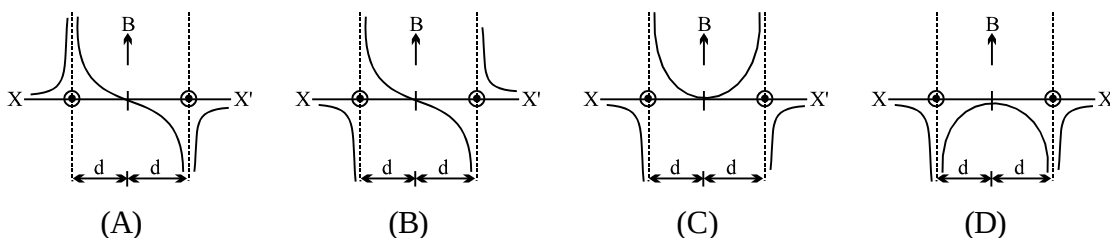
- (P) $\frac{q\omega r^2}{5}$
(Q) $\frac{q\omega r^2}{4}$
(R) $\frac{q\omega r^2}{3}$
(S) $\frac{q\omega r^2}{2}$
(T) $q\omega r^2$

EXERCISE (O-2)

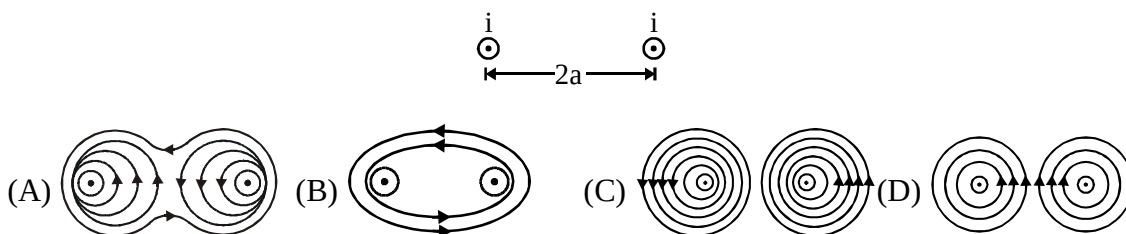
1. A ring like metallic conductor of resistance R and radius a , carries a constant current I . The ratio of the angular momentum L of the conduction electrons (about the axis of the ring) and the magnetic field B at the centre of the ring satisfy [where e and m represent the magnitudes of the electronic charge and mass]

(A) $\frac{B}{L} \propto \frac{e^2}{m}$ (B) $\frac{B}{L} \propto e.m$ (C) $\frac{B}{L} \propto \frac{e}{m}$ (D) $\frac{B}{L} \propto \frac{m}{e}$

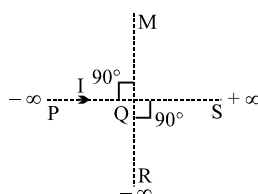
2. Two long parallel wires are at a distance $2d$ apart. They carry steady equal currents flowing out of the plane of the paper, as shown. The variation of the magnetic field B along the XX' is given by



3. Which of the following field patterns is correct for two long straight equal parallel current carrying wires ?



4. 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 in PQ remaining unchanged. The magnetic field at M is now H_2 . The ratio H_1/H_2 is given by

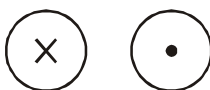


(A) $1/2$ (B) 1 (C) $2/3$ (D) 2

5. The magnetic field at the centre of a current carrying ring is B_0 and at a small axial distance x ($x \ll R$); R = radius of the ring, is B . Then, $\frac{B - B_0}{B_0} =$

(A) $\left(\frac{x}{R}\right)^2$ (B) $\frac{3}{2}\left(\frac{x}{R}\right)^2$ (C) $\frac{5}{2}\left(\frac{x}{R}\right)^3$ (D) None of these

6. Equal antiparallel currents are directed in two parallel wires so that one is out of the page and the other is into the page as shown. Compare the magnitude of the magnetic field B_2 at any arbitrary point equidistant from the wires to the magnitude of the field B_1 at that point from one wire alone :



- (A) $B_2 > B_1$ for all equidistant points (B) $B_2 < B_1$ for all equidistant points
(C) $B_2 > B_1$ for closer equidistant points only (D) $B_2 < B_1$ for closer equidistant points only

7. A long straight wire along the z-axis carries a current I in the negative z direction. The magnetic vector field $\vec{B}$ at a point having coordinates (x, y) in the $z = 0$ plane is

(A) $\frac{\mu_0 I}{2\pi} \frac{(y\hat{i} - x\hat{j})}{(x^2 + y^2)}$ (B) $\frac{\mu_0 I}{2\pi} \frac{(x\hat{i} + y\hat{j})}{(x^2 + y^2)}$ (C) $\frac{\mu_0 I}{2\pi} \frac{(x\hat{j} - y\hat{i})}{(x^2 + y^2)}$ (D) $\frac{\mu_0 I}{2\pi} \frac{(x\hat{i} - y\hat{j})}{(x^2 + y^2)}$

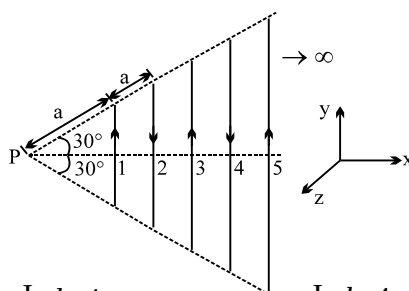
8. Three rings, each having equal radius R , are placed mutually perpendicular to each other and each having its centre at the origin of co-ordinate system. If current I is flowing through each ring then the magnitude of the magnetic field at the common centre is

(A) $\sqrt{3} \frac{\mu_0 I}{2R}$ (B) zero (C) $(\sqrt{2} - 1) \frac{\mu_0 I}{2R}$ (D) $(\sqrt{3} - \sqrt{2}) \frac{\mu_0 I}{2R}$

9. Two concentric coils X and Y of radii 16 cm and 10 cm lie in the same vertical plane containing N-S direction. X has 20 turns and carries 16 A. Y has 25 turns & carries 18 A. X has current in anticlockwise direction and Y has current in clockwise direction for an observer, looking at the coils facing the west. The magnitude of net magnetic field at their common centre is

(A) $5\pi \times 10^{-4}$ T towards west (B) $13\pi \times 10^{-4}$ T towards east
(C) $13\pi \times 10^{-4}$ T towards west (D) $5\pi \times 10^{-4}$ T towards east

10. Infinite number of straight wires each carrying current I are equally placed as shown in the figure. Adjacent wires have current in opposite direction. Net magnetic field at point P is

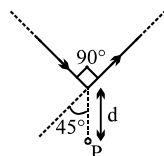


(A) $\frac{\mu_0 I}{4\pi} \frac{\ln 2}{\sqrt{3} a} \hat{k}$ (B) $\frac{\mu_0 I}{4\pi} \frac{\ln 4}{\sqrt{3} a} \hat{k}$ (C) $\frac{\mu_0 I}{4\pi} \frac{\ln 4}{\sqrt{3} a} (-\hat{k})$ (D) Zero

11. Two mutually perpendicular conductors carrying currents I_1 and I_2 lie in one plane. Locus of the point at which the magnetic induction is zero, is a

- (A) circle with centre as the point of intersection of the conductor.
(B) parabola with vertex as the point of intersection of the conductors
(C) straight line passing through the point of intersection of the conductors.
(D) rectangular hyperbola

12. Find the magnetic field at P due to the arrangement shown

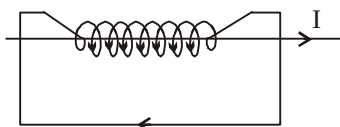


(A) $\frac{\mu_0 i}{\sqrt{2} \pi d} \left(1 - \frac{1}{\sqrt{2}}\right) \otimes$ (B) $\frac{2\mu_0 i}{\sqrt{2} \pi d} \otimes$ (C) $\frac{\mu_0 i}{\sqrt{2} \pi d} \otimes$ (D) $\frac{\mu_0 i}{\sqrt{2} \pi d} \left(1 + \frac{1}{\sqrt{2}}\right) \otimes$

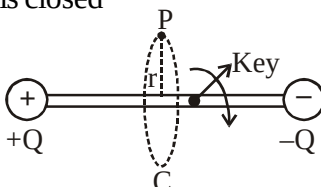
13. A coil having N turns is wound tightly in the form of a spiral with inner and outer radii a and b respectively. When a current I passes through the coil, the magnetic field at the centre is

(A) $\frac{\mu_0 NI}{b}$ (B) $\frac{2\mu_0 NI}{a}$ (C) $\frac{\mu_0 NI}{2(b-a)} \ln \frac{b}{a}$ (D) $\frac{\mu_0 I^N}{2(b-a)} \ln \frac{b}{a}$

14. In the diagram shown, a wire carries current I . What is the value of the $\oint \vec{B} \cdot d\vec{s}$ (as in Ampere's law) on the helical loop shown in the figure? The integration is done in the sense shown. The loop has N turns and part of helical loop on which arrows are drawn is outside the plane of paper.



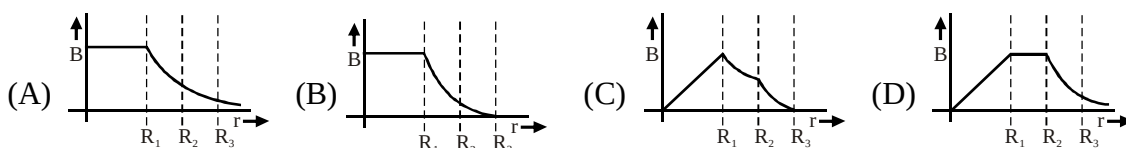
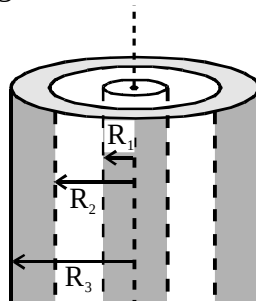
- (A) $-\mu_0(NI)$ (B) $\mu_0(I)$ (C) $\mu_0(NI)$ (D) Zero
15. Two small spherical conductors with initial charge $+Q$ and $-Q$ are connected with a very long straight wire with a switch. When switch is closed



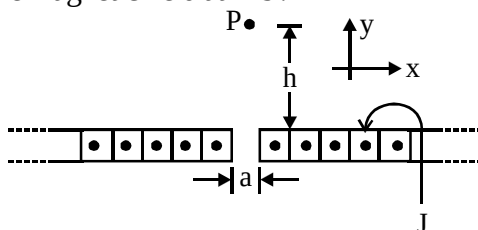
Statement-1: Ampere's law in the form $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{\text{enclosed}}$ is applicable for the curve C encircling the wire.

Statement-2: From symmetry considerations magnetic field is tangent at each point of circle C .

- (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.
16. A coaxial cable is made up of two conductors. The inner conductor is solid and is of radius R_1 & the outer conductor is hollow of inner radius R_2 and outer radius R_3 . The space between the conductors is filled with air. The inner and outer conductors are carrying currents of equal magnitudes and in opposite directions. Then the variation of magnetic field with distance from the axis is best plotted as:



17. A small segment of length a is cut along z -axis from a infinite sheet having a surface current density J (current per unit width). The magnetic field at P is :

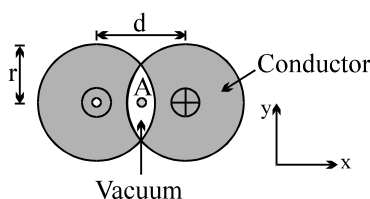


- (A) $2\mu_0 J \left(1 - \frac{h}{a\pi}\right) \hat{i}$ (B) $\frac{\mu_0 J h}{2a\pi} \hat{i}$ (C) $\frac{\mu_0 J}{2} \left(\frac{a}{h\pi} - 1\right) \hat{i}$ (D) $-\frac{\mu_0 J}{2} \left(\frac{h}{a\pi} - 1\right) \hat{i}$

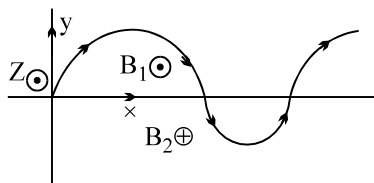
18. A hollow cylinder having infinite length and carrying uniform current per unit length λ along the circumference as shown. Magnetic field inside the cylinder is



- (A) $\frac{\mu_0 \lambda}{2}$ (B) $\mu_0 \lambda$ (C) $2\mu_0 \lambda$ (D) none
19. Two long conductors are arranged as shown above to form overlapping cylinders, each of radius r , whose centers are separated by a distance d . Current of density J flows into the plane of the page along the shaded part of one conductor and an equal current flows out of the plane of the page along the shaded portion of the other, as shown. What are the magnitude and direction of the magnetic field at point A?



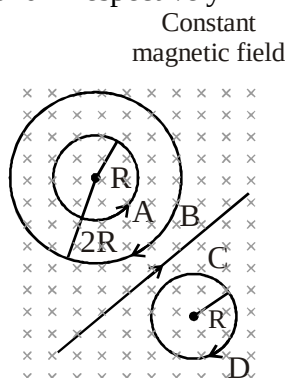
- (A) $(\mu_0/2\pi)\pi dJ$, in the $+y$ -direction (B) $(\mu_0/2\pi)d^2/r$, in the $+y$ -direction
(C) $(\mu_0/2\pi)4d^2J/r$, in the $-y$ -direction (D) $(\mu_0/2\pi)Jr^2/d$, in the $-y$ -direction
20. An ionized gas contains both positive and negative ions. If it is subjected simultaneously to an electric 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.
21. At $t = 0$ a charge q is at the origin and moving in the y -direction with velocity $\vec{v} = v \hat{j}$. The charge moves in a magnetic field that is for $y > 0$ out of page and given by $B_1 \hat{z}$ and for $y < 0$ into the page and given by $-B_2 \hat{z}$. The charge's subsequent trajectory is shown in the sketch. From this information, we can deduce that



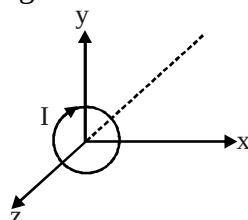
- (A) $q > 0$ and $|B_1| < |B_2|$ (B) $q < 0$ and $|B_1| < |B_2|$
(C) $q > 0$ and $|B_1| > |B_2|$ (D) $q < 0$ and $|B_1| > |B_2|$
22. A particle of charge q and mass m starts moving from the origin under the action of an electric field $\vec{E} = E_0 \hat{i}$ and $\vec{B} = B_0 \hat{i}$ with velocity $\vec{v} = v_0 \hat{j}$. The speed of the particle will become $2v_0$ after a time

- (A) $t = \frac{2mv_0}{qE}$ (B) $t = \frac{2Bq}{mv_0}$ (C) $t = \frac{\sqrt{3} Bq}{mv_0}$ (D) $t = \frac{\sqrt{3} mv_0}{qE}$

23. Four particles A, B, C and D of masses m_A , m_B , m_C and m_D respectively, follow the paths shown in the figure, in a uniform magnetic field. Each particle moving with same speed. Q_A , Q_B , Q_C and Q_D are the specific charge of particles A, B, C and D respectively



- (A) $Q_A < Q_B < Q_C < Q_D$
 (B) $Q_D < Q_B < Q_C < Q_A$
 (C) Charge on the particle B and particle D is of different nature
 (D) Work done by magnetic force on the particle C is minimum as compared to other particle
24. A electron experiences a force $(4.0\hat{i} + 3.0\hat{j}) \times 10^{-13}$ N in a uniform magnetic field when its velocity is $2.5\hat{k} \times 10^7$ ms⁻¹. When the velocity is redirected and becomes $(1.5\hat{i} - 2.0\hat{j}) \times 10^7$ ms⁻¹, the magnetic force of the electron is zero. The magnetic field vector $\vec{B}$ is :
- (A) $-0.075\hat{i} + 0.1\hat{j}$ (B) $0.1\hat{i} + 0.075\hat{j}$ (C) $0.075\hat{i} - 0.1\hat{j} + \hat{k}$ (D) $0.075\hat{i} - 0.1\hat{j}$
25. A non-planar circular loop consists of two semi-circles one of which lies in yz-plane & the other is in xz-plane as shown . The magnetic force experienced by positive charge of value Q moving with velocity v along x direction when it is at the origin is :



- (A) $\frac{Qv\mu_0 I}{4R}$ (B) $\frac{Qv\mu_0 I}{2R}$ (C) $\frac{Qv\mu_0 I}{2\sqrt{2}R}$ (D) 0
26. A charged particle is released from rest in a region of uniform electric and magnetic fields, which are parallel to each other. The locus of the particle will be a
- (A) helix of constant pitch (B) straight line
 (C) helix of varying pitch (D) cycloid
27. 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 $(x_0, y_0, 0)$ 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) $\frac{5\alpha}{2B_0}$
28. A particle of specific charge (q/m) is projected from the origin of coordinates with initial velocity $[u\hat{i} - v\hat{j}]$. Uniform electric magnetic fields exist in the region along the +y direction, of magnitude E and B. The particle will definitely return to the origin once if
- (A) $[vB/2\pi E]$ is an integer (B) $(u^2 + v^2)^{1/2} [B/\pi E]$ is an integer
 (C) $[vB/\pi E]$ is an integer (D) $[uB/\pi E]$ is an integer

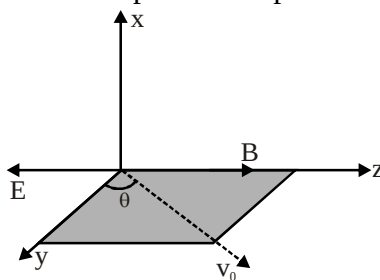
29. An electron moving with a velocity $\vec{V}_1 = 2\hat{i}$ m/s at a point in a magnetic field experiences a force $\vec{F}_1 = -2\hat{j}$ N. If the electron is moving with a velocity $\vec{V}_2 = 2\hat{j}$ m/s at the same point, it experiences a force $\vec{F}_2 = +2\hat{i}$ N. The force the electron would experience if it were moving with a velocity $\vec{V}_3 = 2\hat{k}$ m/s at the same point is

(A) zero (B) $2\hat{k}$ N (C) $-2\hat{k}$ N (D) information is insufficient

30. A metal ring of radius $r = 0.5$ m with its plane normal to a uniform magnetic field B of induction 0.2 T carries a current $I = 100$ A. The tension in newtons developed in the ring is:

(A) 100 (B) 50 (C) 25 (D) 10

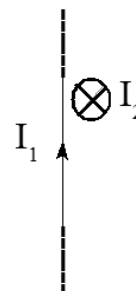
31. In a certain region uniform electric field E and magnetic field B are present in the opposite direction. At the instant $t = 0$, a particle of mass m carrying a charge q is given velocity v_0 at an angle θ , with the y axis, in the yz plane. The time after which the speed of the particle would be minimum is equal to



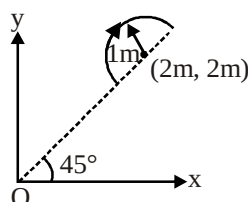
(A) $\frac{mv_0}{qE}$ (B) $\frac{mv_0 \sin \theta}{qE}$ (C) $\frac{mv_0 \cos \theta}{qE}$ (D) $\frac{2\pi m}{qB}$

32. Two long wires which are perpendicular to each other carry currents as shown in the figure. They are free to move. Consider only magnetic interaction

(A) the two wires will come closer transitionally
(B) the two wires will move away transitionally
(C) the two wires will rotate such that the currents become uni-directional and then come closer due to attraction
(D) the two wires will rotate such that the currents become anti-parallel and then move far away due to repulsion.

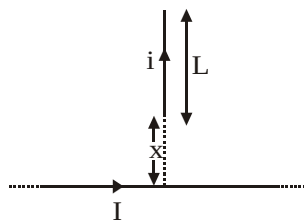


33. A uniform magnetic field $\vec{B} = (3\hat{i} + 4\hat{j} + \hat{k})$ Tesla exist in a region of space. A semicircular wire of radius 1 m carrying a current of 1 A having its centre at $(2, 2, 0)$ m is placed on the X - Y plane as shown. The force on the semicircular wire will be

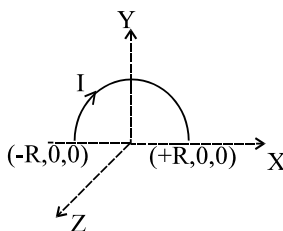


(A) $\frac{1}{\sqrt{2}} (\hat{i} - \hat{j} + \hat{k})$ N (B) $\sqrt{2} (\hat{i} - \hat{j} + \hat{k})$ N
(C) $\frac{1}{\sqrt{2}} (\hat{i} + \hat{j} - \hat{k})$ N (D) $\sqrt{2} (\hat{i} + \hat{j} - \hat{k})$ N

34. The magnetic force between wires as shown in figure is :

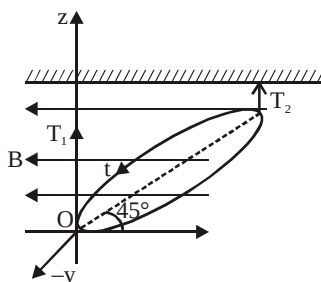


- (A) $\frac{\mu_0 i I^2}{2\pi} \ln\left(\frac{x+\ell}{2x}\right)$ (B) $\frac{\mu_0 i I^2}{2\pi} \ln\left(\frac{2x+\ell}{2x}\right)$ (C) $\frac{\mu_0 i I}{2\pi} \ln\left(\frac{x+\ell}{x}\right)$ (D) None of these
35. A very long wire carrying current I is fixed along x -axis. Another parallel finite wire carrying a current in the opposite direction is kept at a distance d above the wire in xy plane. The second wire is free to move parallel to itself. The options available for its small displacements are in
(i) +ve x direction (ii) +ve y direction (iii) +ve z direction
Taking gravity in negative y direction, the nature of equilibrium of second wire is
(A) stable for movement in x direction, unstable for movement in y direction, neutral for movement in z direction
(B) stable for movement in y direction, unstable for movement in z direction, neutral for movement in x direction
(C) stable for movement in z direction, unstable for movement in y direction, neutral for movement in x direction
(D) stable for movement in y direction, unstable for movement in x direction, neutral for movement in z direction
36. A conductor of length ℓ is placed perpendicular to a horizontal uniform magnetic field B . Suddenly a certain amount of charge 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) $\frac{m\sqrt{gh}}{B\ell}$ (B) $\frac{2m\sqrt{gh}}{3B\ell}$ (C) $\frac{m\sqrt{2gh}}{B\ell}$ (D) None of these
37. A semi circular current carrying wire having radius R is placed in x - y plane with its centre at origin 'O'. There is non-uniform magnetic field $\vec{B} = \frac{B_0 x}{2R} \hat{k}$ (here B_0 is +ve constant) is existing in the region. The magnetic force acting on semi circular wire will be along

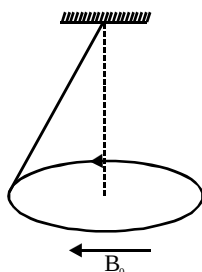


- (A) $-x$ -axis (B) $+y$ -axis (C) $-y$ -axis (D) $+x$ -axis

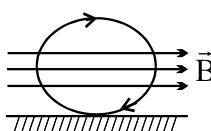
38. A current carrying circular coil of single turn of mass $\frac{\pi}{10}$ kg & radius 25cm is hanging by two ideal strings. A constant magnetic field 1T is set up in the horizontal direction and 1A current flows through coil as shown in figure. Then the ratio of tension (T_1/T_2) in the string will be :



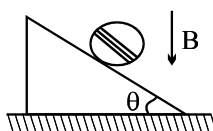
- (A) 2 : 1 (B) 5 : 3 (C) 4 : 1 (D) 1 : 2
39. A uniform current carrying ring of mass m and radius R is connected by a massless string as shown. A uniform magnetic field B_0 exist in the region to keep the ring in horizontal position, then the current in the ring is (ℓ = length of string)



- (A) $\frac{mg}{\pi R B_0}$ (B) $\frac{mg}{R B_0}$ (C) $\frac{mg}{3\pi R B_0}$ (D) $\frac{mg\ell}{\pi R^2 B_0}$
40. A conducting ring of mass 2 kg and radius 0.5 m is placed on a smooth horizontal plane. The ring carries a current $i = 4$ A. A horizontal magnetic field $B = 10$ T is switched on at time $t = 0$ as shown in figure. The initial angular acceleration of the ring will be



- (A) $40 \pi \text{ rad/s}^2$ (B) $20 \pi \text{ rad/s}^2$ (C) $5 \pi \text{ rad/s}^2$ (D) $15 \pi \text{ rad/s}^2$
41. In the figure shown a coil of single turn is wound on a sphere of radius R and mass m . The plane of the coil is parallel to the plane and lies in the equatorial plane of the sphere. Current in the coil is i . The value of B if the sphere is in equilibrium is



- (A) $\frac{mg \cos \theta}{\pi i R}$ (B) $\frac{mg}{\pi i R}$ (C) $\frac{mg \tan \theta}{\pi i R}$ (D) $\frac{mg \sin \theta}{\pi i R}$

MULTIPLE CORRECT TYPE

42. A charged particle is projected with initial velocity in x-y plane in a magnetic field $\vec{B} = 10\hat{k}\text{T}$ from the origin. The particle moves in a circle and just touches a straight line $y = 5\text{ (m)}$ at $x = 5\sqrt{3}\text{ (m)}$. Then (mass of particle = $5 \times 10^{-5}\text{ kg}$, charge = $1\text{ }\mu\text{C}$)
- (A) The particle is projected at an angle 60° with x-axis
 (B) The radius of the circle is 10 m
 (C) The speed of the particle is 2m/s
 (D) The speed of the particle is $5\sqrt{3}\text{ m/s}$

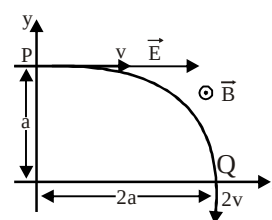
43. A particle of charge $+q$ and mass m moving under the influence of a uniform electric field $E\hat{i}$ and uniform magnetic field $B\hat{k}$ follows a trajectory from P to Q as shown in figure. The velocities at P and Q are $\hat{v}_i$ and $-2v\hat{j}$, Which of the following statement(s) is/are correct ?

(A) $E = \frac{3}{4} \left[\frac{mv^2}{qa} \right]$

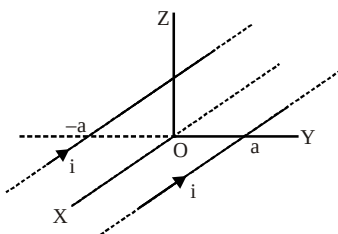
(B) Rate of work done by the electric field at P is $\frac{3}{4} \left[\frac{mv^3}{a} \right]$

(C) Rate of work done by the electric field at P is zero

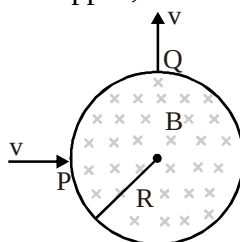
(D) Rate of work done by both the fields at Q is zero



44. Two long thin, parallel conductors carrying equal currents in the same direction are fixed parallel to the x-axis, one passing through $y = a$ and the other through $y = -a$. The resultant magnetic field due to the two conductors at any point is B. Which of the following are correct?



- (A) $B = 0$ for all points on the x-axis
 (B) At all points on the y-axis, excluding the origin, B has only a z-component.
 (C) At all points on the z-axis, excluding the origin, B has only a y-component.
 (D) B cannot have an x-component.
45. A particle of charge ' q ' and mass ' m ' enters normally (at point P) in a region of magnetic field with speed v . It comes out normally from Q after time T as shown in figure. The magnetic field B is present only in the region of radius R and is uniform. Initial and final velocities are along radial direction and they are perpendicular to each other. For this to happen, which of the following expression(s) is/are correct—



(A) $B = \frac{mv}{qR}$

(B) $T = \frac{\pi R}{2v}$

(C) $T = \frac{\pi m}{2qB}$

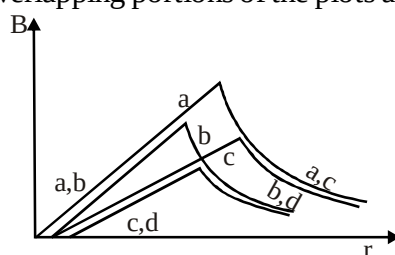
(D) None of these

46. A particle of mass m and charge q moving with velocity $\vec{v}$ enters a region of uniform magnetic field of induction $\vec{B}$. Then
- (A) its path in the region of the field is always circular
- (B) its path in the region of the field is circular if $\vec{v} \cdot \vec{B} = 0$
- (C) its path in the region of the field is a straight line if $\vec{v} \times \vec{B} = 0$
- (D) distance travelled by the particle in time T does not depend on the angle between $\vec{v}$ and $\vec{B}$

COMPREHENSION TYPE

Paragraph for Question Nos. 47 to 49

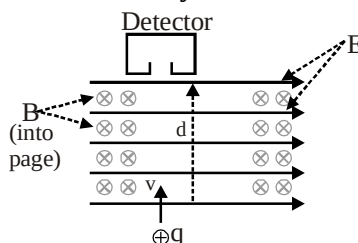
Curves in the graph shown give, as functions of radial distance r , the magnitude B of the magnetic field inside and outside four long wires a, b, c and d, carrying currents that are uniformly distributed across the cross sections of the wires. Overlapping portions of the plots are indicated by double labels.



47. Which wire has the greatest radius?
- (A) a (B) b (C) c (D) d
48. Which wire has the greatest magnitude of the magnetic field on the surface?
- (A) a (B) b (C) c (D) d
49. The current density in wire a is
- (A) greater than in wire c
- (B) less than in wire c
- (C) equal to that in wire c
- (D) not comparable to that in wire c due to lack of information

Paragraph for Question Nos. 50 to 53

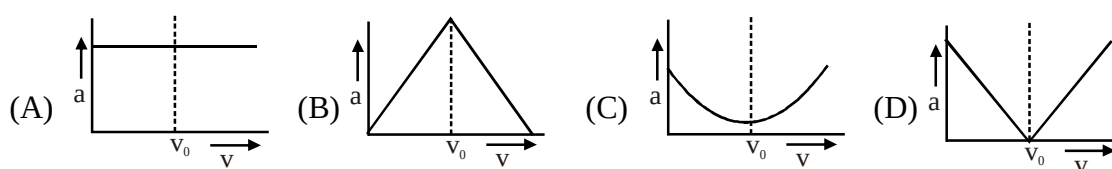
A velocity filter uses the properties of electric and magnetic fields to select charged particles that are moving with a specific velocity. Charged particles with varying speeds are directed into the filter as shown in figure. The filter consists of an electric field E and a magnetic field B , each of constant magnitude, directed perpendicular to each other as shown. The particles that move straight through the filter with their direction unaltered by the fields have the specific filter speed, v_0 . Those with speeds to v_0 may experience sufficiently little deflection that they also enter the detector.



The charged particle will experience a force due to the electric field given by the relationship $\vec{F} = q\vec{E}$, where q is the charge of the particle and $\vec{E}$ is the electric field. The moving particle will also experience a force due to the magnetic field. This force acts to oppose the force due to the electric field. The strength of the force due to the magnetic field is given by the relationship $\vec{F} = q(\vec{v} \times \vec{B})$, where q is the charge

of the particle, $\vec{v}$ is the speed of the particle, and $\vec{B}$ is the magnetic field strength. When the forces due to the two fields are equal and opposite, the net force on the particle will be zero, and the particle will pass through the filter with its path unaltered. The electric and magnetic field strengths can be adjusted to choose the specific velocity to be filtered. The effects of gravity can be neglected.

50. The electric and magnetic fields in the filter of figure are adjusted to detect particles with positive charge q of a certain speed, v_0 . Which of the following expressions is equal to this speed ?
(A) $B/(q^2E)$ (B) $E/(q^2B)$ (C) B/E (D) E/B
51. Which of the following is true about the velocity filter shown in figure ?
(A) It would not work with negatively charged particles
(B) The wider the detector entrance, the more narrow the range of speed detected
(C) The greater the distance d , the more narrow the range of speeds detected
(D) The detector may not detect a charged particle with the desired filter speed if its charge is too high
52. Which of the following statements is true regarding a charged particle that is moving through the filter at a speed that is less than the filter speed ?
(A) It experiences a greater force due to the magnetic field than due to the electric field
(B) It experiences a greater force due to the electric field than due to the magnetic field
(C) It experiences equal force due to both fields but greater acceleration due to the electric field
(D) It experiences equal force due to both fields but greater acceleration due to the magnetic field
53. Particles of identical mass and charge are sent through the filter at varying speeds, and the magnitude of acceleration of each particle is recorded as it first begins to be deflected. If the filter is set to detect particles of speed v_0 , which one of the following is correct graph between acceleration and velocity of particle:



Paragraph for Question Nos. 54 & 55

Each atom in a paramagnetic material has a permanent magnetic moment associated with the net angular momentum of electrons. In a diamagnetic material with no applied magnetic field the individual atoms have no net magnetic moment ; the magnetic effects of the electrons in each individual atom cancel. An external magnetic field changes the motion of the electron and induces a net magnetic moment in each atom.

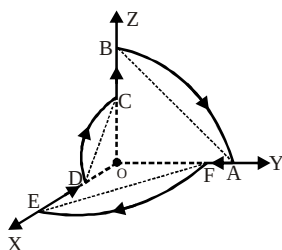
54. Consider an electron (charge e) of mass m orbiting a nucleus in orbit of radius r with speed v . An external field is applied parallel to orbital magnetic moment of electron. Taking change in speed to be small as compared to orbital speed and orbital radius to remain constant, find change in magnitude of magnetic moment :-
(A) $\frac{e^2 r^2 B}{4m}$ (B) $\frac{e^2 r^2 B}{2m}$ (C) $\frac{4e^2 r^2 B}{m}$ (D) $\frac{2e^2 r^2 B}{m}$

55. Mark the **CORRECT** statement :

- (A) If magnetic field is applied parallel to orbital magnetic moment ($\vec{M}$) of electron then M is decreased.
 (B) If magnetic field is applied parallel to orbital magnetic moment ($\vec{M}$) of electron then M is increased.
 (C) Change in magnetic moment $d\vec{M}$ vector is always perpendicular to $\vec{B}$
 (D) Change in magnetic moment $d\vec{M}$ vector is always parallel to $\vec{B}$

Paragraph for Question Nos. 56 to 58

In a rigid wire frame ABCDEFA, as shown in the figure, a current I_0 flows through the wire from F to A as shown in the figure. Radii of the three quarters AB, CD and EF are $r_1=3^{1/4}$ m, $r_2=3^{-1/4}$ m and $r_3=1$ m respectively with common centre at O. All the wires are light except for the portion ED which have a mass of 'm' kg.



56. The magnetic moment of the loop is

- (A) $\frac{\pi I_0}{4} \left[\sqrt{3} \hat{i} + \frac{1}{\sqrt{3}} \hat{j} + \hat{k} \right]$ (B) $-\frac{\pi I_0}{4} \left[\sqrt{3} \hat{i} + \frac{1}{\sqrt{3}} \hat{j} + \hat{k} \right]$
 (C) $\frac{\pi I_0}{4} \left[-\sqrt{3} \hat{i} - \frac{1}{\sqrt{3}} \hat{j} + \hat{k} \right]$ (D) $\frac{\pi I_0}{4} \left[-\sqrt{3} \hat{i} + \frac{1}{\sqrt{3}} \hat{j} + \hat{k} \right]$

57. If this loop is kept in a magnetic field of magnitude 2 T which is directed along positive y-axis, angular acceleration of the loop is [where $\ell = (r_3 - r_2)$]

- (A) $\frac{8\pi I_0}{m\ell^2} [\hat{i} + \sqrt{3}\hat{k}]$ (B) $\frac{6\pi I_0}{m\ell^2} [\hat{i} + \sqrt{3}\hat{k}]$ (C) $\frac{8\pi I_0}{m\ell^2} [\hat{i} - \sqrt{3}\hat{k}]$ (D) $\frac{6\pi I_0}{m\ell^2} [\hat{i} - \sqrt{3}\hat{k}]$

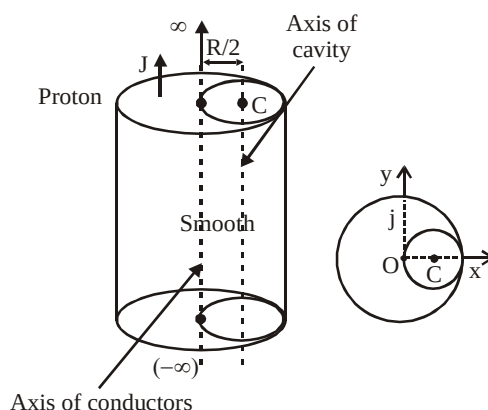
58. If circular wire AB, CD and EF are replaced by straight wires AB, CD and EF, as shown by the dotted lines and keeping the same sense of current, the magnetic field due to the straight wires at the center O is

- (A) $-\frac{\mu_0 I}{2\pi} \left[\frac{\hat{i}}{3^{1/4}} + 3^{1/4} \hat{j} + \hat{k} \right]$ (B) $-\frac{\mu_0 I}{4\pi} \left[\frac{\hat{i}}{3^{1/4}} + 3^{1/4} \hat{j} + \hat{k} \right]$
 (C) $-\frac{\mu_0 I}{\sqrt{2}\pi} \left[\frac{\hat{i}}{3^{1/4}} + 3^{1/4} \hat{j} + \hat{k} \right]$ (D) $-\frac{\mu_0 I}{2\sqrt{2}\pi} \left[\frac{\hat{i}}{3^{1/4}} + 3^{1/4} \hat{j} + \hat{k} \right]$

Paragraph for Question Nos. 59 to 61

Inside a homogenous long straight cylindrical wire of circular cross-sectional area with radius R . There is a circular cylinder cavity of radius $R/2$ whose axis is parallel to the conductor axis and displaced relative to it by a distance $R/2$. A current of density $\vec{j}$ flows along the wire whose top view and side view are shown in the figure.

A point positive charge 'q' and a negative charged particle $(-q)$ of equal mass m are projected with velocity $v_0 \hat{i}$ and $u_0 \hat{j}$ respectively from point C. Given that $\frac{8mv}{\mu_0 q j} < R^2$ and all collisions are perfectly elastic.



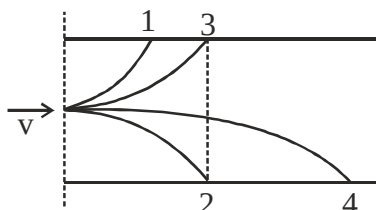
Read the above passage carefully and answer the following question.

59. The trajectory of motion of positive particle lies in plane.
 (A) x-y plane (B) y-z plane (C) x-z plane (D) none
60. The radius of curvature of motion of positive charge particle is given by :
 (A) $\frac{2mv_0}{q\mu_0 JR}$ (B) $\frac{4mv_0}{q\mu_0 JR}$ (C) $\frac{8mv_0}{q\mu_0 JR}$ (D) None of these
61. The time period motion of negative charged particle is given by :
 (A) $\frac{4\pi}{q\mu_0 JR}$ (B) $\frac{8\pi m}{q\mu_0 JR}$ (C) $\frac{16\pi m}{q\mu_0 JR}$ (D) None of these

MATRIX MATCH TYPE

62. A beam consisting of four types of ions A, B, C and D enters a region that contains a uniform magnetic field as shown. The field is perpendicular to the plane of the paper, but its precise direction is not given.

ION	MASS	CHARGE
A	2m	e
B	4m	-e
C	2m	-e
D	m	+e



All ions in the beam travel with the same speed. The table below gives the masses and charges of the ions. The ions fall at different positions 1, 2, 3 and 4, as shown. Correctly match the ions with respective falling positions.

Table-I

- (A) A
(B) B
(C) C
(D) D

Table-II

- (P) 1
(Q) 2
(R) 3
(S) 4

63. A charged particle with some initial velocity is projected in a region where uniform 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 possible paths of charged particle is mentioned. Match the entries of Column I with the entries of Column II.

Column-I

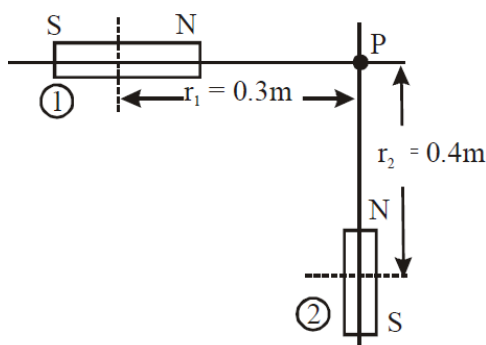
- (A) $\vec{E} = 0, \vec{B} \neq 0$ and initial velocity is at an unknown angle with $\vec{B}$
(B) $\vec{E} \neq 0, \vec{B} = 0$ and initial velocity is at an unknown angle with $\vec{E}$
(C) $\vec{E} \neq 0, \vec{B} \neq 0, \vec{E} \parallel \vec{B}$ and initial velocity is perpendicular to $\vec{E}$
(D) $\vec{E} \neq \vec{B}, B \neq 0, \vec{E}$ perpendicular $\vec{B}$ and initial velocity is perpendicular to both $\vec{E}$ and $\vec{B}$

Column-II

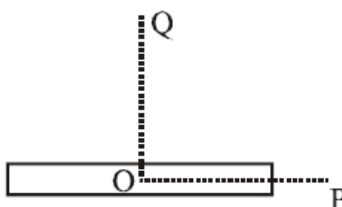
- (P) Straight line
(Q) Parabola
(R) Circular
(S) Helical path with nonuniform pitch
(T) Helical path with uniform pitch

EXERCISE (ONLY FOR JEE MAINS)

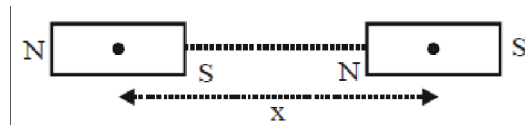
1. Two short magnets of magnetic moment $2Am^2$ and $5Am^2$ respectively are placed along two lines drawn at right angle to each other on the sheet of paper as shown in the figure. What is the magnetic field at the point of intersection of their axis:



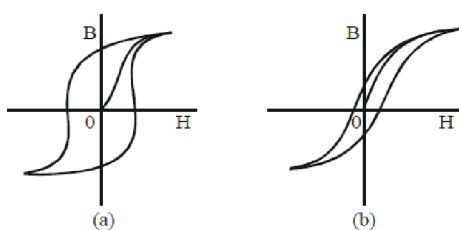
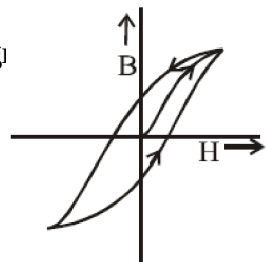
- (A) $2.15 \times 10^{-5} \text{ T}$ (B) $215 \times 10^{-5} \text{ T}$ (C) $2.15 \times 10^{-4} \text{ T}$ (D) $21.5 \times 10^{-5} \text{ T}$
2. A steel wire of length L has a magnetic moment M . It is then bent into a semi-circular arc; the new magnetic moment will be :
 (A) M (B) $2M/p$ (C) M/L (D) $M \times L$
3. Two bar magnets of the same mass, same length and breadth but having magnetic moments M and $2M$ are joined together north pole to north pole and suspended by a string. The time period of assembly in a magnetic field of strength H is 3 seconds. If now the polarity of one of the magnets is reversed and the combination is again made to oscillate in the same field, the time of oscillations is :
 (A) $\sqrt{3} \text{ sec}$ (B) $3\sqrt{3} \text{ sec}$ (C) 3 sec (D) 6 sec
4. When magnetic field at P and Q is same then $OP/OQ = ?$



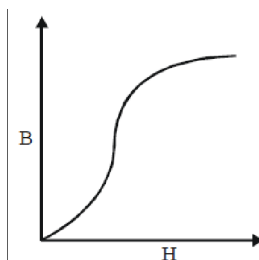
- (A) $\sqrt[3]{2}$ (B) $\frac{1}{\sqrt[3]{2}}$ (C) $2\sqrt{2}$ (D) $\frac{3}{2\sqrt{2}}$
5. Similar pole each of pole strength m are placed at a distance of 1, 2, 4, 8, ...meters from the origin on the x-axis. Where do you place a similar pole n on the other side of the origin so that the origin becomes a neutral point :-
 (A) 0.5 m (B) 0.5774 m (C) 0.86 m (D) 1m
6. Two identical poles each of pole strength $4 \times 10^{-3} \text{ amp-m}$ placed at the two corners of an equilateral triangle of side 20 cm. The magnetic field at the third corner is :-
 (A) $\sqrt{3} \times 10^{-8} \text{ N/amp-m}$ (B) $\frac{\sqrt{3}}{4} \times 10^{-8} \text{ N / amp - m}$
 (C) zero (D) 10^{-8} N/amp-m

7. The magnetic field at a point on the axis of a dipole is 20 Wb/m^2 Northwards. What will be the magnetic induction at the point if the dipole be rotated anticlockwise by 90° :-
 (A) 10 Wb/m^2 Eastwards (B) 10 Wb/m^2 Southwards
 (C) 10 Wb/m^2 Northwards (D) 20 Wb/m^2 Southwards
8. A bar magnet of magnetic moment 2A-m^2 free to rotate about a vertical axis passing through its centre. The magnet is released from rest from east-west position. Then the kinetic energy of the magnet as it takes North-South position is (horizontal component of the earth's field is $25\mu\text{T}$ and angle of declination is zero :-
 (A) $25 \mu\text{J}$ (B) $50 \mu\text{J}$ (C) $100 \mu\text{J}$ (D) $125 \mu\text{J}$
9. The mid points of two small magnetic dipoles of length d in end-on positions, are separated by a distance x , ($x \gg d$). The force between them is proportional to x^{-n} where n is :-
- 
- (A) 3 (B) 4 (C) 2 (D) 1
10. A permanent magnet has shape of a thin disc with magnetic moment along its axis the radius of the disc is 1 cm . The magnetic field due to it can be assumed to be that due to molecular current I' flowing along the rim of the disc. If $\vec{B}$ at a distance of 10 cm from its centre on the axis is $30\mu\text{T}$, find I' (approximately):-
 (A) 1 kA (B) 0.5 kA (C) 2.5 kA (D) 3 kA
11. The angle of dip at a place is 30° and the intensity of the vertical component of the earth's magnetic field $V = 6 \times 10^{-5} \text{ T}$. The total intensity of the earth's magnetic field at this place is :
 (A) $7 \times 10^{-5} \text{ T}$ (B) $6 \times 10^{-5} \text{ T}$ (C) $5 \times 10^{-5} \text{ T}$ (D) $12 \times 10^{-5} \text{ T}$
12. The total intensity of the earth's magnetic field at the magnetic equator is 5 units. What is its value at a magnetic latitude of 37° degree?
 (A) $\sqrt{73}$ units (B) $\sqrt{52}$ units (C) 4 units (D) 3 units
13. A magnet is suspended in the magnetic meridian with an untwisted wire. The upper end of wire is rotated through 180° to deflect the magnet by 30° from magnetic meridian. When the magnet is replaced by another magnet, the upper end of wire is rotated through 270° to deflect the magnet 30° from magnetic meridian. The ratio of magnetic moments of magnets is :-
 (A) 1 : 5 (B) 1 : 8 (C) 5 : 8 (D) 8 : 5
14. The imagined magnet makes an angle of 11.3° with earth's axis. On the earth, there are two points where magnetic equator and geographic equator meet let the angle of dip and angle of declination at these point be θ & ϕ respectively :-
 (A) $\theta = \phi = 0^\circ$ (B) $\theta = 11.3^\circ, \phi = 0^\circ$ (C) $\theta = 0^\circ, \phi = 11.3^\circ$ (D) $\theta = \phi = 11.3^\circ$
15. A specimen of iron of permeability $8 \times 10^{-3} \text{ weber/amp} \times \text{metre}$ is placed in a magnetic field of intensity 160 amp/metre . Then magnetic field in this iron is :
 (A) $20 \times 10^3 \text{ Wb/m}^2$ (B) 1.28 Wb/m^2 (C) $5 \times 10^{-5} \text{ Wb/m}^2$ (D) 0.8 Wb/m^2
16. Curie temperature is the temperature above which :
 (A) a paramagnetic material becomes diamagnetic
 (B) a ferromagnetic material becomes diamagnetic
 (C) a paramagnetic material becomes ferromagnetic
 (D) a ferromagnetic material becomes paramagnetic

17. If a solution of ferromagnetic material is poured into a U-tube and one arm of this is placed between the poles of a strong magnet with the meniscus in line with the field, then the level of the solution will:
(A) Rise (B) Fall
(C) Rise till the liquid comes out (D) Remain unchanged
18. A sample of paramagnetic salt contains 2.0×10^{24} atomic dipoles each of dipole moment $1.5 \times 10^{-23} \text{ J T}^{-1}$. The sample is placed under a homogeneous magnetic field of 0.84T, and cooled to a temperature of 4.2K. The degree of magnetic saturation achieved is equal to 15%. What is the total dipole moment (approximate) of the sample for a magnetic field of 0.98 T and a temperature of 2.8K? (Assume Curie's law).
(A) 7.9 J T^{-1} (B) 52.5 J T^{-1} (C) 30 J T^{-1} (D) 4.6 J T^{-1}
19. The B-H curve for a certain specimen is schematically shown by the given diagram following is the correct magnetic nature of the specimen?
(A) Diamagnetic and not ferromagnetic or paramagnetic
(B) Ferromagnetic and not diamagnetic or paramagnetic
(C) Paramagnetic and not diamagnetic or ferromagnetic
(D) Applicable to all the three types of magnetism mentioned above
20. Two types of steel are characterized by the hysteresis loops shown in figure (a) and (b). The loops are obtained in the processes of magnetization and demagnetization of the steels. Which of the two types is best suited for using as the core of a transformer and which, for using as a permanent magnet ?



- (A) Both are best suited for transformer
(B) Both are best suited for permanent magnet
(C) A is best suited for permanent magnet & B is best suited for core of transformer
(D) A is best suited for core of transformer & B is best suited for permanent magnet
21. A material satisfied the relation $\mu_0(H + M) = 0$, where H and M are magnetic intensity and magnetisation respectively, then material is :-
(A) nonmagnetic (B) paramagnetic (C) ferrormagnetic (D) diamagnetic
22. The figure represent B-H curve for commercial iron. As H is increased, permeability :-



- (A) increases and becomes constant
(B) increases, reaches a maximum and then decreases
(C) decreases continuously till it becomes very small
(D) decreases reaches a minimum and then increases

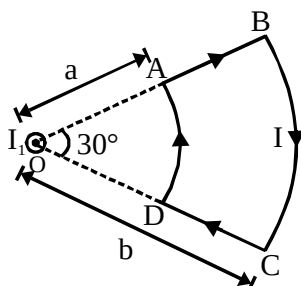
23. Consider magnetisation vector $\vec{M}$, magnetic intensity $\vec{H}$ and magnetic field $\vec{B}$. $(\vec{B} = \mu_0 (\vec{H} + \vec{M}))$. At the centre of a bar magnet :-
 (A) all three vectors point in same direction.
 (B) $\vec{B}$ and $\vec{H}$ point in same direction but $\vec{M}$ points in opposite direction.
 (C) $\vec{B}$ and $\vec{M}$ point in same direction but $\vec{H}$ points in opposite direction.
 (D) $\vec{M}$ and $\vec{H}$ point in same direction but $\vec{B}$ points in opposite direction.
24. Horizontal magnetic field of earth at Mumbai is 1.5×10^{-4} T in North direction. A small bar magnet of magnetic moment 10 Am^2 is kept on a horizontal table such that its North pole points due North. What is the magnetic field at 10 cm from centre of magnet at a point on its axis due North of it :-
 (A) 3.5×10^{-4} T (B) 5×10^{-5} T (C) 2.15×10^{-3} T (D) 1.15×10^{-3} T
25. A compass needle kept on a horizontal table points in direction 30° west of north. A line is marked showing this direction and compass is now kept in vertical plane containing this line. The needle points in direction 30° below horizontal. If the plane of compass is still vertical but contains true north south direction at what angle to horizontal will needle point :-
 (A) $\tan^{-1}\left(\frac{3}{2}\right)$ (B) $\tan^{-1}\left(\frac{2}{3}\right)$ (C) $\tan^{-1}(2)$ (D) $\tan^{-1}\left(\frac{1}{2}\right)$
26. In a moving coil galvanometer the number of turns $N = 24$, area of the coil $A = 2 \times 10^{-3} \text{ m}^2$, and the magnetic field strength $B = 0.2 \text{ T}$. To increase its current sensitivity by 25% we :-
 (A) increase B to 0.30 T (B) decrease A to $1.5 \times 10^{-3} \text{ m}^2$
 (C) increase N to 30 (D) none of the above
27. A thin rectangular magnet suspended freely has a period of oscillation equal to T . Now it is broken into two equal halves (each having half of the original length) and one piece is made to oscillate freely in the same field. If its period of oscillation is T' , the ratio T'/T is-
 (A) $\frac{1}{2\sqrt{2}}$ (B) $\frac{1}{2}$ (C) 2 (D) $\frac{1}{4}$
28. The magnetic lines of force inside a bar magnet:
 (A) are from north-pole to south-pole of the magnet
 (B) do not exist
 (C) depend upon the area of cross-section of the bar magnet
 (D) are from south-pole to north-pole of the magnet
29. The length of a magnet is large compared to its width and breadth. The time period of its oscillation in a vibration magnetometer is 2s. The magnet is cut along its length into three equal parts and three parts are then placed on each other with their like poles together. The time period of this combination will be-
 (A) 2s (B) $2/3 \text{ s}$ (C) $2\sqrt{3} \text{ s}$ (D) $2/\sqrt{3} \text{ s}$
30. The materials suitable for making electromagnets should have-
 (A) high retentivity and high coercivity (B) low retentivity and low coercivity
 (C) high retentivity and low coercivity (D) low retentivity and high coercivity

EXERCISE (JM)

- A long straight wire of radius a carries a steady current i . The current is uniformly distributed across its cross-section. The ratio of the magnetic field at $a/2$ and $2a$ is- [AIEEE - 2007]
 (1) $\frac{1}{4}$ (2) 4 (3) 1 (4) $\frac{1}{2}$
- A current I flows along the length of an infinitely long, straight, thin walled pipe. Then- [AIEEE - 2007]
 (1) the magnetic field is zero only on the axis of the pipe
 (2) the magnetic field is different at different points inside the pipe
 (3) the magnetic field at any point inside the pipe is zero
 (4) the magnetic field at all points inside the pipe is the same, but not zero
- A charged particle with charge q enters a region of constant, uniform and mutually orthogonal fields $\vec{E}$ and $\vec{B}$ with a velocity $\vec{v}$ perpendicular to both $\vec{E}$ and $\vec{B}$, and comes out without any change in magnitude or direction of $\vec{v}$. Then- [AIEEE - 2007]
 (1) $\vec{v} = \vec{E} \times \vec{B} / B^2$ (2) $\vec{v} = \vec{B} \times \vec{E} / B^2$ (3) $\vec{v} = \vec{E} \times \vec{B} / E^2$ (4) $\vec{v} = \vec{B} \times \vec{E} / E^2$
- Two identical conducting wires AOB and COD are placed at right angles to each other. The wire AOB carries an electric current I_1 and COD carries a current I_2 . The magnetic field on a point lying at a distance d from O, in a direction perpendicular to the plane of the wires AOB and COD, will be given by- [AIEEE - 2007]
 (1) $\frac{\mu_0}{2\pi} \left(\frac{I_1 + I_2}{d} \right)^{1/2}$ (2) $\frac{\mu_0}{2\pi d} (I_1^2 + I_2^2)^{1/2}$ (3) $\frac{\mu_0}{2\pi d} (I_1 + I_2)$ (4) $\frac{\mu_0}{2\pi d} (I_1^2 + I_2^2)$
- A charged particle moves through a magnetic field perpendicular to its direction. Then- [AIEEE - 2007]
 (1) the momentum changes but the kinetic energy is constant
 (2) both momentum and kinetic energy of the particle are not constant
 (3) both momentum and kinetic energy of the particle are constant
 (4) kinetic energy changes but the momentum is constant
- A horizontal overhead powerline is at a height of 4m from the ground and carries a current of 100 A from east to west. The magnetic field directly below it on the ground is ($\mu_0 = 4\pi \times 10^{-7} \text{TmA}^{-1}$) [AIEEE - 2008]
 (1) $2.5 \times 10^{-7} \text{T}$ southward (2) $5 \times 10^{-6} \text{T}$ northward
 (3) $5 \times 10^{-6} \text{T}$ southward (4) $2.5 \times 10^{-7} \text{T}$ northward

Direction :- Question number 7 and 8 are based on the following paragraph.

A current loop ABCD is held fixed on the plane of the paper as shown in the figure. The arcs BC (radius = b) and DA (radius = a) of the loop are joined by two straight wires AB and CD. A steady current I is flowing in the loop. Angle made by AB and CD at the origin O is 30° . Another straight thin wire with steady current I_1 flowing out of the plane of the paper is kept at the origin.



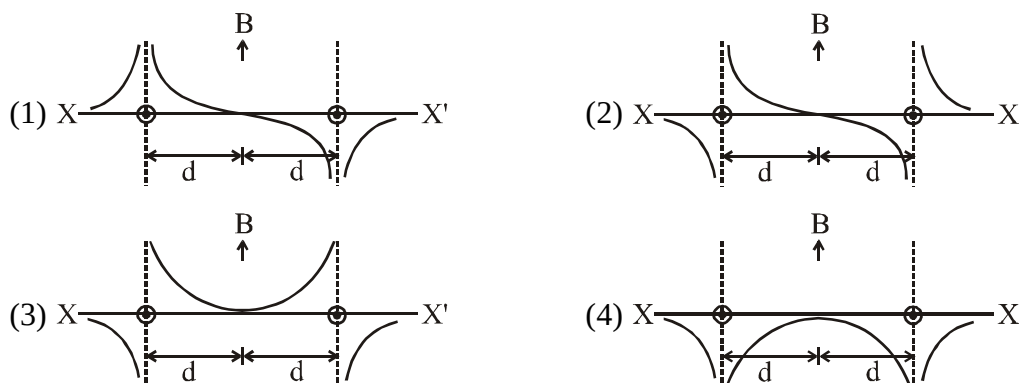
7. The magnitude of the magnetic field (B) due to the loop ABCD at the origin (O) is :- [AIEEE - 2009]

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

8. Due to the presence of the current I_1 at the origin:- [AIEEE - 2009]

- (1) The magnitude of the net force on the loop is given by $\frac{I_1 I}{4\pi} \mu_0 \left[2(b-a) + \frac{\pi}{3}(a+b) \right]$
 (2) The magnitude of the net force on the loop is given by $\frac{\mu_0 I I_1}{24ab} (b-a)$
 (3) The forces on AB and DC are zero
 (4) The forces on AD and BC are zero

9. Two long parallel wires are at a distance $2d$ apart. They carry steady equal currents flowing out of the plane of the paper as shown. The variation of the magnetic field B along the line XX' is given by:- [AIEEE - 2010]



10. A current I flows in an infinity 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 :- [AIEEE - 2011]

(1) $\frac{\mu_0 I}{2\pi R}$ (2) $\frac{\mu_0 I}{4\pi R}$ (3) $\frac{\mu_0 I}{\pi^2 R}$ (4) $\frac{\mu_0 I}{2\pi^2 R}$

11. An electric charge $+q$ moves with velocity $\vec{v} = 3\hat{i} + 4\hat{j} + \hat{k}$, in an electromagnetic field given by :-
 $\vec{E} = 3\hat{i} + \hat{j} + 2\hat{k}$

$\vec{B} = \hat{i} + \hat{j} - 3\hat{k}$. The y-component of the force experienced by $+q$ is :- [AIEEE - 2011]

(1) $2q$ (2) $11q$ (3) $5q$ (4) $3q$

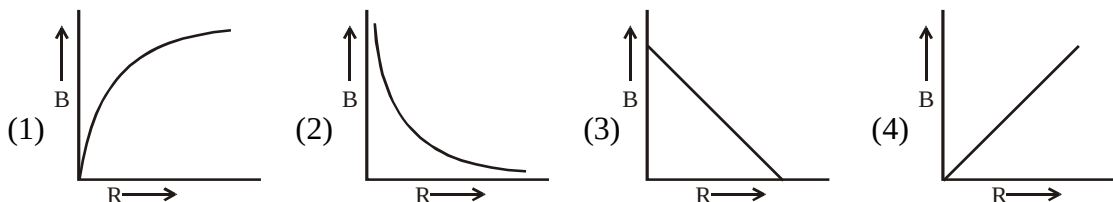
12. A thin circular disk of radius R is uniformly charged with density $\sigma > 0$ per unit area. The disk rotates about its axis with a uniform angular speed ω . The magnetic moment of the disk is :- [AIEEE - 2011]

(1) $2\pi R^4 \sigma \omega$ (2) $\pi R^4 \sigma \omega$ (3) $\frac{\pi R^4}{2} \sigma \omega$ (4) $\frac{\pi R^4}{4} \sigma \omega$

13. Proton, Deuteron and alpha particle of the same kinetic energy are moving in circular trajectories in a constant magnetic field. The radii of proton, deuteron and alpha particle are respectively r_p , r_d and r_α . Which one of the following relations is correct ? [AIEEE - 2012]

(1) $r_\alpha = r_d > r_p$ (2) $r_\alpha = r_d = r_p$ (3) $r_\alpha = r_p < r_d$ (4) $r_\alpha > r_d > r_p$

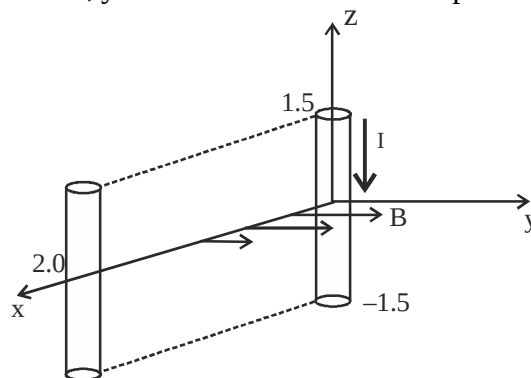
14. A charge Q is uniformly distributed over the surface of non-conducting disc of radius R . The disc rotates about an axis perpendicular to its plane and passing through its centre with an angular velocity ω . As a result of this rotation a magnetic field of induction B is obtained at the centre of the disc. If we keep both the amount of charge placed on the disc and its angular velocity to be constant and vary the radius of the disc then the variation of the magnetic induction at the centre of the disc will be represented by the figure :-
[AIEEE - 2012]



15. Two short bar magnets of length 1 cm each have magnetic moments 1.20 Am^2 and 1.00 Am^2 respectively. They are placed on a horizontal table parallel to each other with their N poles pointing towards the South. They have a common magnetic equator and are separated by a distance of 20.0 cm. The value of the resultant horizontal magnetic induction at the mid-point O of the line joining their centres is close to :-
(Horizontal component of earth's magnetic induction is $3.6 \times 10^{-5} \text{ Wb/m}^2$) [AIEEE - 2013]

- (1) $3.6 \times 10^{-5} \text{ Wb/m}^2$ (2) $2.56 \times 10^{-4} \text{ Wb/m}^2$
(3) $3.50 \times 10^{-4} \text{ Wb/m}^2$ (4) $5.80 \times 10^{-4} \text{ Wb/m}^2$

16. A conductor lies along the z -axis at $-1.5 \leq z \leq 1.5 \text{ m}$ and carries a fixed current of 10.0 A in $-\hat{a}_z$ direction (see figure). For a field $\vec{B} = 3.0 \times 10^{-4} e^{-0.2x} \hat{a}_y \text{ T}$, find the power required to move the conductor at constant speed to $x = 2.0 \text{ m}$, $y = 0 \text{ m}$ in $5 \times 10^{-3} \text{ s}$. Assume parallel motion along the x -axis.



[JEE (Mains)-2014]

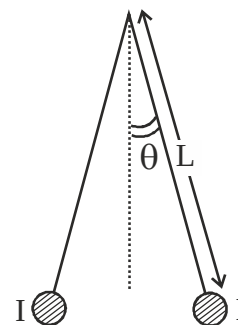
- (1) 14.85 W (2) 29.7 W (3) 1.57 W (4) 2.97 W

17. The coercivity of a small magnet where the ferromagnet gets demagnetized is $3 \times 10^3 \text{ A m}^{-1}$. The current required to be passed in a solenoid of length 10 cm and number of turns 100, so that the magnet gets demagnetized when inside the solenoid, is : [JEE(Mains) - 2014]

- (1) 3A (2) 6 A (3) 30 mA (4) 60 mA

18. Two long current carrying thin wires, both with current I , are held by the insulating threads of length L and are in equilibrium as shown in the figure, with threads making an angle ' θ ' with the vertical. If wires have mass λ per unit length then the value of I is :- (g = gravitational acceleration) [JEE (Mains) - 2015]

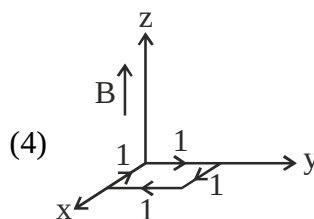
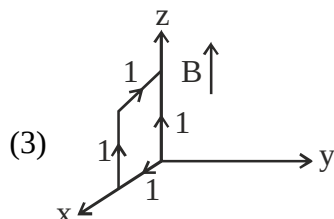
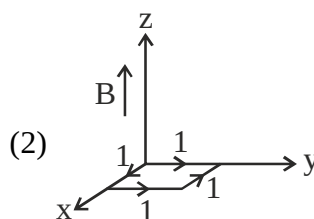
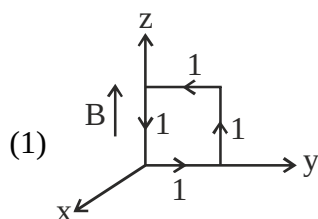
- (1) $2\sqrt{\frac{\pi g L}{\mu_0}} \tan \theta$ (2) $\sqrt{\frac{\pi \lambda g L}{\mu_0}} \tan \theta$
(3) $\sin \theta \sqrt{\frac{\pi \lambda g L}{\mu_0 \cos \theta}}$ (4) $2 \sin \theta \sqrt{\frac{\pi \lambda g L}{\mu_0 \cos \theta}}$



19. Two coaxial solenoids of different radii carry current I in the same direction. Let $\vec{F}_1$ be the magnetic force on the inner solenoid due to the outer one and $\vec{F}_2$ be the magnetic force on the outer solenoid due to the inner one. then : [JEE Main - 2015]

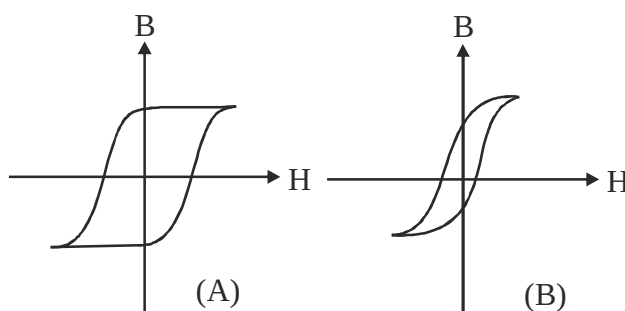
- (1) $\vec{F}_1$ is radially inwards and $\vec{F}_2 = 0$ (2) $\vec{F}_1$ is radially outward and $\vec{F}_2 = 0$
(3) $\vec{F}_1 = \vec{F}_2 = 0$ (4) $\vec{F}_1$ is radially inwards and $\vec{F}_2$ is radially outwards.

20. A rectangular loop of sides 10 cm and 5 cm carrying a current of 12 A is placed in different orientations as shown in the figures below: [JEE MAIN 2015]



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 ?

- (1) (a) and (c), respectively (2) (b) and (d), respectively
(3) (b) and (c), respectively (4) (a) and (b), respectively
21. Hysteresis loops for two magnetic materials A and B are given below :



These materials are used to make magnets for electric generators, transformer core and electromagnet core. Then it is proper to use ; [JEE Main-2016]

- (1) B for electromagnets and transformers.
(2) A for electric generators and transformers.
(3) A for electromagnets and B for electric transformers.
(4) A for transformers and B for electric generators.

22. 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 field at the centres of the circle and square respectively, then the ratio $\frac{B_A}{B_B}$ is: **[JEE MAIN 2016]**

(1) $\frac{\pi^2}{16\sqrt{2}}$ (2) $\frac{\pi^2}{16}$ (3) $\frac{\pi^2}{8\sqrt{2}}$ (4) $\frac{\pi^2}{8}$

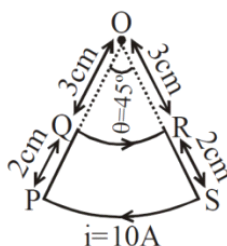
23. A magnetic needle of magnetic moment $6.7 \times 10^{-2} \text{ Am}^2$ and moment of inertia $7.5 \times 10^{-6} \text{ kg m}^2$ is performing simple harmonic oscillations in a magnetic field of 0.01 T . Time taken for 10 complete oscillations is : **[JEE Main-2017]**

(1) 6.98 s (2) 8.76 s (3) 6.65 s (4) 8.89 s

24. An electron, a proton and an alpha particle having the same kinetic energy are moving in circular orbits of radii r_e, r_p, r_α respectively in a uniform magnetic field B . The relation between r_e, r_p, r_α is **[JEE Main-2018]**

(1) $r_e < r_\alpha < r_p$ (2) $r_e > r_p = r_\alpha$ (3) $r_e < r_p = r_\alpha$ (4) $r_e < r_p < r_\alpha$

25. A current loop, having two circular arcs joined by two radial lines is shown in the figure. It carries a current of 10 A . The magnetic field at point O will be close to : **[JEE Main-2019]**



(1) $1.0 \times 10^{-5} \text{ T}$ (2) $1.5 \times 10^{-5} \text{ T}$ (3) $1.0 \times 10^{-7} \text{ T}$ (4) $1.0 \times 10^{-7} \text{ T}$

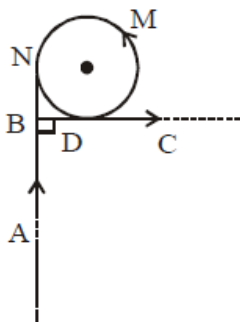
26. One of the two identical conducting wires of length L is bent in the form of a circular loop and the other one into a circular coil of N identical turns. If the same current is passed in both, the ratio of the magnetic field at the central of the loop (B_L) to that at the centre of the coil (B_C), i.e. $\frac{B_L}{B_C}$ will be : **[JEE Main-2019]**

(1) $\frac{1}{N^2}$ (2) N^2 (3) N (4) $\frac{1}{N}$

27. A particle having the same charge as of electron moves in a circular path of radius 0.5 cm under the influence of a magnetic field of 0.5 T . If an electric field of 100 V/m makes it to move in a straight path, then the mass of the particle is (Given charge of electron $= 1.6 \times 10^{-19} \text{ C}$) **[JEE Main-2019]**

(1) $1.6 \times 10^{-27} \text{ kg}$ (2) $1.6 \times 10^{-19} \text{ kg}$ (3) $9.1 \times 10^{-31} \text{ kg}$ (4) $2.0 \times 10^{-24} \text{ kg}$

28. A magnet of total magnetic moment $10^{-2} \hat{i}$ A-m² is placed in a time varying magnetic field, $B \hat{i} (\cos \omega t)$ where $B = 1$ Tesla and $\omega = 0.125$ rad/s. The work done for reversing the direction of the magnetic moment at $t = 1$ second, is : **[JEE Main-2019]**
 (1) 0.014 J (2) 0.028 J (3) 0.007 J (4) 0.01 J
29. In an experiment electrons are accelerated, from rest, by applying a voltage of 500 V. Calculate the radius of the path if a magnetic field 100 mT is then applied.
 [Charge of the electron = 1.6×10^{-19} C **[JEE Main-2019]**
 Mass of the electron = 9.1×10^{-31} kg]
 (1) 7.5×10^{-3} m (2) 7.5×10^{-2} m (3) 7.5×10^{-4} m (4) 7.5 m
30. A paramagnetic substance in the form of a cube with sides 1 cm has a magnetic dipole moment of 20×10^{-6} J/T when a magnetic intensity of 60×10^3 A/m is applied. Its magnetic susceptibility is:- **[JEE Main-2019]**
 (1) 4.3×10^{-2} (2) 3.3×10^{-2} (3) 3.3×10^{-4} (4) 2.3×10^{-2}
31. The dimension of $\frac{B^2}{2\mu_0}$, where B is magnetic field and μ_0 is the magnetic permeability of vacuum, is : **[JEE Main-2020]**
 (1) ML^2T^{-2} (2) MLT^{-2} (3) ML^2T^{-1} (4) $ML^{-1}T^{-2}$
32. A particle of mass m and charge q has an initial velocity $\vec{v} = v_0 \hat{j}$. If an electric field $\vec{E} = E_0 \hat{i}$ and magnetic field $\vec{B} = B_0 \hat{i}$ act on the particle, its speed will double after a time : **[JEE Main-2020]**
 (1) $\frac{3mv_0}{qE_0}$ (2) $\frac{\sqrt{3}mv_0}{qE_0}$ (3) $\frac{2mv_0}{qE_0}$ (4) $\frac{\sqrt{2}mv_0}{qE_0}$
33. Proton with kinetic energy of 1 MeV moves from south to north. It gets an acceleration of 10^{12} m/s² by an applied magnetic field (west to east). The value of magnetic field : (Rest mass of proton is 1.6×10^{-27} kg) **[JEE Main-2020]**
 (1) 71 mT (2) 7.1 mT (3) 0.71 mT (4) 0.071 mT
34. A very long wire ABDMNDC is shown in figure carrying current I . AB and BC parts are straight, long and at right angle. At D wire forms a circular turn DMND of radius R . AB, BC parts are tangential to circular turn at N and D. Magnetic field at the centre of circle is : **[JEE Main-2020]**



- (1) $\frac{\mu_0 I}{2\pi R}(\pi + 1)$ (2) $\frac{\mu_0 I}{2R}$ (3) $\frac{\mu_0 I}{2\pi R}\left(\pi + \frac{1}{\sqrt{2}}\right)$ (4) $\frac{\mu_0 I}{2\pi R}\left(\pi - \frac{1}{\sqrt{2}}\right)$

35. A charged particle of mass 'm' and charge 'q' moving under the influence of uniform electric field $E\hat{i}$ and a uniform magnetic field $B\hat{k}$ follows a trajectory from point P to Q as shown in figure. The velocities at P and Q are respectively, $v\hat{i}$ and $-2v\hat{j}$. Then which of the following statements (A, B, C, D) are the correct? (Trajectory shown is schematic and not to scale)

(A) $E = \frac{3}{4} \left(\frac{mv^2}{qa} \right)$

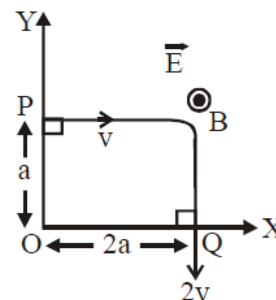
(B) Rate of work done by the electric field at P is $\frac{3}{4} \left(\frac{mv^3}{a} \right)$

(C) Rate of work done by both the fields at Q is zero

(D) The difference between the magnitude of angular momentum of the particle at P and Q is $2mav$.

[JEE Main-2020]

- (1) (A), (C), (D) (2) (A), (B), (C) (3) (B), (C), (D) (4) (A), (B), (C), (D)



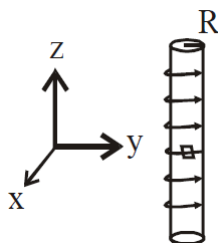
36. A long, straight wire of radius a carries a current distributed uniformly over its cross-section. The ratio of the magnetic fields due to the wire at distance $\frac{a}{3}$ and $2a$, respectively from the axis of the wire is :

[JEE Main-2020]

- (1) $1/3$ (2) $2/3$ (3) 2 (4) $3/2$

37. An electron gun is placed inside a long solenoid of radius R on its axis. The solenoid has n turns/length and carries a current I . The electron gun shoots an electron along the radius of the solenoid with speed v . If the electron does not hit the surface of the solenoid, maximum possible value of v is (all symbols have their standard meaning):

[JEE Main-2020]



- (1) $\frac{e\mu_0 nIR}{m}$ (2) $\frac{e\mu_0 nIR}{4m}$ (3) $\frac{2e\mu_0 nIR}{m}$ (4) $\frac{e\mu_0 nIR}{2m}$

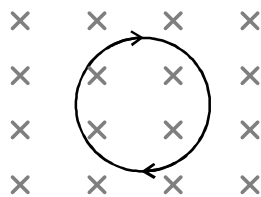
38. A small circular loop of conducting wire has radius a and carries current I . It is placed in a uniform magnetic field B perpendicular to its plane such that when rotated slightly about its diameter and released, it starts performing simple harmonic motion of time period T . If the mass of the loop is m then:

[JEE Main-2020]

- (1) $T = \sqrt{\frac{2\pi m}{IB}}$ (2) $T = \sqrt{\frac{\pi m}{2IB}}$ (3) $T = \sqrt{\frac{2m}{IB}}$ (4) $T = \sqrt{\frac{\pi m}{IB}}$

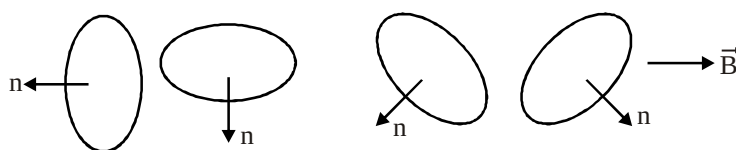
EXERCISE (JA)

1. A circular coil carrying current I is placed in a region of uniform magnetic field acting perpendicular to a coil as shown in the figure. Mark correct option [JEE 2003 (Scr)]



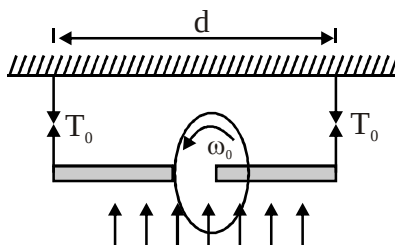
- (A) coil expands (B) coil contracts (C) coil moves left (D) coil moves right

2. Figure represents four positions of a current carrying coil in a magnetic field directed towards right. $\hat{n}$ represent the direction of area vector of the coil. The correct order of potential energy is : [JEE 2003 (Scr)]

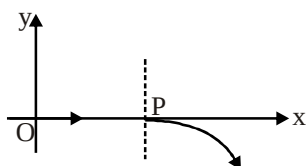


- (A) $I > III > II > IV$ (B) $I < III < II < IV$ (C) $IV < I < II < III$ (D) $III > II > IV > I$

3. A wheel of radius R having charge Q , uniformly distributed on the rim of the wheel is free to rotate about a light horizontal rod. The rod is suspended by light inextensible string and a magnetic field B is applied as shown in the figure. The initial tensions in the strings are T_0 . If the breaking tension of the strings are $\frac{3T_0}{2}$, find the maximum angular velocity ω_0 with which the wheel can be rotate.



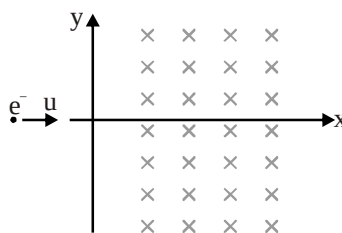
4. For a positively charged particle moving in a $x-y$ plane initially along the x -axis, there is a sudden change in its path due to the presence of electric and/or magnetic field beyond P . The curved path is shown in the $x-y$ plane and is found to be non-circular. Which one of the following combinations is possible? [IIT JEE-2003]



- (A) $\vec{E} = 0$; $\vec{B} = b\hat{j} + c\hat{k}$ (B) $\vec{E} = a\hat{i}$; $\vec{B} = c\hat{k} + a\hat{i}$
(C) $\vec{E} = 0$; $\vec{B} = c\hat{j} + b\hat{k}$ (D) $\vec{E} = a\hat{i}$; $\vec{B} = c\hat{k} + b\hat{j}$

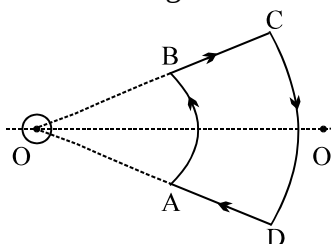
5. A proton and an alpha particle, after being accelerated through same potential difference, enter a uniform magnetic field the direction of which is perpendicular to their velocities. Find the ratio of radii of the circular paths of the two particles. [IIT JEE-2004]

6. An electron moving with a speed u along the positive x -axis at $y = 0$ enters a region of uniform magnetic field $\vec{B} = -B_0 \hat{k}$ which exists to the right of y -axis. The electron exits from the region after sometime with the speed v at co-ordinate y , then : **[IIT JEE-2004]**

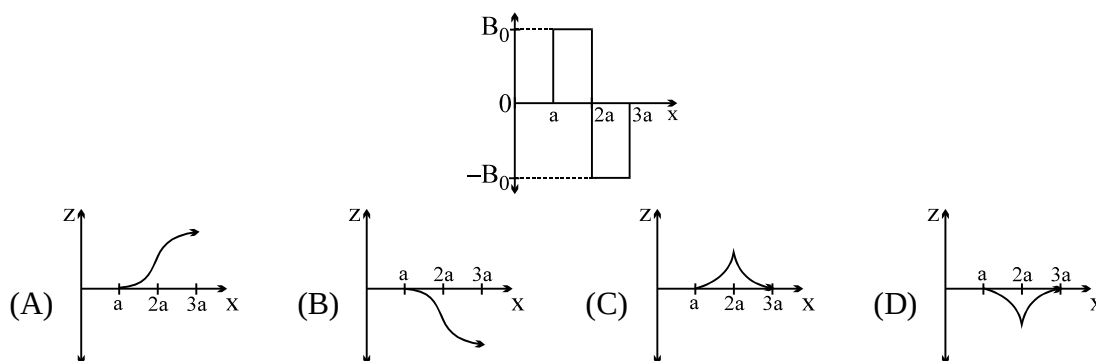


- (A) $v > u, y < 0$ (B) $v = u, y > 0$ (C) $v > u, y > 0$ (D) $v = u, y < 0$
7. A moving coil galvanometer experiences torque $= ki$ where i is current. If N coils of area A each and moment of inertia I is kept in magnetic field B . **[IIT JEE-2005]**
- (i) Find k in terms of given parameters,
 (ii) If for current i deflection is $\frac{\pi}{2}$, find out torsional constant of spring.
 (iii) If a charge Q is passed suddenly through the galvanometer. Find out maximum angle of deflection.

8. An infinite current carrying wire passes through point O and is perpendicular to the plane containing a current carrying loop $ABCD$ as shown in the figure. Choose the correct option (s). **[IIT JEE-2006]**

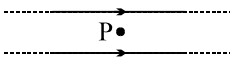
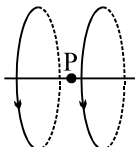
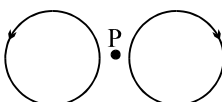
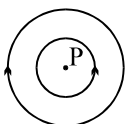


- (A) Net force on the loop is zero. (B) Net torque on the loop is zero.
 (C) As seen from O , the loop rotates clockwise. (D) As seen from O , the loop rotates anticlockwise
9. A magnetic field $\vec{B} = B_0 \hat{j}$ exists in the region $a < x < 2a$ and $\vec{B} = -B_0 \hat{j}$, in the region $2a < x < 3a$, where B_0 is a positive constant. A positive point charge moving with a velocity $\vec{v} = v_0 \hat{i}$, where v_0 is a positive constant, enters the magnetic field at $x = a$. The trajectory of the charge in this region can be like,



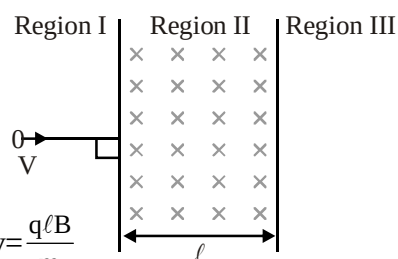
[IIT JEE-2007]

10. Two wires each carrying a steady current I are shown in four configurations in **Column I**. Some of the resulting effects are described in **Column II**. Match the statements in **Column I** with the statements in **Column II** and indicate your answer by darkening appropriate bubbles in the 4×4 matrix given in the ORS. **[IIT JEE-2007]**

Column I	Column II
(A) Point P is situated midway between the wires 	(P) The magnetic fields (B) at P due to the currents in the wires are in the same direction.
(B) Point P is situated at the mid-point of the line joining the centers of the circular wires, which have same radii. 	(Q) The magnetic fields (B) at P due to the currents in the wires are in opposite directions
(C) Point P is situated at the mid-point of the line joining the centers of the circular wires, which have same radii. 	(R) There is no magnetic field at P
(D) Point P is situated at the common center of the wires 	(S) The wires repel each other

11. A particle of mass m and charge q , moving with velocity v enters region II normal to the boundary as shown in the figure. Region II has a uniform magnetic field B perpendicular to the plane of the paper. The length of the Region II is ℓ . Choose the correct choice (s). **[IIT JEE-2008]**

- (A) The particle enters Region III only if its velocity $v > \frac{q\ell B}{m}$
- (B) The particle enters Region III only if its velocity $v < \frac{q\ell B}{m}$
- (C) Path length of the particle in Region II is max. when velocity $v = \frac{q\ell B}{m}$
- (D) Time spent in Region II is same for any velocity v as long as the particle returns to Region I



12. **Statement-1:** The sensitivity of a moving coil galvanometer is increased by placing a suitable magnetic material as a core inside the coil.

and

[IIT-JEE 2008]

Statement -2: Soft iron has a high magnetic permeability and cannot be easily magnetized or demagnetized.

- (A) Statement-1 is True, Statement-2 is True ; Statement-2 is a correct explanation for Statement-1
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

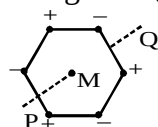
13. Six point charges, each of the same magnitude q , are arranged in different manners as shown in Column II. In each case, a point M and a line PQ passing through M are shown. Let E be the electric field and V be the electric potential at M (potential at infinity is zero) due to the given charge distribution when it is at rest. Now, the whole system is set into rotation with a constant angular velocity ω about the line PQ. Let B be the magnetic field at M and μ be the magnetic moment of the system in this condition. Assume each rotating charge to be equivalent to a steady current. [IIT JEE-2009]

Column I

Column II

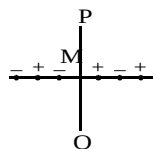
(A) $E = 0$

(P) Charges are at the corners of a regular hexagon. M is at the centre of the hexagon. PQ is perpendicular to the plane of the hexagon.



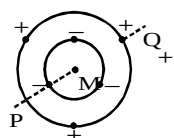
(B) $V \neq 0$

(Q) Charges are on a line perpendicular to PQ at equal intervals. M is the mid-point between the two innermost charges.



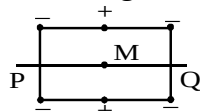
(C) $B = 0$

(R) Charges are placed on two coplanar circles of radius a and $2a$. M is the centre of the circle PQ is perpendicular to the plane of the circles.

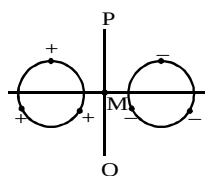


(D) $\mu \neq 0$

(S) Charges are placed at the corners of a rectangle of sides a and $2a$ and at the mid points of the longer sides. M is at the centre of the rectangle. PQ is parallel to the longer sides.



(T) Charges are placed on two coplanar, identical insulating rings at equal intervals. M is the mid point between the centres of the rings. PQ is perpendicular to the line joining the centres and coplanar to the rings



14. **Column II** shows five systems in which two objects are labelled as X and Y. Also in each case a point P is shown. **Column I** gives some statements about X and/or Y. Match these statements to the appropriate system(s) from **Column II**. [IIT JEE-2009]

Column-I

(A) The force exerted by X on Y has a magnitude Mg .

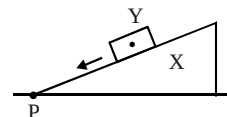
(B) The gravitational potential energy of X is continuously increasing

(C) Mechanical energy of the system X + Y is continuously decreasing

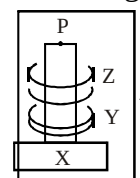
(D) The torque of the weight of Y about point P is zero.

Column-II

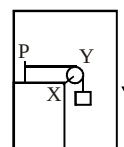
(P) Block Y of mass M left on a fixed inclined plane X, slides on it with a constant velocity.



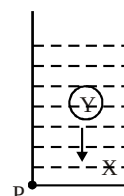
(Q) Two ring magnets Y and Z, each of mass M, are kept in frictionless vertical plastic stand so that they repel each other. Y rests on the base X and Z hangs in air in equilibrium. P is the top most point of the stand on the common axis of the two rings. The whole system is in a lift that is going up with a constant velocity.



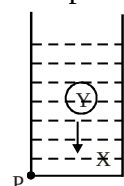
(R) A pulley Y of mass m_0 is fixed to a table through a clamp X. A block of mass M hangs from a string that goes over the pulley and is fixed at point P of the table. The whole system is kept in a lift that is going down with a constant velocity.



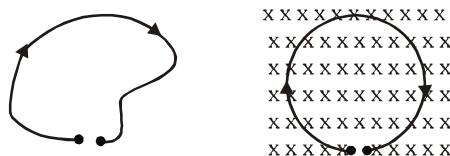
(S) A sphere Y of mass M is put in a nonviscous liquid X kept in a container at rest. The sphere is released and it moves down in the liquid.



(T) A sphere Y of mass M is falling with its terminal velocity in a viscous liquid X kept in a container.



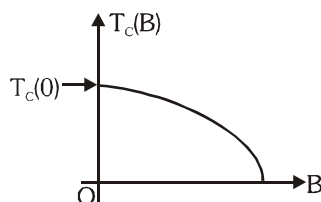
15. A steady current I goes through a wire loop PQR having shape of a right angle triangle with $PQ = 3x$, $PR = 4x$ and $QR = 5x$. If the magnitude of the magnetic field at P due to this loop is $k \left(\frac{\mu_0 I}{48\pi x} \right)$, find the value of k . [IIT JEE-2009]
16. A thin flexible wire of length L is connected to two adjacent fixed points and carries a current I in the clockwise direction, as shown in the figure. When the system is put in a uniform magnetic field of strength B going into the plane of the paper, the wire takes the shape of a circle. The tension in the wire is : [IIT JEE-2010]



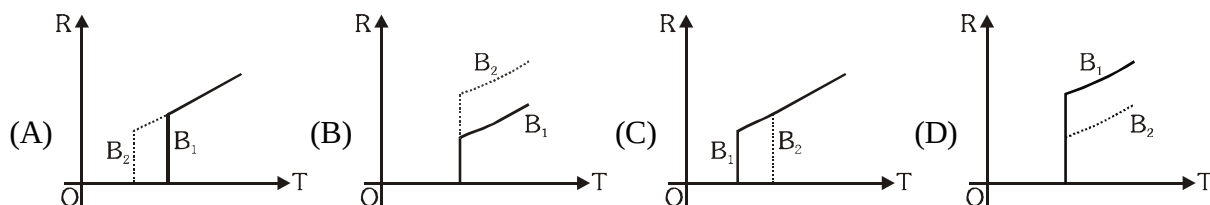
- (A) IBL (B) $\frac{IBL}{\pi}$ (C) $\frac{IBL}{2\pi}$ (D) $\frac{IBL}{4\pi}$

Paragraph for Q.No. 17 to 18

Electrical resistance of certain materials, known as superconductors, changes abruptly from a nonzero value to zero as their temperature is lowered below a critical temperature $T_c(0)$. An interesting property of superconductors is that their critical temperature becomes smaller than $T_c(0)$ if they are placed in a magnetic field, i.e., the critical temperature $T_c(B)$ is a function of the magnetic field strength B . The dependence of $T_c(B)$ on B is shown in the figure. [IIT JEE-2010]

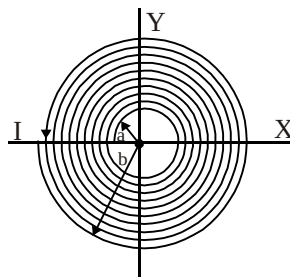


17. In the graphs below, the resistance R of a superconductor is shown as a function of its temperature T for two different magnetic fields B_1 (solid line) and B_2 (dashed line). If B_2 is larger than B_1 , which of the following graphs shows the correct variation of R with T in these fields?



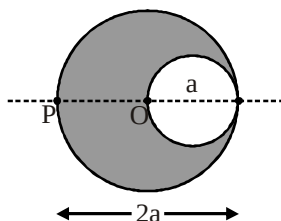
18. A superconductor has $T_c(0) = 100$ K. When a magnetic field of 7.5 Tesla is applied, its T_c decreases to 75 K. For this material one can definitely say that when
- (A) $B = 5$ Tesla, $T_c(B) = 80$ K (B) $B = 5$ Tesla, $75 \text{ K} < T_c(B) < 100$ K
(C) $B = 10$ Tesla, $75 \text{ K} < T_c(B) < 100$ K (D) $B = 10$ Tesla, $T_c(B) = 70$ K

19. An electron and a proton are moving on straight parallel paths with same velocity. They enter a semi-infinite region of uniform magnetic field perpendicular to the velocity. Which of the following statement(s) is/are true? [IIT JEE - 2011]
 (A) they will never come out of the magnetic field region
 (B) they will come out travelling along parallel paths
 (C) they will come out of the same time (D) they will come out at different times
20. 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 center of the spiral is [IIT JEE - 2011]



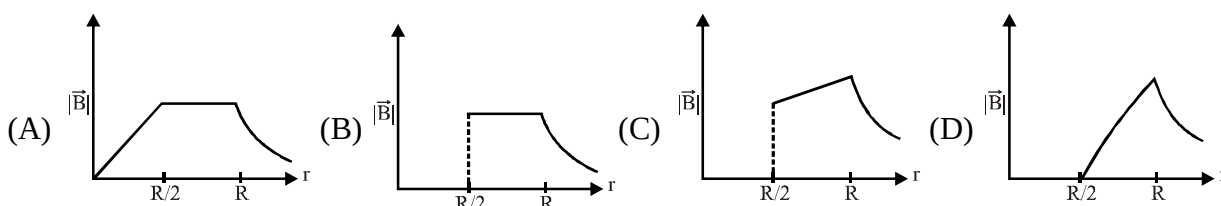
(A) $\frac{\mu_0 NI}{2(b-a)} \ln\left(\frac{b}{a}\right)$ (B) $\frac{\mu_0 NI}{2b} \ln\left(\frac{b}{a}\right)$ (C) $\frac{\mu_0 NI}{2(b-a)} \ln\left(\frac{b+a}{b-a}\right)$ (D) $\frac{\mu_0 NI}{2b} \ln\left(\frac{b+a}{b-a}\right)$

21. Consider the motion of a positive point charge in a region where there are simultaneous uniform electric and magnetic fields $\vec{E} = E_0 \hat{j}$ and $\vec{B} = B_0 \hat{j}$. At time $t = 0$, this charge has velocity $\vec{v}$ in the x-y plane, making an angle θ with the x-axis. Which of the following option (s) is (are) correct for time $t > 0$? [IIT JEE - 2012]
 (A) If $\theta = 0^\circ$, the charge moves in a circular path in the x-z plane.
 (B) If $\theta = 0^\circ$, the charge undergoes helical motion with constant pitch along the y-axis.
 (C) If $\theta = 10^\circ$, the charge undergoes helical motion with its pitch increasing with time, along the y-axis
 (D) If $\theta = 90^\circ$, the charge undergoes linear but accelerated motion along the y-axis
22. A cylindrical cavity of diameter a exists inside a cylinder of diameter $2a$ as shown in the figure. Both the cylinder and the cavity are infinitely long. A uniform current density J flows along the length. If the magnitude of the magnetic field at the point P is given by $\frac{N}{12} \mu_0 a J$, then the value of N is



[IIT JEE- 2012]

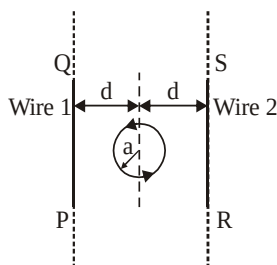
23. An infinitely long hollow conducting cylinder with inner radius $R/2$ and outer radius R carries a uniform current density along its length. The magnitude of the magnetic field, $|\vec{B}|$ as a function of the radial distance r from the axis is best represented by [IIT JEE-2012]



24. A particle of mass M and positive charge Q , moving with a constant velocity $\vec{u}_1 = 4\hat{i} \text{ ms}^{-1}$, enters a region of uniform static magnetic field normal to the x - y plane. The region of the magnetic field extends from $x = 0$ to $x = L$ from all values of y . After passing through this region, the particle emerges on the other side after 10 milliseconds with a velocity $\vec{u}_2 = 2(\sqrt{3}\hat{i} + \hat{j}) \text{ ms}^{-1}$. The correct statement(s) is (are) [IIT JEE- 2013]
- (A) The direction of the magnetic field is $-z$ direction.
 (B) The direction of the magnetic field is $+z$ direction.
 (C) The magnitude of the magnetic field is $\frac{50\pi M}{3Q}$ units.
 (D) The magnitude of the magnetic field is $\frac{100\pi M}{3Q}$ units.
25. A steady current I flows along an infinitely long hollow cylindrical conductor of radius R . This cylinder is placed coaxially inside an infinite solenoid of radius $2R$. The solenoid has n turns per unit length and carries a steady current I . Consider a point P at a distance r from the common axis. The correct statement(s) is (are) : [IIT JEE- 2013]
- (A) In the region $0 < r < R$, the magnetic field is non-zero
 (B) In the region $R < r < 2R$, the magnetic field is along the common axis
 (C) In the region $R < r < 2R$, the magnetic field is tangential to the circle of radius r , centred on the axis
 (D) In the region $r > 2R$, the magnetic field is non-zero
26. Two parallel wires in the plane of the paper are distance X_0 apart. A point charge is moving with speed u between the wires in the same plane at a distance X_1 from one of the wires. When the wires carry current of magnitude I in the same direction, the radius of curvature of the path of the point charge is R_1 . In contrast, if the currents I in the two wires have directions opposite to each other, the radius of curvature of the path is R_2 . If $\frac{X_0}{X_1} = 3$, the value of $\frac{R_1}{R_2}$ is [JEE Adv.-2014]

Paragraph for Questions 27 & 28

The figure shows a circular loop of radius a with two long parallel wires (numbered 1 and 2) all in the plane of the paper. The distance of each wire from the centre of the loop is d . The loop and the wires are carrying the same current I . The current in the loop is in the counter clockwise direction if seen from above. [JEE Adv.-2014]

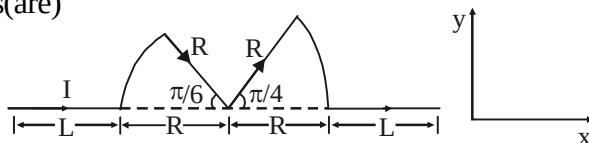


27. When $d \approx a$ but wires are not touching the loop, it is found that the net magnetic field on the axis of the loop is zero at a height h above the loop. In that case
- (A) current in wire 1 and wire 2 is the direction PQ and RS, respectively and $h \approx a$
 (B) current in wire 1 and wire 2 is the direction PQ and SR, respectively and $h \approx a$
 (C) current in wire 1 and wire 2 is the direction PQ and SR, respectively and $h \approx 1.2a$
 (D) current in wire 1 and wire 2 is the direction PQ and RS, respectively and $h \approx 1.2a$

28. Consider $d \gg a$, and the loop is rotated about its diameter parallel to the wires by 30° from the position shown in the figure. If the currents in the wires are in the opposite directions, the torque on the loop at its new position will be (assume that the net field due to the wires is constant over the loop)

(A) $\frac{\mu_0 I^2 a^2}{d}$ (B) $\frac{\mu_0 I^2 a^2}{2d}$ (C) $\frac{\sqrt{3} \mu_0 I^2 a^2}{d}$ (D) $\frac{\sqrt{3} \mu_0 I^2 a^2}{2d}$

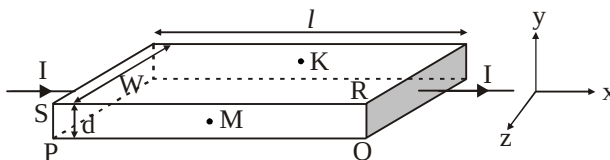
29. A conductor (shown in the figure) carrying constant current I is kept in the x - y plane in a uniform magnetic field $\vec{B}$. If F is the magnitude of the total magnetic force acting on the conductor, then the correct statement(s) is(are) [JEE Adv.-2015]



- (A) If $\vec{B}$ is along $\hat{z}$, $F \propto (L + R)$ (B) If $\vec{B}$ is along $\hat{x}$, $F = 0$
(C) If $\vec{B}$ is along $\hat{y}$, $F \propto (L + R)$ (D) If $\vec{B}$ is along $\hat{z}$, $F = 0$

Paragraph for Questions 30 & 31

In a thin rectangular metallic strip a constant current I flows along the positive x -direction, as shown in the figure. The length, width and thickness of the strip are ℓ , w and d , respectively. A uniform magnetic field $\vec{B}$ is applied on the strip along the positive y -direction. Due to this, the charge carriers experience a net deflection along the z -direction. This results in accumulation of charge carriers on the surface PQRS and appearance of equal and opposite charges on the face opposite to PQRS. A potential difference along the z -direction is thus developed. Charge accumulation continues until the magnetic force is balanced by the electric force. The current is assumed to be uniformly distributed on the cross section of the strip and carried by electrons. [JEE Adv.-2015(Paper-2)]



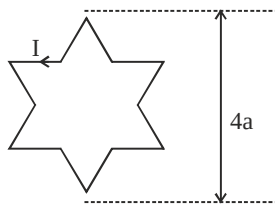
30. Consider two different metallic strips (1 and 2) of the same material. Their lengths are the same, widths are w_1 and w_2 and thicknesses are d_1 and d_2 , respectively. Two points K and M are symmetrically located on the opposite faces parallel to the x - y plane (see figure). V_1 and V_2 are the potential differences between K and M in strips 1 and 2, respectively. Then, for a given current I flowing through them in a given magnetic field strength B , the correct statement(s) is(are)

- (A) If $w_1 = w_2$ and $d_1 = 2d_2$, then $V_2 = 2V_1$ (B) If $w_1 = w_2$ and $d_1 = 2d_2$, then $V_2 = V_1$
(C) If $w_1 = 2w_2$ and $d_1 = d_2$, then $V_2 = 2V_1$ (D) If $w_1 = 2w_2$ and $d_1 = d_2$, then $V_2 = V_1$

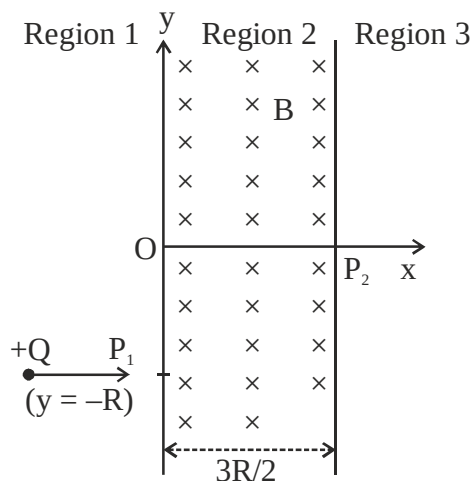
31. Consider two different metallic strips (1 and 2) of same dimensions (lengths ℓ , width w and thickness d) with carrier densities n_1 and n_2 , respectively. Strip 1 is placed in magnetic field B_1 and strip 2 is placed in magnetic field B_2 , both along positive y -directions. Then V_1 and V_2 are the potential differences developed between K and M in strips 1 and 2, respectively. Assuming that the current I is the same for both the strips, the correct option(s) is(are)

- (A) If $B_1 = B_2$ and $n_1 = 2n_2$, then $V_2 = 2V_1$ (B) If $B_1 = B_2$ and $n_1 = 2n_2$, then $V_2 = V_1$
(C) If $B_1 = 2B_2$ and $n_1 = n_2$, then $V_2 = 0.5V_1$ (D) If $B_1 = 2B_2$ and $n_1 = n_2$, then $V_2 = V_1$

32. A symmetric star shaped conducting wire loop is carrying a steady state current I as shown in the figure. The distance between the diametrically opposite vertices of the star is $4a$. The magnitude of the magnetic field at the center of the loop is **[JEE Adv.-2017]**



- (A) $\frac{\mu_0 I}{4\pi a} 6[\sqrt{3}-1]$ (B) $\frac{\mu_0 I}{4\pi a} 6[\sqrt{3}+1]$ (C) $\frac{\mu_0 I}{4\pi a} 3[\sqrt{3}-1]$ (D) $\frac{\mu_0 I}{4\pi a} 3[2-\sqrt{3}]$
33. A uniform magnetic field B exists in the region between $x = 0$ and $x = \frac{3R}{2}$ (region 2 in the figure) pointing normally into the plane of the paper. A particle with charge $+Q$ and momentum p directed along x -axis enters region 2 from region 1 at point P_1 ($y = -R$). Which of the following option(s) is/are correct? **[JEE Adv.-2017]**



- (A) For $B > \frac{2}{3} \frac{p}{QR}$, the particle will re-enter region 1
- (B) For $B = \frac{8}{13} \frac{p}{QR}$, the particle will enter region 3 through the point P_2 on x -axis
- (C) When the particle re-enters region 1 through the longest possible path in region 2, the magnitude of the change in its linear momentum between point P_1 and the farthest point from y -axis is $p / \sqrt{2}$
- (D) For a fixed B , particle of same charge Q and same velocity v , the distance between the point P_1 and the point of re-entry into region 1 is inversely proportional to the mass of the particle

Answer Q.34, Q.35 and Q.36 by appropriately matching the information given in the three columns of the following table.

A charged particle (electron or proton) is introduced at the origin ($x = 0, y = 0, z = 0$) with a given initial velocity $\vec{v}$. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity $\vec{v}$, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in column 1, 2 and 3, respectively. The quantities E_0, B_0 are positive in magnitude.

[JEE Adv.-2017]

Column-1	Column-2	Column-3
(I) Electron with $\vec{v} = 2 \frac{E_0}{B_0} \hat{x}$	(i) $\vec{E} = E_0 \hat{z}$	(P) $\vec{B} = -B_0 \hat{x}$
(II) Electron with $\vec{v} = \frac{E_0}{B_0} \hat{y}$	(ii) $\vec{E} = -E_0 \hat{y}$	(Q) $\vec{B} = B_0 \hat{x}$
(III) Proton with $\vec{v} = 0$	(iii) $\vec{E} = -E_0 \hat{x}$	(R) $\vec{B} = B_0 \hat{y}$
(IV) Proton with $\vec{v} = 2 \frac{E_0}{B_0} \hat{x}$	(iv) $\vec{E} = E_0 \hat{x}$	(S) $\vec{B} = B_0 \hat{z}$

34. In which case will the particle move in a straight line with constant velocity?
(A) (II) (iii) (S) (B) (IV) (i) (S) (C) (III) (ii) (R) (D) (III) (iii) (P)
35. In which case will the particle describe a helical path with axis along the positive z direction?
(A) (II) (ii) (R) (B) (IV) (ii) (R) (C) (IV) (i) (S) (D) (III) (iii) (P)
36. In which case would the particle move in a straight line along the negative direction of y-axis (i.e., move along $-\hat{y}$)?
(A) (IV) (ii) (S) (B) (III) (ii) (P) (C) (II) (iii) (Q) (D) (III) (ii) (R)
37. Two infinitely long straight wires lie in the xy-plane along the lines $x = \pm R$. The wire located at $x = +R$ carries a constant current I_1 and the wire located at $x = -R$ carries a constant current I_2 . A circular loop of radius R is suspended with its centre at $(0, 0, \sqrt{3} R)$ and in a plane parallel to the xy-plane. This loop carries a constant current I in the clockwise direction as seen from above the loop. The current in the wire is taken to be positive if it is in the $+\hat{j}$ direction. Which of the following statements regarding the magnetic field $\vec{B}$ is (are) true?

[JEE Adv.-2018]

- (A) If $I_1 = I_2$, then $\vec{B}$ **cannot** be equal to zero at the origin $(0, 0, 0)$
 (B) If $I_1 > 0$ and $I_2 < 0$, then $\vec{B}$ can be equal to zero at the origin $(0, 0, 0)$
 (C) If $I_1 < 0$ and $I_2 > 0$, then $\vec{B}$ can be equal to zero at the origin $(0, 0, 0)$
 (D) If $I_1 = I_2$, then the z-component of the magnetic field at the centre of the loop is $\left(-\frac{\mu_0 I}{2R}\right)$

PARAGRAPH “X” (For Question 38, 39)

In electromagnetic theory, the electric and magnetic phenomena are related to each other. Therefore, the dimensions of electric and magnetic quantities must also be related to each other. In the questions below, $[E]$ and $[B]$ stand for dimensions of electric and magnetic fields respectively, while $[\epsilon_0]$ and $[\mu_0]$ stand for dimensions of the permittivity and permeability of free space respectively. $[L]$ and $[T]$ are dimensions of length and time respectively. All the quantities are given in SI units.

(There are two questions based on **PARAGRAPH “X”**, the question given below is one of them)

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38. The relation between $[E]$ and $[B]$ is

(A) $[E] = [B] [L] [T]$

(B) $[E] = [B] [L]^{-1} [T]$

(C) $[E] = [B] [L] [T]^{-1}$

(D) $[E] = [B] [L]^{-1} [T]^{-1}$

39. The relation between $[\epsilon_0]$ and $[\mu_0]$ is

(A) $[\mu_0] = [\epsilon_0] [L]^2 [T]^{-2}$

(B) $[\mu_0] = [\epsilon_0] [L]^{-2} [T]^2$

(C) $[\mu_0] = [\epsilon_0]^{-1} [L]^2 [T]^{-2}$

(D) $[\mu_0] = [\epsilon_0]^{-1} [L]^{-2} [T]^2$

40. A moving coil galvanometer has 50 turns and each turn has an area $2 \times 10^{-4} \text{ m}^2$. The magnetic field produced by the magnet inside the galvanometer is 0.02 T . The torsional constant of the suspension wire is $10^{-4} \text{ N m rad}^{-1}$. When a current flows through the galvanometer, a full scale deflection occurs if the coil rotates by 0.2 rad . The resistance of the coil of the galvanometer is 50Ω . This galvanometer is to be converted into an ammeter capable of measuring current in the range $0-1.0 \text{ A}$. For this purpose, a shunt resistance is to be added in parallel to the galvanometer. The value of this shunt resistance, in ohm, is

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ANSWER KEY

EXERCISE (S-1)

1. (a) $1\mu\text{T}$ along the negative Z-axis (b) $3\mu\text{T}$ along the Z-axis (c) $1\mu\text{T}$ along the Z-axis (d) $3\mu\text{T}$ along the negative Z-axis
2. $4.0 \times 10^{-5} \text{ T}$, downwards in both the cases
3. $5\pi \times 10^{-4} \text{ T} = 1.6 \times 10^{-3} \text{ T}$ towards west
4. (b) in a small region of length $2d$ about the mid-point between the coils,

$$B = \frac{\mu_0 I R^2 N}{2} \times \left[\left\{ \left(\frac{R}{2} + d \right)^2 + R^2 \right\}^{-3/2} + \left\{ \left(\frac{R}{2} - d \right)^2 + R^2 \right\}^{-3/2} \right]$$

$$\approx \frac{\mu_0 I R^2 N}{2} \times \left(\frac{5R^2}{4} \right)^{-3/2} \times \left[\left(1 + \frac{4d}{5R} \right)^{-3/2} + \left(1 - \frac{4d}{5R} \right)^{-3/2} \right]$$

$$\approx \frac{\mu_0 I R^2 N}{2R^3} \times \left(\frac{4}{5} \right)^{-3/2} \times \left[1 - \frac{6d}{5R} + 1 + \frac{6d}{5R} \right]$$

where in the second and third steps above, terms containing d^2/R^2 and higher powers of d/R are neglected since $\frac{d}{R} \ll 1$. The terms linear in d/R cancel giving a uniform field B in a small region:

$$B = \left(\frac{4}{5} \right)^{3/2} \frac{\mu_0 I N}{R} \approx 0.72 \frac{\mu_0 I N}{R}$$

5. $\frac{1}{\sqrt{2}} \times 10^{-9} \hat{k}$
6. At a distance of $\frac{4r}{\pi}$ from the centre in such a way that the direction of the current in it is opposite to that in the nearest part of the circular wire.
7. 10^{-4} T , perpendicular to paper outwards
8. (a) 0; (b) $1.41 \times 10^{-6} \text{ T}$, 45° in xz -plane, (c) $5 \times 10^{-6} \text{ T}$, $+x$ -direction
9. $\frac{\sqrt{5}}{2\sqrt{2}} 4\pi \times 10^{-5} \text{ T}$
10. μ_0 weber. m^{-1}
11. (a) zero; (b) $\frac{3\mu_0 i}{8\pi r}$
12. (a) zero; (b) $\frac{\mu_0 j(b^2 - a^2)}{2b}$
13. **Hint:** B for a toroid is given by $n = \frac{N}{2\pi r}$. The field is non-zero only inside the core surrounded by the windings. (a) Zero, (b) $3.0 \times 10^{-2} \text{ T}$, (c) zero, Note, the field varies slightly across the cross-section of the toroid as r varies from the inner to outer radius. Answer (b) corresponds to the mean radius $r = 25.5 \text{ cm}$.
14. Magnetic field strength, $B = 100 \text{ G} = 100 \times 10^{-4} \text{ T}$
number of turns per unit length, $n = 1000 \text{ turns m}^{-1}$
Current flowing in the coil, $I = 15 \text{ A}$
Permeability of free space, $= 4\pi \times 10^{-7} \text{ T mA}^{-1}$
Magnetic field is given by the relation,

$$B = \mu_0 nI$$

$$\therefore nI = \frac{B}{\mu_0} = \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}} = 7957.74$$

$$\approx 8000 \text{ A/m}$$

If the length of the coil is taken as 50 cm, radius 4 cm, number of turns 400, and current 10A, then these values are not unique for the given purpose. There is always a possibility of some adjustments with limits.

15. $\frac{2mv_0}{qB}$
16. $1.2 \times 10^{-2} \text{ m}, 4.37 \times 10^{-2} \text{ m}$
17. (a) Circular trajectory of radius 1.0 mm normal to B.
(b) Helical trajectory of radius 0.5 mm with velocity component $2.3 \times 10^7 \text{ ms}^{-1}$ along B.
18. 4.2 cm
19. (a) Initial v is either parallel or anti-parallel to B.
(b) Yes, because magnetic force can change the direction of v , not its magnitude.
(c) B should be in a vertically downward direction.
20. Deuterium ions or deutrons ; the answer is not unique because only the ratio of charge to mass is determined. Other possible answers are He^{++} , Li^{+++} , etc.
21. 18 MHz
22. (a) A horizontal magnetic field of magnitude 0.26 T normal to the conductor in such a direction that Fleming's left-hand rule gives a magnetic force upward.
(b) 1.176 N.
23. (a) 2.1 N vertically downwards
(b) 2.1 N vertically downwards (true for any angle between current direction and B since $I \sin \theta$ remains fixed, equal to 20 cm)
(c) 1.68 N vertically downwards
24. (a) 3.1 Nm, (b) No, the answer is unchanged because the formula $\tau = N I A \times B$ is true for a planar loop of any shape.
25. Use $\tau = I A \times B$ and $F = I l \times B$
(a) $1.8 \times 10^{-2} \text{ N m}$ along $-y$ direction (b) same as in (a)
(c) $1.8 \times 10^{-2} \text{ N m}$ along $-x$ direction (d) $1.8 \times 10^{-2} \text{ N m}$ at an angle of 240° with the $+x$ direction
(e) zero (f) zero
Force is zero in each case. Case (e) corresponds to stable, and case (f) corresponds to unstable equilibrium
26. (a) Zero, (b) zero, (c) force on each electron is $e v B = IB/(nA) = 5 \times 10^{-25} \text{ N}$.
Note : Answer (c) denotes only the magnetic force.
27. (a) 1.4, (b) 1

EXERCISE (S-2)

1. $\frac{\mu_0 I \sqrt{2}}{4\pi^2 R}$
2. 2
3. $B_1 = \frac{\mu_0 b r_1^2}{3}, B_2 = \frac{\mu_0 b R^3}{3 r_2}$
4. $B_{\min} = 4.7 \times 10^{-3} \text{ T}$
5. $\sqrt{15} \text{ C}$
6. (6.4 m, 0,0) (6.4m, 0, 2m)
7. $\sqrt{v_0^2 - \left(v_0 - \frac{3qB_0 d}{2m}\right)^2}$
8. $i_1 = 0.1110 \text{ A}, i_2 = 0.096 \text{ A}$
9. $\frac{\mu_0 I_1 I_2}{4\pi} \ln(3)$ along -ve z direction
10. (i) $-\frac{\mu_0 I}{4R} q v_0 \hat{k}$
(ii) $F_1 = 2 I R B, F_2 = 2 I R B$, Net force = $F_1 + F_2 = 4 I R B \hat{i}$
11. (a) $6.6 \times 10^{-5} \text{ T}$, (b) 0, 0, $8 \times 10^{-6} \text{ Nt}$
12. (a) $\frac{3mv^2}{4qa}$, (b) $\frac{3mv^3}{4a}$, (c) zero
13. $\frac{\mu_0 i q v}{2\pi a}$
14. 5
15. $\frac{mEI}{Be}$
16. $0.62 \text{ N} < F < 0.88 \text{ N}$
17. 8
18. 4
19. 4
20. 20
21. $\frac{Q_\omega}{4} h^2 \tan^2 \theta$
22. (a) 20 min. (b) $5.94 \times 10^{-2} \text{ Nm}$
23. $T_0 = 2\pi \sqrt{\frac{m}{6IB}} = 0.57 \text{ s}$
24. $z = 0, x = \pm \frac{d}{\sqrt{3}}, (ii) \frac{I}{2\pi d} \sqrt{\frac{\mu_0}{\pi \lambda}}$
25. (a) current in loop PQRS is clockwise from P to QRS., (b) $\vec{F} = BI_0 b(3\hat{k} - 4\hat{i})$, (c) $I = \frac{mg}{6b B_0}$
26. $F = \alpha a^2 i \hat{j}$
27. 4
28. $F = \left(\frac{\mu_0 I^2}{2\pi}\right) \ln\left(\frac{L^2 + a^2}{a^2}\right) (-\hat{k})$, zero
29. 525

EXERCISE (O-1)

- | | | | | |
|------------------------------------|--|---------|---------|---------|
| 1. A | 2. B | 3. C | 4. D | 5. A |
| 6. B | 7. C | 8. C | 9. C | 10. C |
| 11. D | 12. D | 13. A | 14. B | 15. C |
| 16. C | 17. D | 18. D | 19. B | 20. A |
| 21. C | 22. B | 23. C | 24. A | 25. B |
| 26. A | 27. B | 28. B | 29. C | 30. D |
| 31. C | 32. A | 33. A | 34. B | 35. C |
| 36. D | 37. A | 38. B | 39. D | 40. C |
| 41. C | 42. C | 43. B | 44. C | 45. A |
| 46. D | 47. D | 48. ABC | 49. ABC | 50. ABC |
| 51. ACD | 52. AC | 53. D | 54. C | 55. BD |
| 56. AD | 57. AB | 58. A | | |
| 59. (A)→QS; (B)→PS; (C)→QS; (D)→P; | 60. (A)→S; (B)→S; (C)→Q; (D)→R; (E)→P; | | | |

EXERCISE (O-2)

1.	C	2.	B	3.	A	4.	C	5.	B
6.	C	7.	A	8.	A	9.	A	10.	B
11.	C	12.	A	13.	C	14.	C	15.	D
16.	C	17.	C	18.	B	19.	A	20.	C
21.	A	22.	D	23.	B	24.	A	25.	A
26.	B	27.	C	28.	C	29.	A	30.	D
31.	B	32.	C	33.	B	34.	C	35.	B
36.	C	37.	A	38.	B	39.	A	40.	A
41.	B	42.	ABC	43.	ABD	44.	ABC	45.	ABC
46.	BCD	47.	C	48.	A	49.	A	50.	D
51.	C	52.	B	53.	D	54.	A	55.	A
56.	B	57.	C	58.	A	59.	C	60.	B
61.	D	62. (A)→R; (B)→S; (C)→Q; (D)→P;							
63. (A)→PRT; (B)→PQ; (C)→S; (D)→P;									

EXERCISE (ONLY FOR JEE MAINS)

1.	(A)	2.	(B)	3.	(B)	4.	(A)	5.	(C)
6.	(A)	7.	(A)	8.	(B)	9.	(B)	10.	(B)
11.	(D)	12.	(B)	13.	(C)	14.	(C)	15.	(B)
16.	(A)	17.	(A)	18.	(A)	19.	(B)	20.	(C)
21.	(D)	22.	(B)	23.	(C)	24.	(C)	25.	(B)
26.	(C)	27.	(B)	28.	(D)	29.	(A)	30.	(B)

EXERCISE (JM)

1.	3	2.	3	3.	1	4.	2	5.	1	6.	3	7.	4
8.	4	9.	2	10.	3	11.	2	12.	4	13.	3	14.	2
15.	2	16.	4	17.	1	18.	4	19.	3	20.	2	21.	1
22.	3	23.	3	24.	3	25.	1	26.	1	27.	4	28.	1
29.	3	30.	3	31.	4	32.	2	33.	3	34.	3	35.	2
36.	2	37.	4	38.	1								

EXERCISE (JA)

1.	A	2.	A	3.	$\omega_{\text{disk}} = \frac{T_0 d}{qBR^2}$	4.	B		
5.	$\frac{1}{\sqrt{2}}$	6.	D	7.	(a) $k = NAB$; (b) $C = \frac{2I_0 NAB}{\pi}$; (c) $\theta = Q\sqrt{\frac{NAB\pi}{2I_0 I}}$				
8.	AC	9.	A						
10.	(A)→QR; (B)→P; (C)→QR; (D)→QS;			OR	(A)→QR; (B)→P; (C)→QR; (D)→Q;				
11.	ACD	12.	C	13.	(A)→PRS; (B)→RS; (C)→PQT; (D)→RS;				
14.	(A)→PT; (B)→QST; (C)→PRT; (D)→Q;			15.	7	16.	C	17.	A
18.	B	19.	BC,BD,BCD	20.	A	21.	CD	22.	5
23.	D	24.	AC	25.	AD	26.	3	27.	C
28.	B	29.	ABC	30.	AD	31.	AC	32.	A
33.	AB	34.	A	35.	C	36.	D		
37.	ABD	38.	C	39.	D	40.	5.55 / 5.56		