Solved Examples

JEE Main/Boards

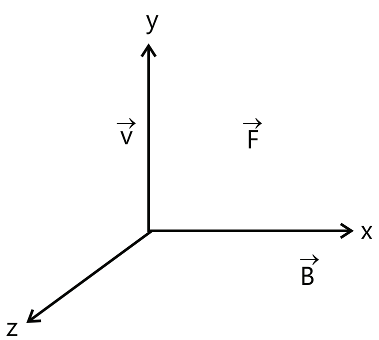
Example 1: A uniform magnetic fields of 30 mT exists in the +X direction. A particle of charge +e and mass1.67 x 10^{-27} kg is projected into the field along the +Y direction with a speed of 4.8 x 10^{6} m/s

(i) Find the force on the charged particle in magnitude and direction

(ii) Find the force if the particle were negatively charged.

(iii) Describe the nature of path followed by the particle in both the cases.

Sol: The force on the particle in external magnetic field is $\vec{F} = q(\vec{v} \times \vec{B})$. Take vector product of velocity and magnetic field vector, and solve for force.



(i) Force acting on a charge particle moving in the magnetic field

$\vec{F} = q(\vec{v} \times \vec{B})$ Magnetic field $\vec{B} = 30(mT)\hat{j}$

Velocity of the charge particle $\vec{V} = 4.8 \times 10^{6}\,(m/s)\hat{j}$

$$\vec{F} = 1.6 \times 10^{-19}\left[\left(4.8 \times 10^{6}\hat{j}\right) \times \left(30 \times 10^{-3}\right)\left(\hat{i}\right)\right]$$

$\vec{F}$ =230.4 x $10^{-16}(-\hat{k})$N.

(ii) If the particle were negatively charged, the magnitude of the force will be the same but the direction will be along (+z) direction.

(iii) As v $\perp$ B, the path describe is a circle

$$R = \frac{mv}{qB} = (1.67 \times 10^{-27}) \cdot (4.8 \times 10^{6}) /$$

$$(1.6 \times 10^{-19}) \cdot (30 \times 10^{-3}) = 1.67 \text{ m.}$$

Example 2: A magnetic field of (4.0 x $10^{-3}\hat{k}$) T exerts a force (4.0 $\hat{i}$ +3.0 $\hat{j}$) x 10^{-10}N on a particle having a charge 10^{-9}C and moving in the x-y plane. Find the velocity of the particle.

Sol: The force on the particle in external magnetic field is $\vec{F} = q(\vec{v} \times \vec{B})$. Take vector product of velocity and magnetic field vector.

Given, $\vec{B} = \left(4 \times 10^{-3}\hat{k}\right)T, q = 10^{-9}C$

and Magnetic force $\vec{F}_m = (4.0\hat{i} + 3.0\hat{j})10^{-10}$ N

Let Velocity of the particle in x-y plane be, $\vec{v} = \nu_x\hat{i} + \nu_y\hat{j}$

Then From the relation, $\vec{F}m = q(\vec{v} \times \vec{B})$

We have,

$$(4.0\hat{i} + 3.0\hat{j}) \times 10^{-10} = 10^{-9}\left[\left(\nu_x\hat{i} + \nu_y\hat{j}\right) \times \left(4 \times 10^{-3}\hat{k}\right)\right]$$

$$= \left(4\nu_y X 10^{-12}\hat{j} - 4\nu_x 10^{-12}\hat{j}\right)$$

Comparing the coefficients of $\hat{i}$ and $\hat{j}$ we have,

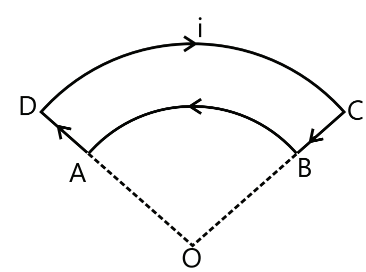
$$4 \times 10^{-10} = 4\nu_y \times 10^{-12}$$

$\therefore$ $\nu_y = 10^{2}\,m/s = 100\,m/s$

and $3.0 \times 10^{-10} = 4\nu_y \times 10^{-12}$

$\therefore \nu_x = -75 m/s;\ \therefore \vec{V} = -75\hat{i} + 100\hat{j}$

Example 3: Figure shows current loop having two circular arcs joined by two radial lines. Find the magnetic field B at the center O.



Sol: Find magnetic field at the center O of concentric arcs AB and CD by $B = \frac{\mu_0 I\theta}{4\pi R}$ where θ is the angle subtended at the center.

Magnetic field at point O, due to wires CB and AD will be zero. Magnetic field due to wire BA will be, $B_1 = \left(\frac{\theta}{2\pi}\right)\left(\frac{\mu_0 i}{2a}\right)$ Direction of field $\vec{B}_1$ is coming out of the plane of the figure. Similarly, field at O due to arc

DC will be, $B_2 = \left(\frac{\theta}{2\pi}\right)\left(\frac{\mu_0 i}{2a}\right)$

Direction of field $\vec{B}_2$ is going into the plane of the figure. The resultant field at O is

$B = B_1 - B_2 = \frac{\mu_0 i\theta(b-a)}{4\pi ab}$ Coming out of theplane,

Example 4: A current of 2.00 A exist in a square loop of edge 10.0 cm. Find the magnetic field B at the center of the square loop.

Sol: The center of the loop is equidistant from all the sides, and can be considered as a point on the perpendicular bisector of one side.The field at the point due to one side is

$$B = \frac{\mu_0 Ia}{2\pi d\sqrt{a^2 + 4d^2}}$$

The magnetic field at the center due to the four sides will be equal in magnitude and direction. The field due to one side will be

$$B_1 = \frac{\mu_0 ia}{2\pi d\sqrt{a^2 + 4d^2}}$$

Here, a=10 cm and d=a/2=5 cm.

$$\text{Thus, } B_1 = \frac{\mu_0 (2\,A)}{2\pi(5\,cm)}\left[\frac{10\,cm}{\sqrt{(10\,cm)^2 + 4(5\,cm)^2}}\right]$$

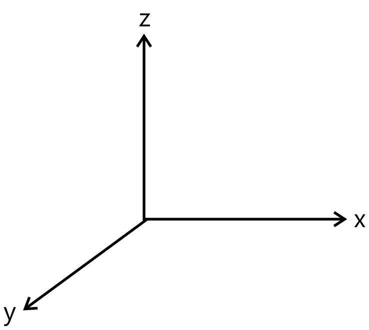
$= 2 \times 10^{-7}$ T mA^{-1} x 2 A x $\frac{1}{5\sqrt{2}\,cm}$ = 5·66 x 10^{-6} T

Hence, the net field at the center of the loop will be 4 x 5·66 x 10^{-6}T=22·6x10^{-6} T.

Example 5: A particle of mass 1 x 10^{-26}kg and charge 1.6 x 10^{-19}C travelling with a velocity 1.28 x 10^6 ms^{-1} in the +x direction enters a region in which uniform magnetic field of induction B are present such that $E_x=E_y=0$, E_z = -102.4 kVm^{-1} and $B_x = B_z=0$. $B_y=8 \times 10^{-2}$. 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 x 10^{-6}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 x 10^{-6} s?

Sol: In presence of simultaneous electric and magnetic field, the Lorentz force is $\vec{F} = q\left(\vec{E} + (\vec{v}\times\vec{B})\right)$. Under action of uniform magnetic field only, the particle performs uniform circular motion of radius $r = \frac{mv}{qB}$.

Let $\hat{i}$, $\hat{j}$ and $\hat{k}$ be unit vector along the positive directions of x, y and z axes. Q=charge on the particle=1.6 x 10^{-19}C, v=velocity of the charged particle



=(1.28 x 10^6)ms^{-1}

$\vec{E}$ = electric field intensity;

=(-102.4 x 10^3Vm^{-1})$\hat{k}$ $\vec{B}$ =magnetic induction of the magnetic field = (8 x 10^{-2} Wbm^{-2}) $\hat{j}$

$\therefore$ $\vec{F}_e$ =electric force on the charge

=qE=1.6 x 10^{-19}(-102.4x10^3)N$\hat{k}$ = 163.84 x 10^{-16}N(-$\hat{k}$)

F_m =magnetic force on the charge = qv x B

= [1.6x10^{-19}(1.28x10^6)(8x10^{-2})N]($\hat{i}$ x $\hat{j}$)= (163.84x10^{-16}N) ($\hat{k}$)

The two forces $\vec{F}_e$ and $\vec{F}_m$ are along z-axis and equal, opposite and collinear. The net force on the charge is zero and hence the particle does not get deflection and continues to travel along x-axis. (a) At time t=5x10^{-6}s

x=(5 x 10^{-6})(1.28 x 10^6)=6.4m$\therefore$ Coordinates of the particle = (6.4 m,0,0)

(b) When the electric field is switched off, the particle is in the uniform magnetic field perpendicular to its velocity only and has a uniform circular motion in the x-z plane (i.e. the plane of velocity and magnetic force), anticlockwise as seen along+ y axis.

Now, $\frac{mv^2}{r}$ =qvB where r is the radius of the circle.

$$\therefore r = \frac{mv}{qB} = \frac{\left(1x10^{-26}\right)\left(1.28x10^6\right)}{\left(1.6x10^{-19}\right)\left(8x10^{-2}\right)} = 1$$

The length of the arc traced by the particle in [(7.5-5) x 10^{-6}s]

= (v)(T)=(1.28 x 10^60)(2.45 x 10^{-6})=3.136m= π m= $\frac{1}{2}$ circumference

$\therefore$ The particle has the coordinates (6,4,0,2m) as (x,y,z).

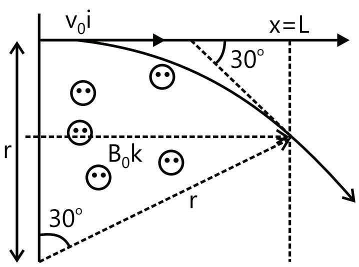
Example 6: The region between x=0 and x=L is filled with uniform, steady magnetic field $B_0 k$. A particle of mass m, positive charge q and velocity $v_0\,\hat{i}$ travels along x-axis and enters the region of magnetic field. Neglect gravity throughout the question.

(i) Find the value of L if it emerges from the region of magnetic field with its final velocity at an angle 30° to the initial velocity.

(i) Find the final velocity of the particle and the time spent by it in the magnetic field, if the field now extents up to x=2. 1L.

Sol: The particle under action of uniform magnetic field performs uniform circular motion. The magnetic force acting on it provides the centripetal force. The radius of the circular orbit is $r = \frac{mv}{qB}$.

(i) As the initial velocity of the particle is perpendicular to the field the particle will move along the arc of a circle as shown.

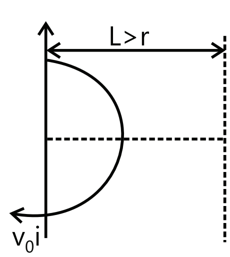


If r is the radius of the circle, then

$\frac{mv_0^2}{r} = qv_0B_0$ Also from geometry, L=r sin 30°

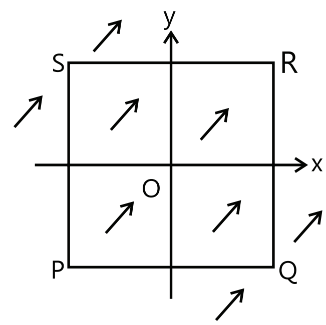
$\Rightarrow r = 2L$ or $L = \frac{mv_0}{2qB_0}$

(ii) In this case $L = \frac{2.1mv_0}{2qB_0} > r$ Hence the particle will complete a semi-circular path and emerge from the field with velocity $v_0\hat{i}$ as shown. Time spent by the particle in the magnetic field $T = \frac{\pi r}{v_0} = \frac{\pi m}{qB_0}$



The speed of the particle does not change due to the magnetic field.

Example 7: A uniform, constantmagnetic field $\vec{B}$ is directed at an angle of 45° to the x-axis in the xy-plane. PQRS is a rigid, square wire frame carrying a steady current I_0, with its center at the origin. O. At time t=0, the frame is at rest in the position (shown the Figure) with its sides parallel to the x and y axes. Each side of the frame is of mass M and length L.

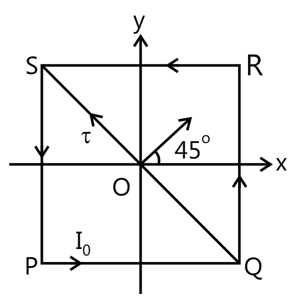


(a) What is the torque τ about O acting on the frame due to the magnetic field?

(b) Find the angle by which the frame rotates under the action of this torque in a short interval of time Δt, and the axis about which this rotation occurs. (Δt is so short that any variation i n the torque during this interval may be neglected). Given moment of any variation in the torque during this interval may be neglected). Given moment of inertia of the frame about an axis through its center perpendicular to its p late is (4/3) ML^2.

Sol: The torque acting on loop is $\vec{\tau} = \vec{M} \times \vec{B}$.

$\alpha = \frac{d\omega}{dt} = \frac{\tau}{I}$ and



$\theta = \int \omega dt$ (a) As magnetic field B is in x-y plane and subtends an angle of 45° with x-axis.

$B_x = B\cos 45° = B/\sqrt{2}$

and $B_y = B\sin 45° = B/\sqrt{2}$

So in vector from

$\vec{B} = \hat{i}\left(B/\sqrt{2}\right) + j\left(B/\sqrt{2}\right)$

and $\vec{M} = I_0 S\hat{k} = I_0 L^2 \hat{k}$

so, $\hat{\tau} = \vec{M} \times \vec{B} = I_0 L^2 \hat{k} \times \left(\frac{B}{\sqrt{2}} \hat{i} + \frac{B}{\sqrt{2}} \hat{j} \right)$

i.e., $\hat{\tau} = \frac{I_0 L^2 B}{\sqrt{2}} \times \left(-\hat{i} + \hat{j} \right)$

i.e., torque has magnitude $I_0 L^2 B$ and is directed along line QS from Q to S.

(b) As by theorem of perpendicular axes, moment of inertia of the frame about QS,

$$I_{QS} = \frac{1}{2} I_z = \frac{1}{2} \left(\frac{4}{3} ML^2 \right) = \frac{2}{3} ML^2$$

And as $\tau = I\alpha$,

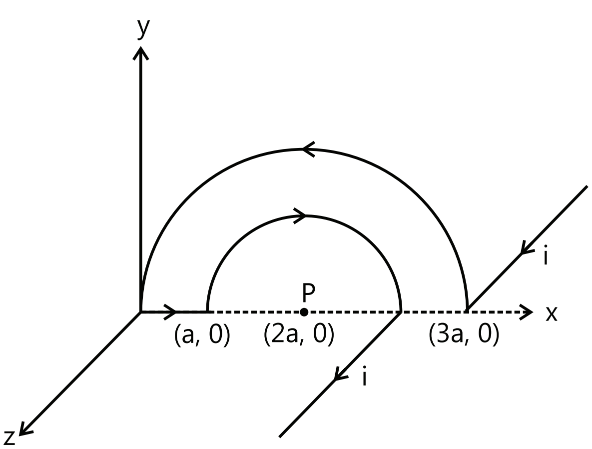
$$\alpha = \frac{\tau}{1} = \frac{I_0 L^2 B \times 3}{2L^2 M} = \frac{3}{2} \frac{I_0 B}{M}$$

As here α is constant, equations of circular motion are valid and hence from

$\theta = \omega_0 t + \frac{1}{2} \alpha t^2$ with $\omega_0 = 0$ we have

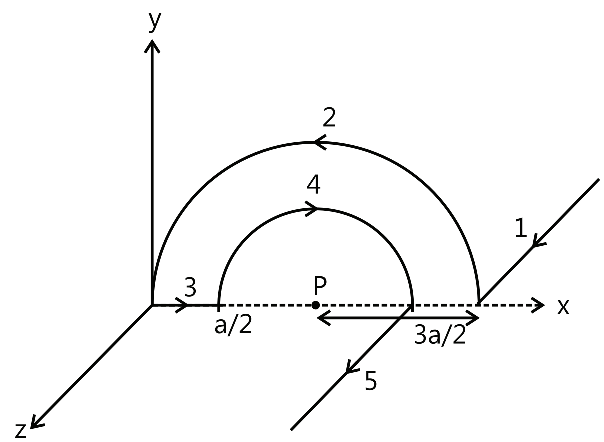
$$\theta = \frac{1}{2} \alpha t^2 = \frac{1}{2} \left(\frac{3}{2} \frac{I_0 B}{M} \right) (\Delta t)^2 = \frac{3}{4} \frac{I_0 B}{M} \Delta t^2$$

Example 8: In the figure shown the magnetic field at the point P.



Sol: The conductor forms two concentric semicircles and two straight wires. Find magnetic field at the center P due to concentric arcs by formula $B = \frac{\mu_0 I \theta}{4\pi R}$, and fields due to straight wires by formula $B = \frac{\mu_0 I}{4\pi d}$ and then add the fields due to individual parts.

Consider the figure.



$$\vec{B}_P = \left(\vec{B}_1\right)_P + \left(\vec{B}_2\right)_P + \left(\vec{B}_3\right)_P + \left(\vec{B}_4\right)_P + \left(\vec{B}_5\right)_P$$

where $\left(\vec{B}_1\right)_P = \frac{\mu_0 i}{4\pi \left(\frac{3a}{2} \right)} \left(-\hat{j} \right)$

(Semi-infinite wire) $\left(\vec{B}_2\right)_P = \frac{\mu_0 i}{4 \left(\frac{3a}{2} \right)} \left(+\hat{k} \right)$ $\left(\vec{B}_3\right)_P = 0$;

$\left(\vec{B}_4\right)_P = \frac{\mu_0 i}{4 \left(\frac{a}{2} \right)} \left(-\hat{k} \right)$

$$\Rightarrow \vec{B}_P = \frac{\mu_0 i}{2a} \left[-\left(\frac{1}{3\pi} + \frac{1}{\pi} \right) \hat{j} - \left(1 - \frac{1}{3} \right) \hat{k} \right]$$

$$\Rightarrow \vec{B}_P = \frac{2\mu_0 i}{3a} \left[\frac{1}{\pi} \hat{j} - \hat{k} \right] \qquad \Rightarrow \vec{B}_P = \frac{\mu_0 i}{3\pi a} \sqrt{1 + \pi^2}$$

Example 9: What is the smallest value of B that can be set up at the equator to permit a portion of speed 10^7 m/s to circulate around the earth?

$\left[R = 6.4 \times 10^6 m, m_p = 1.67 \times 10^{-27} kg \right]$.

Sol: Particle under action of force in uniform magnetic field, moves in circular orbit whose radius is given by $r = \frac{mv}{Bq}$. For charged particle orbiting near earth with high velocity, the magnetic field can be obtained rearranging above formula.

From the relation $r = \frac{mv}{Bq}$

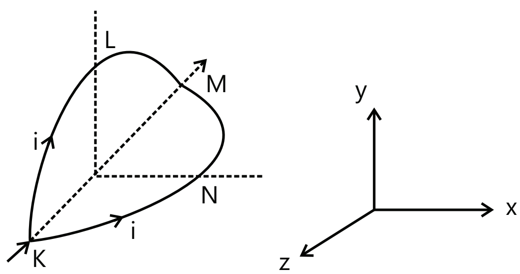
We have $B = \frac{mv}{qr}$

Substituting the values,we have

$$B = \frac{\left(1.67\times10^{-27}\right)\left(10^{7}\right)}{\left(1.6\times10^{-19}\right)\left(6.4\times10^{6}\right)} = 1.6\times10^{8}\,T$$

JEE Advanced/Boards

Example 1: A circular loop of radius R is bent along a diameter and given a shape as shown in figure. One of the semi-circle (KNM) lies in the x-z plane and the other one (KLM) in the y-z plane with their centers at origin. Current I is flowing through each of the semi-circles as shown in Figure.



A particle of charge q is released at the origin with a velocity $V = -V_0\hat{i}$. Find the instantaneous force F in the particle. Assume that space is gravity free.

Sol: For wire bent as shown the magnetic field at the center is calculated as $B = \frac{\mu_0 I(\pi)}{4\pi R}$, where π is the angle subtended by the wire at center. The Lorentz force acting on particle is $\vec{F} = q(\vec{v}\times\vec{B})$

Magnetic field at the center of a circular wire of radius R carrying a current I is given by $B = \frac{\mu_0 I}{2R}$

In this problem, current are flowing in two semi-circles, KLM in the y-z plane and KNM in the x-z plane. The centers of these semi-circles coincide with the origin of the Cartesian system of axes.

$\therefore \vec{B}_{KLM} = \frac{1}{2}\left(\frac{\mu_0 I}{2R}\right)\left(-\hat{i}\right)$ $\therefore \vec{B}_{KNM} = \frac{1}{2}\left(\frac{\mu_0 I}{2R}\right)\left(-\hat{j}\right)$

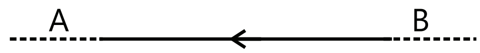
The total magnetic field at the origin is $B_0 = \frac{\mu_0 I}{4R}\left(-\hat{i}+\hat{j}\right)$

It is given that a particle of charge q is released at the origin with a velocity $V = -V_0\hat{i}$. The instantaneous force acting on this particle is given by

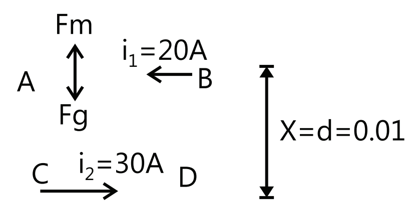
$$f = q\left[V\times B\right] \quad = q\left(-V_0\hat{i}\right)\times\left[\frac{\mu_0 I}{4R}\left(-\hat{i}+\hat{j}\right)\right]$$

$$= \left(\frac{qV_0\mu_0 I}{4R}\right)\left[\left(-\hat{i}\right)\times\left(-\hat{i}+\hat{j}\right)\right] = \frac{qV_0\mu_0 I}{4R}\left(-\hat{k}\right)$$

Example 2: A long horizontal wire AB, which is free to move in a vertical plane and carries a steady current of 20 A, is in equilibrium at a height of 0.01 m over another parallel long wire CD which is fixed in a horizontal plane and carries a steady current of 30 A, as shown in figure Show that when AB is slightlydeed it executes simple harmonic motion. Find the period of oscillation.



Sol: The current carrying wire AB, experiences force due to the magnetic field created by wire CD. Find the equation of motion of wire AB. If the force acting on wire AB is restoring in nature and directly proportional to its displacement from the equilibrium position, then we compare the equation of acceleration with the standard differential equation of SHM. Then time period of oscillation is given by $T = 2\pi\sqrt{\frac{\omega}{g}}$ Let m be the mass per unit length of wire AB. At a height x about the wire AB will be given by



$F_m = \frac{\mu_0 i_1 i_2}{2\pi x}$ (upwards) ... (i)

Wt. per unit of wire AB is F_g =mg (downwards) At x=d, wire in equilibrium

i.e., $F_m = F_g \Rightarrow \frac{\mu_0}{2\pi}\frac{i_1 i_2}{d} = mg$

$$\Rightarrow \frac{\mu_0 i_1 i_2}{2\pi d^2} = \frac{mg}{d} \quad \text{...(ii)}$$

When AB is deed, x decreases therefore, F_m will increase, F_g remains the same. Let

AB is displaced by dx downwards.

Differentiating equation (i) w.r. t.x, we get

$$dF_m = -\frac{\mu_0}{2\pi}\frac{i_1 i_2}{x^2}dx \quad \text{...(iii)}$$

i.e., restoring force, F=d $F_m \propto -dx$

Hence the motion of wire is simple harmonic. From equation (ii) and (iii), we can write

$$dF_m = -\left(\frac{mg}{d}\right).dx \qquad (x=d)$$

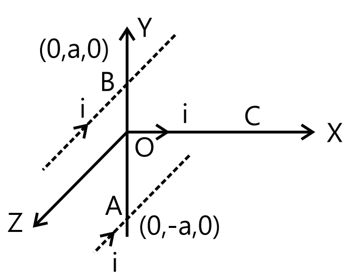
$$\therefore \text{Acceleration of wire, } a = -\left(\frac{g}{d}\right).dx$$

Hence period of oscillations

$$T = 2\pi\sqrt{\frac{dx}{a}} = 2\pi\sqrt{\left|\frac{\text{disp.}}{\text{acc.}}\right|}$$

$$\Rightarrow T = 2\pi\sqrt{d/g} = 2\pi\sqrt{\frac{0.01}{9.8}} \quad \Rightarrow T = 0.2s$$

Example 3: A straight segment OC (of length L meter) of a circuit carrying a current 1 amp is placed along the x-axis. Two infinitely long straight wire A and B, each extending $z = -\infty$ to $+\infty$ are fixed at y=-a meter and y=+a meter respectively, as shown in the figure. If the wires A and B each carry a current 1 amp into the plane of the paper, obtain the expression for the force acting on segment OC. What will be the force on OC if the current in the wire B is reversed?



Sol: Find the net field due to wires A and B at any point on the wire OC.Find the force due to this field on a small current element of wire OC at that point. Then integrate this expression to find force on wire OC.

Magnetic field B_A produced at P(x,0, 0) due to wire, $B_A = \mu_0 I/2\pi R$, $B_B = \mu_0 I/2\pi R$.

Components of B_A and B_B along x-axis cancel, while those along y-axis add up to give total field.

$$B = 2\left(\frac{\mu_0 I}{2\pi R}\right)\cos\theta = \frac{2\mu_0 I}{2\pi R}\frac{x}{R} = \frac{\mu_0 I}{\pi}\frac{x}{\left(a^2+x^2\right)}$$

(along – y direction)

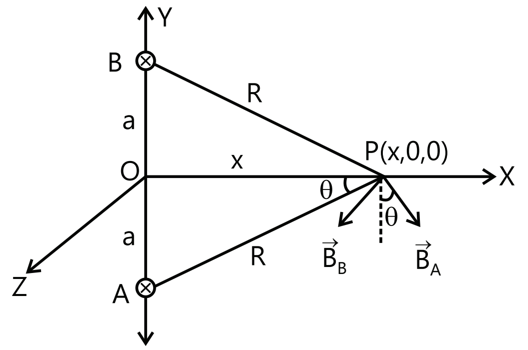
The force dF acting on the current element is

$$dF = I(d\ell \times B)$$

$$dF = \frac{\mu_0 I^2}{\pi}\frac{x\,dx}{a^2+x^2} \quad \left[\because \sin 90^\circ = 1\right]$$

$$\Rightarrow F = \frac{\mu_0 I^2}{\pi}\int_0^L \frac{xdx}{a^2+x^2} = \frac{\mu_0 I^2}{2\pi}\ln\frac{a^2+L^2}{a^2}$$

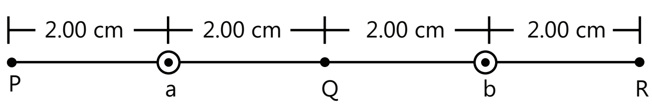
If the current in B is reversed, the magnetic field due to the two wires would be only along



x- direction and the force on the current along

x- direction will be zero.

Example 4: Two long wires a and b, carrying equal currents of 10.0 A, are placed parallel to each other with a separation of 4.00 cm between them as shown in figure. Find the magnetic field B at each of the points P, Q and R.



Sol: Net field at a point will be the vector sum of the fields due to the two wires.

The magnetic field at P due to the wire a has magnitude

$$B_1 = \frac{\mu_0 i}{2\pi d} = \frac{4\pi\times10^{-7}\,TmA^{-1}\times10A}{2\pi\times2\times10^{-2}m} = 1.00\times10^{-4}\,T.$$

Its direction will be perpendicular to the line shown and will point downward in the figure. The field at this point due to the other wire has magnitude

$$B_2 = \frac{\mu_0 i}{2\pi d} = \frac{4\pi\times10^{-7}\,TmA^{-1}\times10A}{2\pi\times6\times10^{-2}m} = 0.33\times10^{-4}\,T.$$

Its direction will be the same as that of B_1. Thus, the resultant field will be $1.33\times10^{-4}\,T$ also along the same direction.

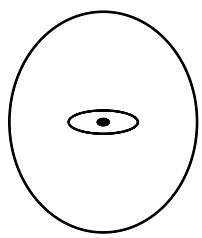
Similarly, the resultant magnetic field at R will be $= 1.33\times10^{-4}\,T$ along the direction pointing upward in the figure.

The magnetic field at point Q due to the two wires will have equal magnitudes but opposite directions and hence the resultant field will be zero.

Example 5: A coil of radius R carries current I. Another concentric coil of radius (r<<R) carries current i. Planes of two coils are mutually perpendicular and both the coils are free to rotate about a common diameter. Find maximum kinetic energy of smaller coil when both the coils are released, masses of coils are M and m respectively.

Sol: For rotating coils, kinetic energy is $\frac{1}{2}I\,\omega^2$.

Each coil is a magnetic dipole and has a potential energy in magnetic field due to other coil. This potential energy is converted into kinetic energy as the dipole moment of the coil aligns itself with the magnetic field.



If a magnetic dipole having moment M be rotated through angle θ from equilibrium position in a uniform magnetic field B, work done on it is $W = MB(1-\cos\theta)$. This work is stored in the system in the form of energy. When system is release, dipole starts to rotate to occupy equilibrium position and the energy converts into kinetic energy and kinetic energy of the system is maximum when stored energy is completely released.

Magnetic induction, at centers due to current in larger coil $B = \frac{\mu_0 i}{2R}$ Magnetic dipole moment of smaller coil is $i\pi r^2$. Initially planes of two coils are mutually perpendicular, therefore θ is $90°$ or energy of the system is $U = \left(i\pi r^2\right)B\left(1-\cos 90°\right)$

$$U = \frac{\mu_0 Ii\pi r^2}{2R}$$

When coils are released, both the coils start to rotate about their common diameter and their kinetic energies are maximum when they become coplanar.

Moment of inertia of larger coil about axis of rotation is $I_1 = \frac{1}{2}mR^2$ and that of smaller coil is $I_2 = \frac{1}{2}mr^2$.

Since, two coils rotate due to their mutual interaction only, therefore, if one coil rotates clockwise then the other rotates anticlockwise.

Let angular velocities of larger and smaller coils be numerically equal to ω_1 and ω_2 respectively when they become coplanar,

According to law of conservation of angular momentum,

$$I_1\omega_1 = I_2\omega_2$$

and according to law of conservation of energy,

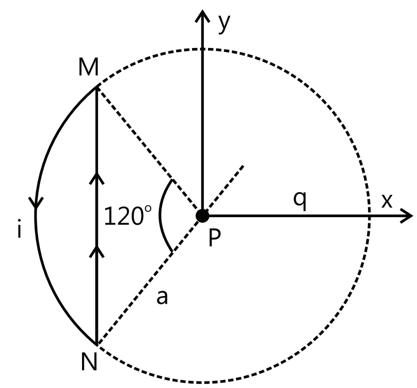
$$\frac{1}{2}I_1\omega_1^2 + \frac{1}{2}I_2\omega_2^2 = U$$

From above equations, maximum kinetic energy of smaller coil,

$$\frac{1}{2}I_2\omega_2^2 = \frac{UI_1}{I_1+I_2} = \frac{\mu_0\pi IiMr^2}{2\left(MR^2+mr^2\right)}$$

Example 6: A wire loop carrying a current I is placed in the x-y plane as shown in Figure.

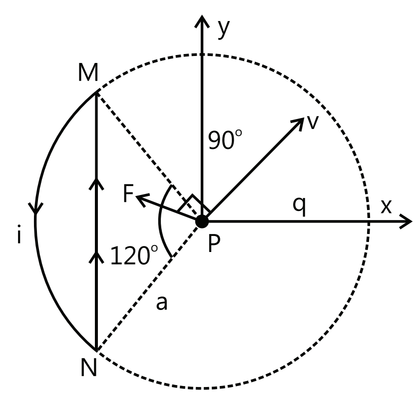
(a) If a particle with charge q and mass m is placed at the centerP and given a velocity v along NP find its instantaneous acceleration.



(b) If an external uniform magnetic induction $B = B\hat{i}$ is applied, find the force and torque acting on the loop.

Sol: Find the net magnetic field at the point P due to the arc and the straight wire and find the magnetic force on q by rules of vector cross product. The magnetic force on a current loop in uniform magnetic field is zero. The toque will be non-zero depending on the angle between field and the area vector of the loop.

(a) As in case of current-carrying straight conductor and arc, the magnitude of B is given by



$$B_1 = \frac{\mu_0 i}{4\pi d}(\sin\alpha + \sin\beta) \text{ and } B_2 = \frac{\mu_0 I\phi}{4\pi r}$$

So in accordance with right hand screw rule,

$$\left(\vec{B}_W\right) = \frac{\mu_0}{4\pi}\frac{1}{(a\cos 60)} \times 2\sin 60(-\hat{k}) \text{ and due to are}$$

$$\left(\vec{B}\right)_{MN} = \frac{\mu_0}{4\pi}\frac{I}{a} \times \left(\frac{2}{3}\pi\right)\left(+\hat{k}\right)$$

and hence net $\vec{B}$ at P due to the givenloop

$$\vec{B} = \vec{B}_W + \vec{B}_A$$

$$\Rightarrow \vec{B} = \frac{\mu_0}{4\pi}\frac{2I}{a}\left[\sqrt{3} - \frac{\pi}{3}\right](-\hat{k}) \quad \text{...(i)}$$

Now as force on charged particle in a magnetic fields is given by

$$\vec{F} = q\left(\vec{v} \times \vec{B}\right)$$

So here, $\vec{F} = qvB\sin 90°$ along PF

i.e. $\vec{F} = \frac{\mu_0}{4\pi}\frac{2qvI}{a}\left[\sqrt{3} - \frac{\pi}{3}\right]$ along PF

and so $\vec{a} = \frac{\vec{F}}{m} = 10^{-7}\frac{2qvI}{a}\left[\sqrt{3} - \frac{\pi}{3}\right]$ along PF

(b) As $d\vec{F} = Id\vec{L} \times \vec{B}$, so $\vec{F} = \int Id\vec{L} \times \vec{B}$

As here I and $\vec{B}$ are constant

$$F = I\left[\int dL\right] \times B = 0\left[as \int dL = 0\right]$$

Further as area of coil,

$$\vec{S} = \left[\frac{1}{3}\pi a^2 - \frac{1}{2}.2a \sin 60° \times a \cos 60°\right]\hat{k}$$

$$= a^2\left[\frac{\pi}{3} - \frac{\sqrt{3}}{4}\right]\hat{k}$$

So $\vec{M} = I\vec{S} = Ia^2\left[\frac{\pi}{3} - \frac{\sqrt{3}}{4}\right]\hat{k}$

and hence $\vec{\tau} = \vec{M} \times \vec{B} = Ia^2B\left[\frac{\pi}{3} - \frac{\sqrt{3}}{4}\right]\left(\hat{k} \times \hat{i}\right)$

i.e. $\vec{\tau} = Ia^2B\left[\frac{\pi}{3} - \frac{\sqrt{3}}{4}\right]\hat{j}N - m$ as $\left(\hat{k} \times \hat{i} = \hat{j}\right)$.

Example 7: A disc of radius R rotates at an angular velocity ω about the axis perpendicular to its surface and passing through its center. If the disc has a uniform charge density σ, find the magnetic induction on the axis of rotation at a

Sol: The disc can be thought as made-up of elementary rings. When disc rotates about axis passing through center and perpendicular to plane of disc, then each elementary ring constitutes a current. The magnetic field along axis of rotation due to each elementary ring is to be considered.

At distance r from the center of disc consider a ring of radius r and width dr.

Charge on the ring, $dq = (2\pi r\, dr)\sigma$

Current due to ring is $dI = \frac{dq}{T} = \frac{\omega dq}{2\pi} = \sigma\omega r\, dr$

Magnetic field due to ring at point P on axis is

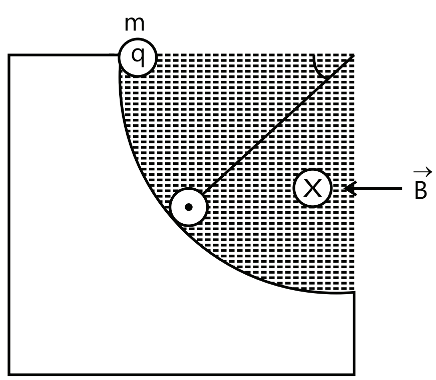
$$dB = \frac{\mu_0 dI r^2}{2\left(r^2 + x^2\right)^{3/2}} \quad \text{or}$$

$$B = \int dB = \frac{\mu_0\sigma\omega}{2}\int_0^R \frac{r^3 dr}{\left(r^2 + x^2\right)^{3/2}} \quad \text{...(i)}$$

Putting $r^2 + x^2 = t^2$ and 2r dr=2t dt and integrating (i) we get

$$B = \frac{\mu_0\sigma\omega}{2}\left[\frac{R^2 + 2x^2}{\sqrt{R^2 + x^2}} - 2x\right].$$

Example 8: In the figure a charged sphere of mass m and charge q starts sliding from rest on a vertical fixed circular track of radius R from the position shown. There exists a uniform and constant horizontal magnetic field of induction B. The maximum force exerted by the track on the sphere.



Sol: As the sphere moves along the circular track the vector sum of radial component of magnetic force, the normal reaction and the radial component of weight of the sphere provide the necessary centripetal force.

$F_m = qvB$, and directed radially outward.

$$\therefore N - mg\sin\theta + qvB = \frac{mv^2}{R} \Rightarrow N = \frac{mv^2}{R} + mg\sin\theta - qvB$$

Hence at $\theta = \pi/2$

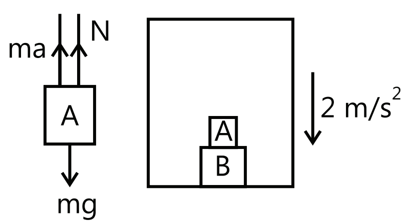
$$\Rightarrow N_{max} = \frac{2mgR}{R} + mg - qB\sqrt{2gR}$$

$$= 3mg - qB\sqrt{2gR}.$$

Example 9: What is the work done in transferring the wire from position (1) to position (2)?

Sol: While transfering wire from position 1 to position 2 find the change in the potential energy of the loop in the field of the wire. This chage in potential energy will be equal to the work done.

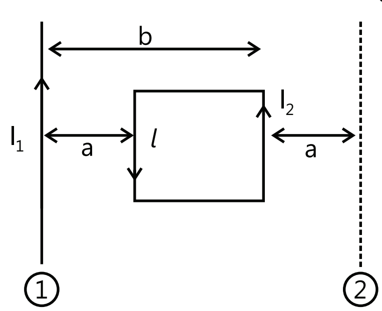
The loop can be considered as the combination of the number of elementary loops. The net current in the dotted wires is 0 as current in the neighboring loops flowing through the same wire opposite in direction. Consider an elementary loop of width dr at a distance r from the wire



The 'dμ' magnetic moment of the elemental loop

$= I_2 l dr$

The B at that point due to straight wire $= \mu_0 I_1/2\pi r$.



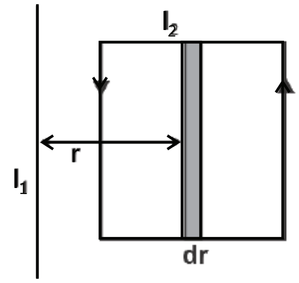
$$dU = -B.d\mu = -\frac{\mu_0 I_1}{2\pi r} I_2 l dr(\cos\pi)$$

[As $d\mu$ is anti-parallel to B.]

$$U_1 = \int du = \frac{\mu_0 I_1 I_2 l}{2\pi}\int_a^b \frac{1}{r}dr = \frac{\mu_0 I_1 I_2 l}{2\pi}\ln\left(\frac{a}{b}\right)$$

By symmetry, $U_2 = -U_1$

$\Rightarrow -\Delta U =$ work done

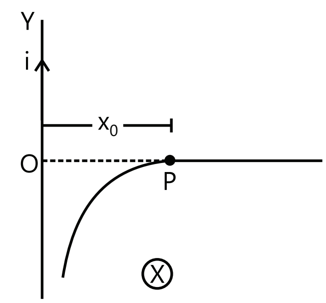


$$= -(U_2 - U_1) = 2\frac{\mu_0 I_1 I_2 l}{2\pi}\ln\frac{b}{a}.$$

The work done in transferring the wire from

Position 1 to 2 $= \frac{\mu_0 I_1 I_2 l}{\pi}\ln\frac{b}{a}$

Example 10: A long, straight wire carries a current i. A particle having a positive charge q and mass m, kept at a distance x_0 from the wire is projected towards it with a speed v. Find the minimum separation between the wire and the particle.



Sol: At minimum separation the x-component of velocity of the particle will be zero. Find the acceleration of the particle due to the magnetic force and solve to get the expression for velocity and displacement.

Let the particle be initially at P. Take the wire as the y-axis and the foot of perpendicular from P to the wire as the origin. Take the line OP as the x-axis. We have, OP= X_0. The magnetic field B at any point to the right of the wire is along the negative z-axis. The magnetic force on the particle is, therefore, in the x-y plane. As there is no initial velocity along the z-axis, the motion will be in the x-y plane. Also, its speed remains unchanged. As the magnetic field is not uniform, the particle does not go along a circle.

The force at time t is $\vec{F} = q\vec{v}\times\vec{B} = q(\vec{i}v_x + \vec{j}v_y)\times\left(-\frac{\mu_0 i}{2\pi x}\vec{k}\right)$

$$= \vec{j}qv_x\frac{\mu_0 i}{2\pi x} - \vec{i}qv_y\frac{\mu_0 i}{2\pi x}.$$

Thus $a_x = \dfrac{F_x}{m} = -\dfrac{\mu_0 qi}{2\pi m}\dfrac{\mu_y}{x} = -\lambda\dfrac{\mu_y}{x}$ ...(i)

Where $\lambda = \dfrac{\mu_0 qi}{2\pi m}$.

Also, $a_x = \dfrac{dv_x}{dt} = \dfrac{dv_x}{dx}\dfrac{dx}{dt} = \dfrac{v_x dv_x}{dx}$. ...(ii)

As $v_x^2 + v_y^2 = v^2$,

$2v_x dv_x + 2v_y dv_y = 0$

giving $v_x dv_x = -v_y dv_y$. ...(iii)

From (i), (ii) and (iii),

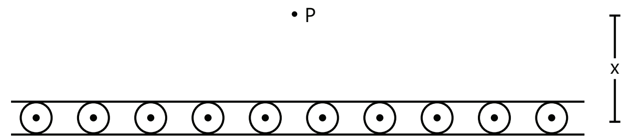
$\dfrac{v_y dv_y}{dx} = \dfrac{\lambda v_y}{x}$ or $\dfrac{dx}{x} = \dfrac{dv_y}{\lambda}$.

Initially $x = x_0$ and $v_y = 0$. At minimum separation from the wire, $v_x = 0$ so that $v_y = -v$.

Thus $\displaystyle\int_{x_0}^{x}\frac{dx}{x} = \int_0^{-v}\frac{dv_y}{\lambda}$ or, $\ln\dfrac{x}{x_0} = -\dfrac{v}{\lambda}$

or, $x = x_0 e^{-v/\lambda} = x_0 e^{-\frac{2\pi mv}{\mu_0 qi}}$

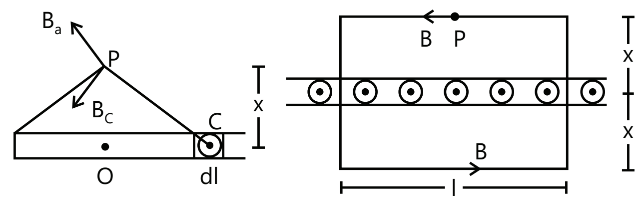
Example 11: Figure shows a cross section of a large metal sheet carrying an electric current along its surface. The current in a strip of width dl is Kdl where K is a constant. Find the magnetic field at a point P at a distance x from the metal sheet.



Sol: Field due to the sheet will be symmetric. Field lines will be parallel to the sheet at points near it. Select a rectangular amperian loop and use Ampere's Law to find the field.

Consider two strips A and C of the sheet situated symmetrically on the two sides of P.The magnetic field at P due to the strip A is B_a perpendicular to AP and that due to the strip C is B_c perpendicular to CP. The resultant of these two is parallel to the width AC of the sheet. The field due to the whole sheet will also be in this direction. Suppose this field has magnitude B.

The field on the opposite side of the sheet at the same distance will also be B but in opposite direction. Applying Ampere's law to the rectangle shown in figure.



(a) (b)

$2Bl = \mu_0 Kl$ or, $B = \dfrac{1}{2}\mu_0 K$ Note that it is independent of x.

JEE Main/Boards

Exercise 1

Q.1 A circular coil of wire consisting of 100 turns, each of radius 8.0 cm carries current of 0.40 A. What is the magnitude of the magnetic field B at the center of the coil?

Q.2 A long straight wire carries a current of 35 A. What is the magnitude of the field B at a point 20 cm from the wire?

Q.3 A long straight wire in the horizontal plane carrier of 50 A in north to south direction. Give the magnitude and direction of Bat a point 2.5 m east of the wire.

Q.4 A horizontal overhead power line carries a current of 90 A in east west direction. What is the magnitude and direction of the magnetic field due to the current 1.5 m below the line?

Q.5 What is the magnitude of a 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?

Q.6 In a chamber, a uniform magnetic field of 6.5 G($1G = 10^{-4}$ T) is maintained. An electron is shot into the field with a speed of 4.8×10^6 ms^{-1} normal to the field. Explain why the path of the electron is a circle. Determine the radius of the circular orbit.

$\left(e = 1.6 \times 10^{-19} C,\ m_e = 9.1 \times 10^{-31} kg\right)$

Q.7 (i) 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^o with the normal of the coil. Calculate the magnitude of the counter torque that must be applied to prevent the coil from turning.

(ii) Would your answer change, if the circular coil in (a) were replaced by a planner coil of some irregular shape that encloses the same area? (All other particulars are also unaltered.)

Q.8 Two concentric circular coils X and Y 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 16 A; 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 center.

Q.9 A straight horizontal conducting rod of length 0.45 m and mass 60 g is suspended by two vertical wires at its ends. A current of 5.0 A is set up in the rod through the wires.

(a) What magnetic field should be set up normal to the conductor in order that the tension in the wire 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?

Q.10 The wires which connect 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 its wires if they are 70 cm long and 1.5 cm apart? Is the force attractive of repulsive?

Q.11 A uniform magnetic field of 1.5 T exists in a cylindrical region of radius10.0 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,

(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?

Q.12 A circular coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2. Current I remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil.

Q.13 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

(a) Total torque on the coil,

(b) Total force on the coil

(c) Average force on each electron is 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 $10^{29} m^{-3}$.)

Q.14 State the Biot-Savart law for the magnetic field due to a current-carrying element. Use this law to obtain a formula for magnetic field at the center of a circular loop of radius a carrying a, steady current I.

Q.15 Give the formula for the magnetic field produced by a straight infinitely long current-carrying wire. Describe the lines of field B in this case.

Q.16 How much is the density B at the center of a long solenoid?

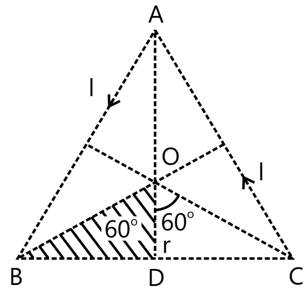
Q.17 A proton shot at normal to magnetic field describe a circular path of radius R. If a deuteron $\left({}_1H^2\right)$ is to move on the same path, what should be the ratio of the velocity of proton and the velocity of deuteron?

Q.18 State the principle of cyclotron.

Q.19 A charge q is moving in a region where both the magnetic field B and electric field E are simultaneously present. What is the Lorentz force acting on the charge?

Q.20 A charged particle moving in a straight line enters a uniform magnetic field at an angle of 45°. What will be its path?

Q.21 A current of 1A is flowing in the sides of an equilateral triangle of side $4.5 \times 10^{-2} m$. Find the magnetic field at the centroid of the triangle.



Q.22 The radius of the first electron orbit of a hydrogen atom is 0.5 Å. The electron moves in this orbit with a uniform speed of $2.2 \times 10^6 ms^{-1}$. What is the magnetic field produced at the center of the nucleus due to the motion of this electron?

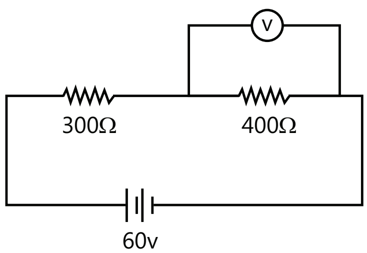
Q.23 A solenoid is 2 m long and 3 cm in diameter. It has 5 layers of windings of 1000 turns each and carries a current of 5 A. What is the magnetic field at itscenter? Use the standard value of μ_0.

Q.24 A proton entersa magnetic field of flux density 2.5 T with a velocity of $1.5 \times 10^7 ms^{-1}$ at an angle of $30°$ with the field. Find the force on the proton.

Q.25 Two parallel wires one meter apart carry currents of 1A and 3 respectively in opposite directions. Calculate the force per unit length acting between these wires.

Q.26 A solenoid of length 0.4, and having 400 turns of wire carries a current of 3 A. A thin coil having 10 turns of wire and radius 0.01 m carries a current 0.4 A. Calculate the torque required to hold the coil in the middle of the solenoid with its axis perpendicularto the axis of the solenoid.

Q.27 In a circuit shown in figure a voltmeter reads 30 V, when it is connected across 400ohm resistance. Calculate what the same voltmeter will read when connected across the 300 Ω resistance?



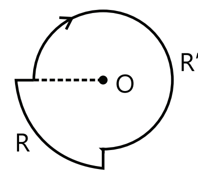
Q.28 Two long straight parallel wires are 2m apart, perpendicular to the plane of the paper. The wire A carries a current of 9.6 ampere directed into the plane of the paper. The wire B carries a current such that the magnetic field induction at the point P, at a distance of $\frac{10}{11}$ m from the wire B, is zero. Calculate

(i) the magnitude and direction of current in B (ii) the magnitude of magnetic field induction at S

(ii) the force per unit length of the wire B.

Exercise 2

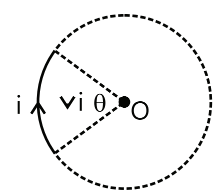
Q.1 A current 1 ampere is flowing through each of the bent wires as shown figure. The magnitude and direction of magnetic field at O is



(A) $\frac{\mu_0 i}{4}\left(\frac{1}{R}+\frac{2}{R'}\right)$ (B) $\frac{\mu_0 i}{4}\left(\frac{1}{R}+\frac{3}{R'}\right)$

(C) $\frac{\mu_0 i}{8}\left(\frac{1}{R}+\frac{3}{2R'}\right)$ (D) $\frac{\mu_0 i}{8}\left(\frac{1}{R}+\frac{3}{R'}\right)$

Q.2 Net magnetic field at the center of the circle O due to a current carrying loop as shown in figure is $(\theta < 180°)$



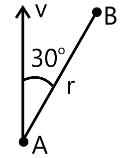
(A) Zero

(B) Perpendicular to paper inwards

(C) Perpendicular to paper outwards

(D) Is perpendicular to paper inwards if $\theta \le 90°$ and perpendicular to paper outwards if $90° \le \theta < 180°$

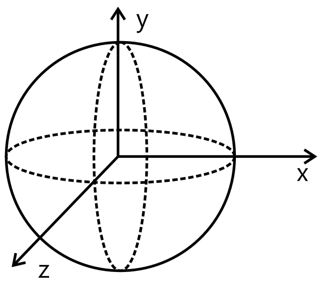
Q.3 A charge particle A of charge q=2C has velocity v=100 m/s. When it passes through point A and has velocity in the direction shown. The strength of magnetic field at point B due to this moving charge is (r=2 m).



(A) 2.5 μT (B) 5.0 μT

(C) 2.0 μT (D) None

Q.4 Three rings, each having equal radius R, are placed mutually perpendicular to each other and each having its center at the origin of co-ordinates system. If current is flowing through each ring then the magnitude of the magnetic field at the common center is



(A) $\sqrt{3}\frac{\mu_0 I}{2R}$ (B) Zero

(C) $\left(\sqrt{2}-1\right)\frac{\mu_0 I}{2R}$ (D) $\left(\sqrt{3}-\sqrt{2}\right)\frac{\mu_0 I}{2R}$

Q.5 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 center is

(A) $5\pi\times10^{-4}$ T towards west

(B) $13\pi\times10^{-4}$ T towards east

(C) $13\pi\times10^{-4}$ T towards west

(D) $5\pi\times10^{-4}$ T towards east

Q.6 Equal current i is flowing in three infinitely long wires along positive x, y and z directions. The magnetic field at a point (0, 0, -a) would be:

(A) $\frac{\mu_0 i}{2\pi a}\left(\hat{j}-\hat{i}\right)$ (B) $\frac{\mu_0 i}{2\pi a}\left(\hat{i}+\hat{j}\right)$

(C) $\frac{\mu_0 i}{2\pi a}\left(\hat{i}-\hat{j}\right)$ (D) $\frac{\mu_0 i}{2\pi a}\left(\hat{i}+\hat{j}+\hat{k}\right)$

Q.7 An electron is moving along positive x-axis. A uniform electric field exists towards negatively 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

Q.8 A particle of charge q and mass m starts moving from the origin under the action of an electric field $E=E_0\hat{i}$ and $B=B_0\hat{i}$ 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) $t=\frac{3Bq}{mv_0}$ (D) $t=\frac{\sqrt{3}mv_0}{qE}$

Q.9 An electron is projected with velocity v_0 in a uniform electric field E perpendicular to the field. Again it is projected with velocity v_0 perpendicular to a uniform magnetic field B. If r_1 is initial radius of curvature just after entering in the electric field and r_2 in initial radius of curvature just after entering in magnetic field then the ratio r_1/r_2 is equal to

(A) $\frac{Bv^2 0}{E}$ (B) $\frac{B}{E}$ (C) $\frac{Ev_0}{B}$ (D) $\frac{Bv_0}{E}$

Q.10 A uniform magnetic field $B=B_0\hat{j}$ exists in a space. A particle of mass m and charge q is projected towards negative x-axis with speed v from the point (d, 0, 0). The maximum value v for which the particle does not hit y-z plane is

(A) $\frac{2B_0q}{dm}$ (B) $\frac{B_0q}{m}$ (C) $\frac{B_0q}{2dm}$ (D) $\frac{B_0qd}{2m}$

Q.11 Two protons move parallel to each other, keeping distance r between them, both moving with same velocity 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

Q.12 Three ions H^+, He^+ and O^{+2} having same kinetic energy pass through a region in which there width is a uniform magnetic field perpendicular to their velocity, then:

(A) H^+ will be least deflected.

(B) He^+ and O^{+2} will be deflected equally.

(C) O^{+2} will be deflected most.

(D) all will be deflected equally.

Q.13 An electron having kinetic energy T is moving in a circular orbit of radius R perpendicular to a uniform magnetic induction 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) $\sqrt{\frac{4}{3}}R$

Q.14 A charged particle moves in magnetic field $B = 10\hat{i}$ 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

Q.15 A electron experiences a force $(4.0\hat{i} + 3.0\hat{j})\ x10^{-13}N$ 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 $(1.5\hat{i} - 2.0\hat{j})x10^7 ms^{-1}$, the magnetic force of the electron is zero. The magnetic field vector B is :

(A) $-0.075\hat{i} + 0.1\hat{j}$ (B) $0.1\hat{i} + 0.075\hat{j}$

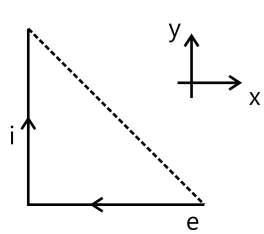
(C) $0.075\hat{i} + 0.1\hat{j} + \hat{k}$ (D) $0.075\hat{i} + 0.1\hat{j}$

Q.16 An electron moving with a velocity $V_1 = 2\hat{i}\, m/s$ at a point in a magnetic field experiences a force $F_1 = -2\hat{j}\, N$. If the electron is moving with a velocity $V_2 = 2\hat{j}\, m/s$ at the same point, it experiences a force $F_2 = +2\hat{i}\, N$. The force the electron would experience if it were moving with a velocity $V_3 = 2\hat{k}\, m/s$ at the same point is

(A) Zero (B) $2\hat{k}$ N

(C) $-2\hat{k}$ N (D) Information is insufficient

Q.17 The direction of magnetic force on the electron as shown in the diagram is along



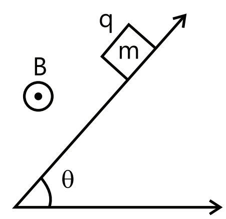
(A) y-axis (B) –y-axis (C) z-axis (D) –z-axis

Q.18 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) $\frac{m\,\text{cosec}\,\theta}{qB}$

(C) $\frac{m\cot\theta}{qB}$ (D) None

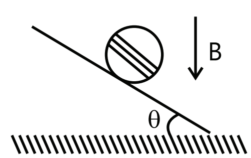
Q.19 A metal ring of radius r=0.5m with its plane normal to a uniform magnetic field B of induction 0.2T carries a current I=100A. The tension in Newton developed in the ring is:



(A) 100 (B) 50

(C) 25 (D) 10

Q.20 In the 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) $\frac{mg\cos\theta}{\pi iR}$ (B) $\frac{mg}{\pi iR}$

(C) $\frac{mg\tan\theta}{\pi iR}$ (D) $\frac{mg\sin\theta}{\pi iR}$

Q.21 The magnetic moment of a circular orbit of radius ‘r’ carrying a charge ‘q’ and rotating with velocity v is given by

(A) $\frac{qvr}{2\pi}$ (B) $\frac{qvr}{2}$

(C) $qv\pi r$ (D) $qv\pi r^2$

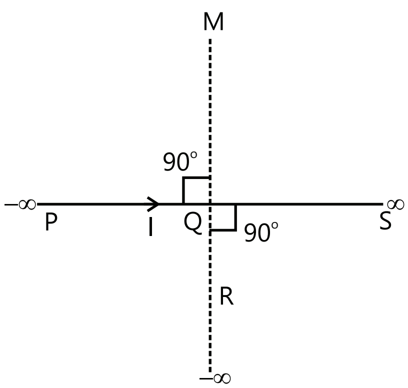
Previous Years' Questions

Q.1 Two very long straight parallel wires carry steady currents I and –I respectively. The distance between the wires is d. At a certain instant of time, a point charge q is at a point equidistant from the two wires in the plane of the wires. Its instantaneous velocity $\vec{V}$ is perpendicular to this plane. The magnitude of the force due to the magnetic field acting on the charge at this instant is ***(1998)***

(A) $\frac{\mu_0 Iqv}{2\pi d}$ (B) $\frac{\mu_0 Iqv}{\pi d}$

(C) $\frac{2\mu_0 Iqv}{\pi d}$ (D) Zero

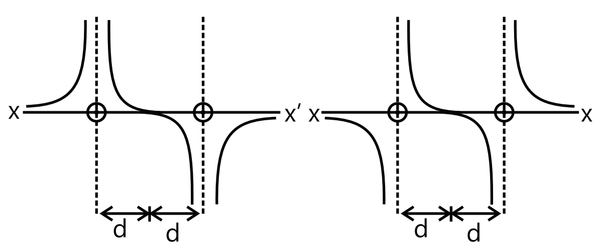
Q.2 An infinitely long conductor PQR is bent to form a right angle as shown in Figure. A current I flows through PQR. The magnetic field due to this current at the point M is H_1. Now, another infinitely long straight conductor QS is connected at Q, so that current is I/2 in QR as well as in QS, the current in PQ remaining uncharged. The magnetic field at M is now H_2. The ratio H_1/H_2 is given by ***(2000)***



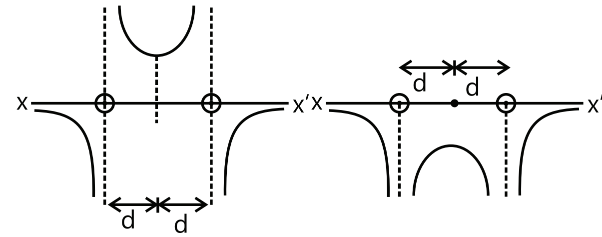
(A) 1/2 (B) 1

(C) 2/3 (D) 2

Q.3 Two long parallel wire 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 ***(2000)***

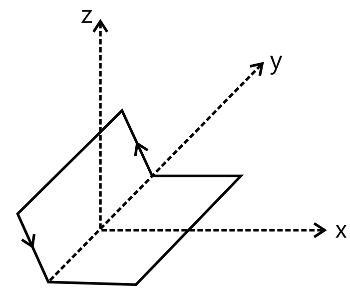


(a) (b)



(a) (b)

Q.4 A non-planar loop of conducting wire carrying a current I is placed as shown in the figure. Each of the straight section of the loop is of length 2a. The magnetic field due tothis loop at the point P(a,0,a) points in the direction ***(2001)***



(A) $\frac{1}{\sqrt{2}}\left(-\hat{j}+\hat{k}\right)$ (B) $\frac{1}{\sqrt{3}}\left(-\hat{j}+\hat{k}+\hat{i}\right)$

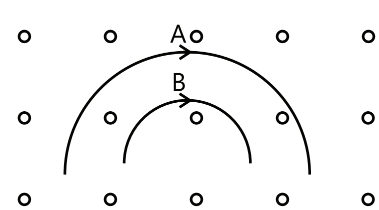
(C) $\frac{1}{\sqrt{3}}\left(\hat{i}+\hat{j}+\hat{k}\right)$ (D) $\frac{1}{\sqrt{2}}\left(\hat{i}+\hat{k}\right)$

Q.5 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 center is ***(2001)***

(A) $\frac{\mu_0 NI}{b}$ (B) $\frac{2\mu_0 NI}{a}$

(C) $\frac{\mu_0 NI}{2(b-a)}\log\frac{b}{a}$ (D) $\frac{\mu_0 I^N}{2(b-a)}\log\left(\frac{b}{a}\right)$

Q.6 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 ***(2001)***



(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 $v_A = v_B$

Q.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 coordinate (x,y) on the z=0 plane is ***(2002)***

(A) $\dfrac{\mu_0 I\left(y\hat{i}-x\hat{j}\right)}{2\pi(x^2+y^2)}$ (B) $\dfrac{\mu_0 I\left(x\hat{i}-y\hat{j}\right)}{2\pi(x^2+y^2)}$

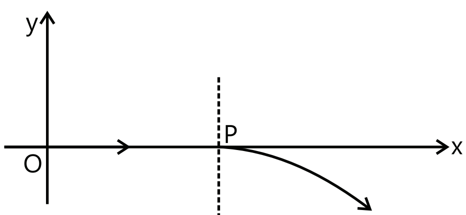
(C) $\dfrac{\mu_0 I\left(x\hat{j}-y\hat{i}\right)}{2\pi(x^2+y^2)}$ (D) $\dfrac{\mu_0 I\left(x\hat{i}-y\hat{j}\right)}{2\pi(x^2+y^2)}$

Q.8 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 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 ***(2002)***

(A) $\dfrac{qbB}{m}$ (B) $\dfrac{q(b-a)B}{m}$ (C) $\dfrac{qaB}{m}$ (D) $\dfrac{q(b+a)B}{2m}$

Q.9 For a positively charged particle moving in a x-y plane initially along x-axis, there is a sudden change in its path due to presence of electric and/or magnetic fields beyond P. The curved path is shown in the x-y plane and is found to be non-circular.

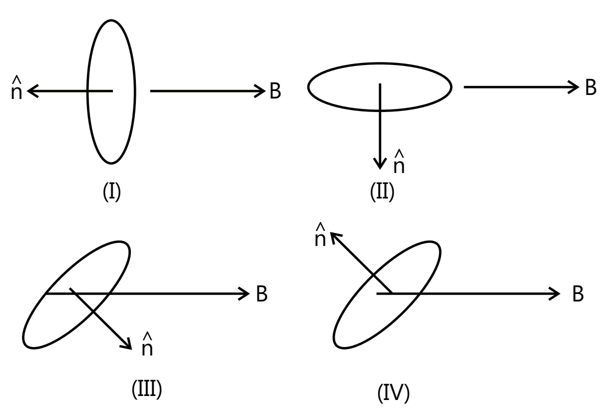
Which one of the following combinations is possible? ***(2003)***



(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) $\vec{E}=a\hat{i};\ \vec{B}=c\hat{k}+b\hat{j}$

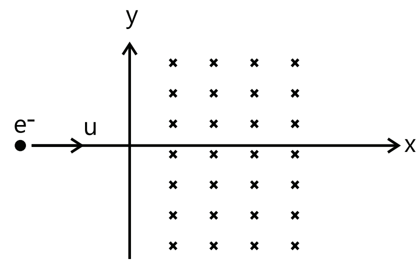
Q.10 A current carrying loop is placed in a uniform magnetic field in four different orientations, I, II, III and IV, arrange them in the decreasing order of potential energy ***(2003)***



(A) I > III > II > IV (B) I > II > III > IV

(C) I > IV > II > III (D) III > IV > I > II

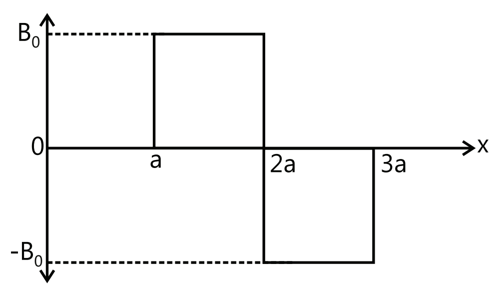
Q.11 An electron moving with a speed u along the position x-axis at y=0 enters a region of uniform magnetic field $\vec{B}=-B_0\hat{k}$ which exists to the right of y-axis. The electron exits from the region after sometime with the speed v at coordinate y, then ***(2004)***



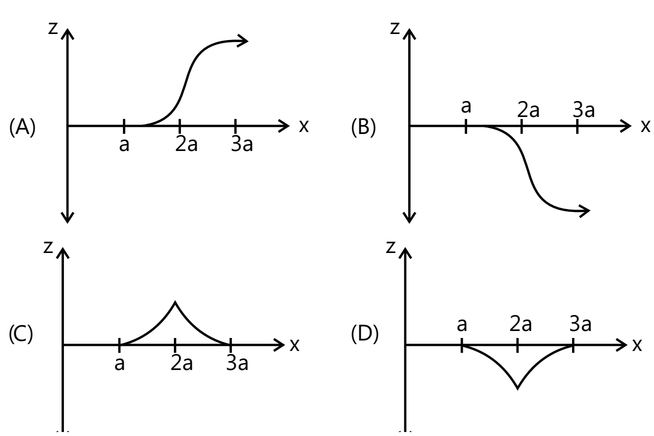
(A) v>u, y<0 (B) v=u, y>0

(C) v>u, y>0 (D) v=u, v<0

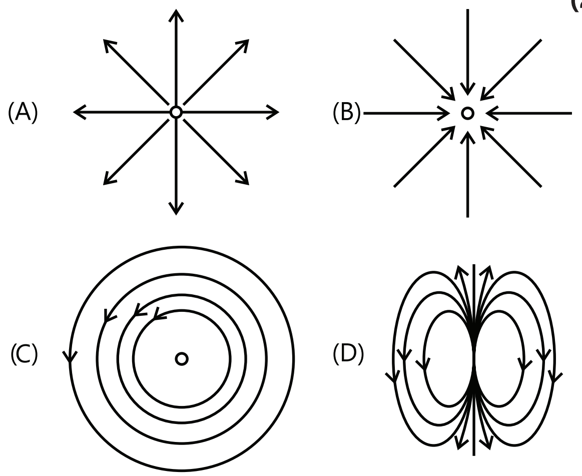
Q.12 A magnetic field $\vec{B}=-B_0\hat{j}$ exists in the region a<x<2a and $\vec{B}=-B_0\hat{j}$, in the region 2a<x<3a, where B_0 is a positive constant. A positive point charge moving with a velocity $\vec{v}=-v_0\hat{i}$, where v_0 is a positive constant, enters the magnetic field at x=a.



The trajectory of the charge in this region can be like ***(2007)***



Q.13 Which of the field patterns given in the figure is valid for electric field as well as for magnetic field? ***(2011)***



Q.14 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 ***(2011)***

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

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

Q.15 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? ***(2012)***

(A) $r_\alpha = r_p = r_d$ (B) $r_\alpha = r_p < r_d$

(C) $r_\alpha > r_d > r_p$ (D) $r_\alpha = r_d > r_p$

Q.16 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 $3.6\times10^{-5}\,Wb/m^2$) ***(2013)***

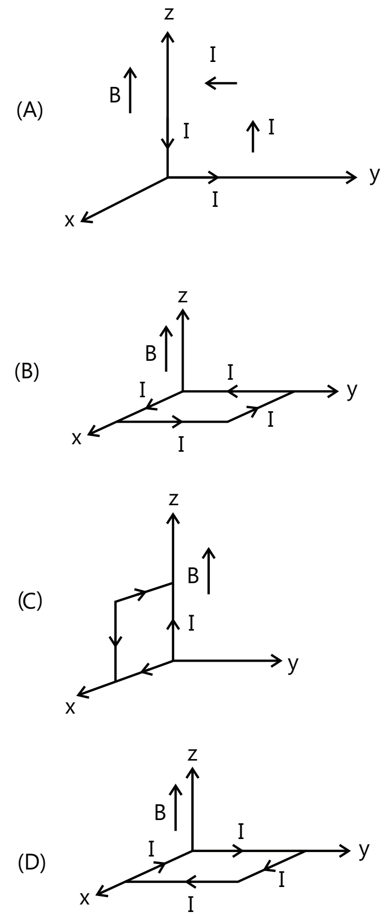
(A) $2.56\times10^{-4}\,Wb/m^2$ (B) $3.50\times10^{-4}\,Wb/m^2$

(C) $5.80\times10^{-4}\,Wb/m^2$ (D) $3.6\times10^{-5}\,Wb/m^2$

Q.17 The coercivity of a small magnet where the ferromagnet gets demagnetized is $3\times10^3\,Am^{-1}$. 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: ***(2014)***

(A) 3A (B) 6A (C) 30 mA (D) 60 mA

Q.18 A rectangular loop of sides 10 cm and 5 cm carrying a current I of 12 A is placed in different orientations as shown in the figures below:



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? ***(2015)***

(A) (a) and (c), respectively

(B) (b) and (d), respectively

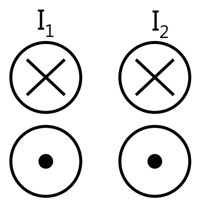
(C) (b) and (c), respectively

(D) (a) and (b), respectively

JEE Advanced/Boards

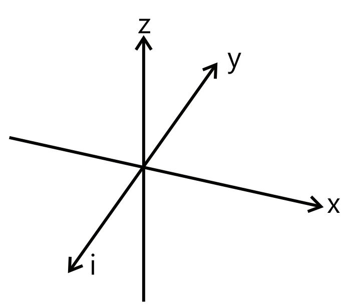
Exercise 1

Q.1 A system of long four parallel conductors whose sections with the plane of the drawing lie at the vertices of a square there flow four equal currents. The directions of these currents are as follows:



Those marked ⊗ point away from the reader, while those marked with a dot point towards the reader. How is the vector of magnetic induction directed at the center of the square?

Q.2 A long straight wire carriers a current of 10A 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?

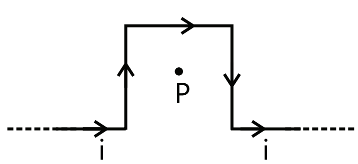


(a) x=0, z=2m ;

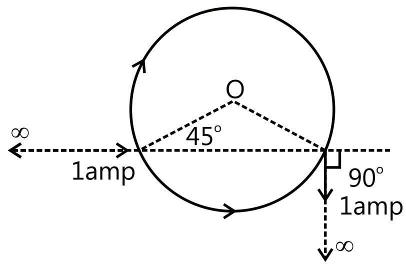
(b) x=2m, z=0

(c) x=0, z=-0.5m

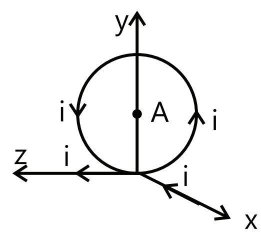
Q.3 Find the magnetic field at the center P of square of side a shown in figure.



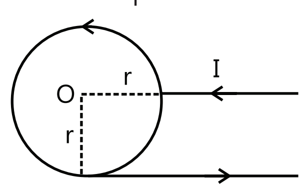
Q.4 What is the magnitude of magnetic field at the center 'O' of loop of radius $\sqrt{2}$ m made of uniform wire when a current of 1amp enters in the loop and taken out of it by two long wires as shown in the figure.



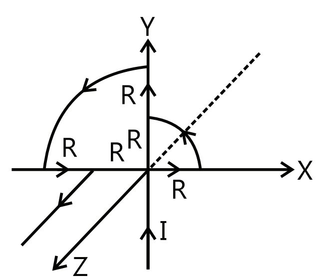
Q.5 Find the magnetic induction at the origin in the figure shown.



Q.6 Find themagnetic induction at point O, if the current carrying wire is in the shape shown in the figure.

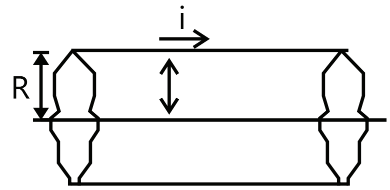


Q.7 Find the magnitude of the magnetic induction B of a magnetic field generated by a system of thin conductors along which a current I is flowing at a point A(O,R,O), that is the center of a circular conductor of radius R. The ring is in the yz plane.



Q.8 A cylindrical conductor of radius R carriers a current along its length. The current density J, however, 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



Q.9 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 lengths with a uniform velocity V.

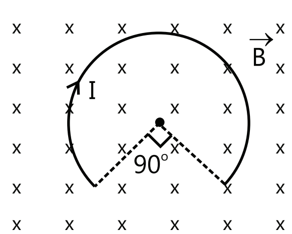
Q.10 An electron moving with a velocity $5x10^{6}ms^{-1}\hat{j}$ in the uniform electric field of $5x10^{7}Vm^{-1}\hat{j}$. Find the magnitude and direction of a minimum uniform magnetic field in tesla that will cause the electron to move undeviated along it original path.

Q.11 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 the particle when it crosses y axis.

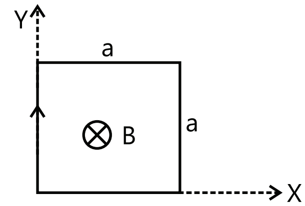
Q.12 A proton beam passes without deviation through a region of space where there are uniform transverse mutually perpendicular electric and magnetic field with E and B. Then the beam strikes a grounded target. Find the force imparted by a beam on the target if the beam current is equal to I.

Q.13 A conducting circular loop of radius r carriers a constant current i. It is placed in a uniform magnetic field B_0 such that B_0 is perpendicular to the plane of the loop. Find the magnetic force acting on the loop.

Q.14 An arc of a circular loop of radius R is kept in the horizontal plane and a constant magnetic field B is applied in the vertical direction as shown in the figure. If the carries current I then find the force on the arc.



Q.15 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.



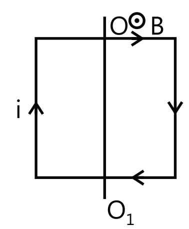
Q.16 A particle of charge +q and mass m moving under the influence of a uniform electric field $E\hat{i}$ and a magnetic field $B\hat{k}$ enters in I quadrant of a coordinate system at a point (0, a) with initial velocity $v\ \hat{i}$ and leaves the quadrant at a point (2a, 0) with velocity $-2v\ \hat{j}$. Find Magnitude of electric field

(a) Rate of work done by the electric field at point

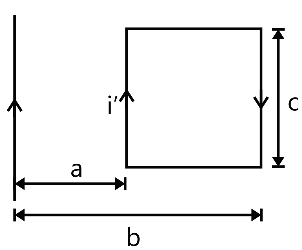
(b) (0, a) Rate of work done by both the fields at.

(c) (2a, 0).

Q.17 A square current carrying loop made of thin wire and having a mass m=10g can rotate without friction with respect to the vertical axis OO_I, passing through the center of the loop at right angles to two opposite sides of the loop. The loop is placed in a uniform magnetic field with an induction $B=10^{-1}T$ directed at right angles to the plane of the drawing. A current I=2A is flowing in the loop. Find the period of small oscillations that the loop performs about its position of stable equilibrium.



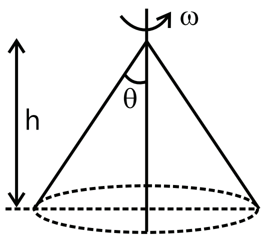
Q.18 An infinitely long straight wire carries a conventional current I as shown in the figure. The rectangular loop carries a conventional current I' in the clockwise direction. Find the net force on the rectangular loop.



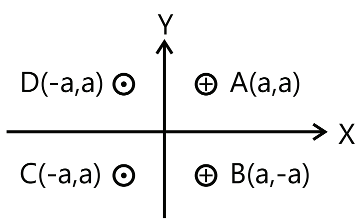
Q.19 3 Infinitely long thin wires each carrying current i in the same direction, are in the x-y plane of a gravity free space. The central wire is along the y-axis while the other two are along $x = \pm d$. (i) Find the locus of the points for which the magnetic field B is zero.

(ii) 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.

Q.20 Q charge isuniformly 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. Calculated associated magnetic dipole moment.



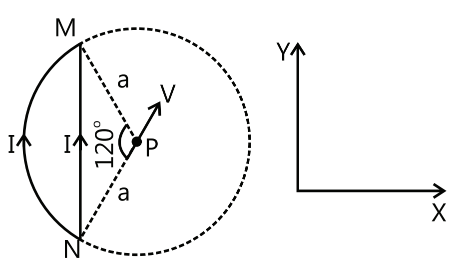
Q.21 Four long wires each carrying current I as shown in the figure are placed at the point A, B, C and D. Find the magnitude and direction of



(i) Magnetic field at the center of the square.

(ii) Force per metre acting on wire at point D.

Q.22 A wire loop carrying current I is placed in the X-Y plane as shown in the figure.



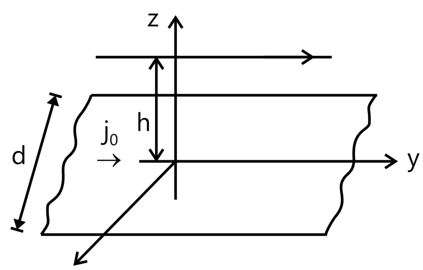
(a) If a particle with charge +Q and mass m is placed at the center P and given a velocity along NP (see figure). Find its instantaneous acceleration.

(b) If an external uniformmagnetic induction field $B = B\hat{i}$ is applied, find the torque acting on the loop due to the field.

Q.23 (a) A rigid circular loop of radius r & mass m lies in the xy plane on a flat table and has a current I flowing in it. At this particular place, the earth's magnetic field is $B = B_x\hat{i} + B_y\hat{j}$. How large must I be before one edge of the loop will lift from table?

(b) Repeat if, $B = B_x\hat{i} + B_z\hat{k}$.

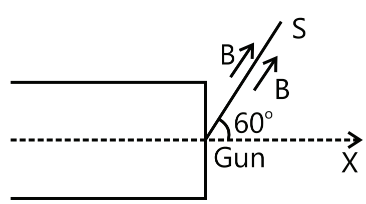
Q.24 A conductor carrying a current is placed parallel a current per unit width j_0 and width d, as shown in the Figure.



Find the force per unit length on the conductor.

Q.25 The figure shows a conductor of weight 1.0N and length L= 0.5m placed on a rough inclined plane making an angle 30^0 with the horizontal so that conductor is perpendicular to a uniform horizontal magnetic field of induction B=0.10 T. The coefficient of static friction between the conductor and the plane is 0.1. A current of I=10A flows through the conductor inside the plane of this paper as shown. What is the force that should be applied parallel to the inclined plane for sustaining the conductor at rest?

Q.26 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=0.1m & line GS makes an angle of 60^0 with the x-axis, as shown in the figure. A uniform magnetic field B parallel to GS exists in the region outside to the electron gun. Find the minimum value of B needed to make the electron hit S.



Q.27 Two coils each of 100 turns are held such that one lies in the vertical plane with their centers coinciding. The radius of the vertical coil is 20cm and that of the horizontal coil is 30cm. How would you neutralize the magnetic field of the earth at their common center? What is the current to be passed through each coil? Horizontal component of earth's magnetic induction = 3.49×10^{-5}T and angle of dip=30^0.

Q.28 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 $+30^0$ and -60^0 at the origin with positive x-direction. The rod is at a distance a from the origin. Find net force on the rod.

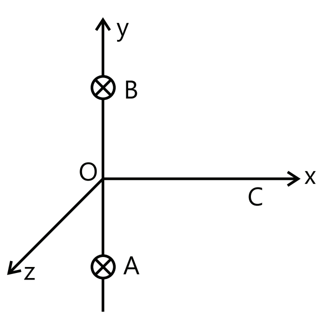
Q.29 A square loop of wire of edge a carries a current i.

(a) Show that B for a point on the axis of the loop and a distance x from its center is given by,

$$B = \frac{4\mu_0 i a^2}{\pi\left(4x^2 + a^2\right)\left(4x^2 + 2a^2\right)^{1/2}}$$

(b) Can the result of the above problem be reduced to give field at x=0?

Q.30 A straight segment OC (of length L meter) of a circuit carrying a current I amp is placed along the x-axis. Two infinitely line straight wires A and B, each extending from $z = -\infty$ to $+\infty$, are fixed by y=−a meter and y=+a meter respectively, as shown in the Figure.

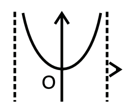


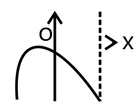
If the wires A and B each carry a current I amp into plane of the paper. Obtain the expression for the force acting on the segment OC. What will be the force OC if current in the wire B is reversed?

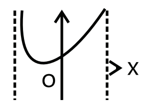
Exercise 2

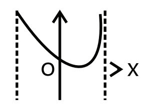
Single Correct Choice Type

Q.1 Two very long straight parallel wires, parallel to -y direction, respectively. The wire are passes through the x-axis at the point (d, 0, 0) and (-d, 0, 0)respectively. The graph of magnetic field z-component as one moves along the x-axis from x=-d to x=+d, is best given by

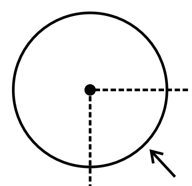
(A) 

(B) 

(C) 

(D) 

Q.2 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



(A) $\frac{\mu_0 I\sqrt{2}}{4\pi^2 R}$ (B) $\frac{\mu_0 I}{\pi^2 R}$

(C) $\frac{2\mu_0 I\sqrt{2}}{\pi^2 R}$ (D) None

Q.3 An electron (mass=9.1×10^{-31}; charge=-1.6×10^{-19}C) experiences no deflection if subjected to an electric field of 3.2×10^5 V/m and a magnetic field of 2.0×10^{-3} Wb/m^2. Both the fields are normal to the path of electron and to each other. If the electric field is removed, then the electron will revolve in an orbit of radius:

(A) 45m (B) 4.5m (C) 0.45m (D) 0.045m

Q.4 A particle of specific charge (charge/mass) α starts moving from the origin under the action of an electric field $E = E_0\hat{i}$ and magnetic field $B = B_0\hat{k}$. Its velocity at $\left(x_0, y_0, 0\right)$ is $\left(4\hat{i} - 3\hat{j}\right)$. 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) $\frac{5\alpha}{2B_0}$

Q.5 A particle of specific charge (q/m) is projected from the origin of coordinates with initial velocity [ui-vj]. Uniform electric magnetic field exist in the region along the +y direction, of magnitude E and B. The particle will definitely return to the origin once if

(A) $\left[vB/2\pi E\right]$ is an integer

(B) $\left(u^2+v^2\right)^{1/2}\left[B/\pi E\right]$ is an integer

(C) $\left[vB/\pi E\right]$ in an integer

(D) $\left[uB/\pi E\right]$ is an integer.

Q.6 Two particles of charges +Q and –Q are projected from the same point with a velocity v in a region of uniform magnetic field B such that the velocity vector makes an angle θ with the magnetic field. Their masses are M and 2M, respectively. Then, they will meet again for the first time at a point whose distance from the point of projection is

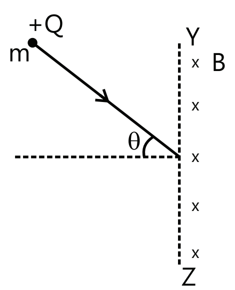
(A) $2\pi Mv\cos\theta/QB$ (B) $8\pi Mv\cos\theta/QB$

(C) $\pi Mv\cos\theta QB$ (D) $4\pi Mv\cos\theta/QB$

Q.7 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 $T=\dfrac{2\pi M}{QB}$. The time spent by the particle in the field will be

(A) $T\theta$ (B) $2T\theta$

(C) $T\left(\dfrac{\pi+2\theta}{2\pi}\right)$ (D) $T\left(\dfrac{\pi-2\theta}{2\pi}\right)$

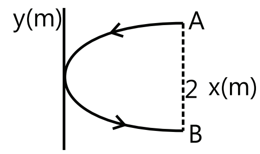


Q.8 In the previous question, if the particle has-Q charge, the time spend by the particle in the field will be

(A) $T\theta$ (B) $2T\theta$

(C) $T\left(\dfrac{\pi+2\theta}{2\pi}\right)$ (D) $T\left(\dfrac{\pi-2\theta}{2\pi}\right)$

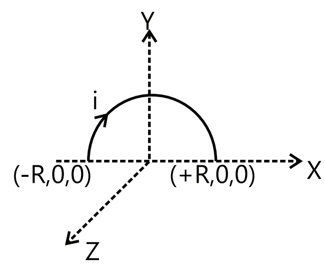
Q.9 A conducting wire bent in the form of a parabola $y^2=2x$ carriers a current i=2A as shown in figure. This wire is placed in a uniform magnetic field $B=-4\hat{k}$ Tesla. The magnetic force on the wire is (in newton).



(A) $-16\hat{i}$ (B) $32\hat{i}$

(C) $-32\hat{i}$ (D) $16\hat{i}$

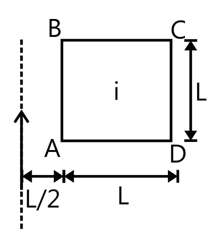
Q.10 A semicircular current carrying wire having radius R is placed in x-y plane with its center at origin 'O'. There is non-uniform magnetic field $\vec{B}=\dfrac{B_o x}{2R}\hat{k}$ (here B_o is +ve constant) is existing in the region. The magnetic force acting on semicircular wire will be along



(A) –x-axis (B) +y-axis

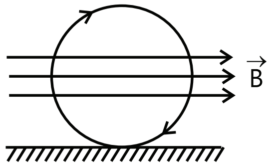
(C) –y-axis (D) +x-axis

Q.11 A square loop ABCD, carrying a current I, is placed near and coplanar with a long straight conductor XY carrying a current I, the net force on the loop will be



(A) $\dfrac{2\mu_0 Ii}{3\pi}$ (B) $\dfrac{\mu_0 Ii}{2\pi}$ (C) $\dfrac{2\mu_0 Iil}{3\pi}$ (D) $\dfrac{\mu_0 Iil}{2\pi}$

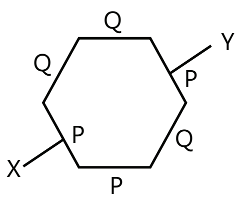
Q.12 A conducting ring of mass 2kg and radius 0.5m is placed on a smooth horizontal plane. The ring carries a current i=4A. A horizontal magnetic field B=10T is switched on at time t=0 as shown in figure. The initial angular acceleration of the ring will be

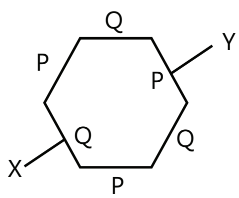


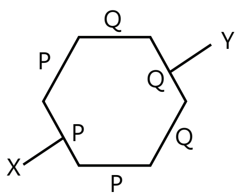
(A) $40\pi rad / s^2$ (B) $20\pi rad / s^2$

(C) $5\pi rad / s^2$ (D) $15\pi rad / s^2$

Q.13 In the following hexagons, made up of two different material P and Q, current enters and leaves from points X and Y respectively. In which case the magnetic field at its center is not zero.

(A)


(B)


(C)


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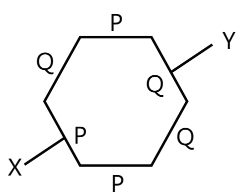
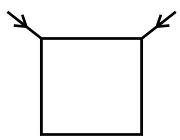
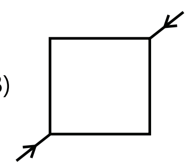
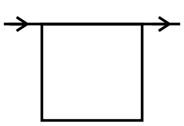


Q.14 Current flows through uniform, square frames as shown.

In which case is the magnetic field at the center of the frame not zero?

(A)


(B)


(C)


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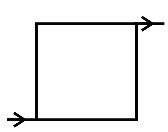
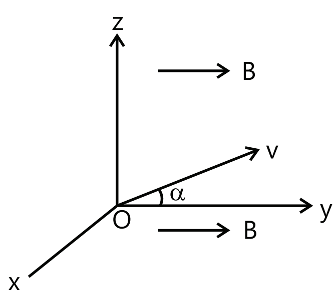


Q.15 In a region of space, a uniform magnetic field B exists in the y-direction. A proton is fired from the origin, with initial velocity v making a small angle α with the y-direction in the yz plane. In the subsequent motion of the proton,



(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.

Multiple Correct Choice Type

Q.16 Which of the following statements is correct:

(A) A charged particle enters a region of uniform magnetic field at an angle 85^0 to magnetic lines of force. The path of the particle is a circle.

(B) An electron and proton are moving with the same kinetic energy along the same direction. When they pass through uniform magnetic field perpendicular to their direction of motion, they describe circular path.

(C) There is no change in the energy of a charged particle moving in a magnetic field although magnetic force acts on it.

(D) Two electrons enter with the same speed but in opposite direction in a uniform transverse magnetic field. Then the two describe circle of the same radius and these move in the same direction.

Q.17 Consider the magnetic field produced by a finitely long current carrying wire.

(A) The lines of field will be concentric circles with centers on the wire.

(B) There can be two points in the same plane where magnetic fields are same.

(C) There can be large number of points where the magnetic field is same.

(D) The magnetic field at a point is inversely proportional to the distance of the point from the wire.

Q.18 A long straight wire carriers 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 field of the same magnitude?

(A) A and B (B) A and C (C) B and C (D) B and D

Q.19 Consider three quantities x=E/B, $y=\sqrt{1/\mu_0\varepsilon_0}$ and $z=\frac{1}{CR}$. Here, l is the length of a wire, C is a capacitance and R is a resistance. All other symbols have standard meanings.

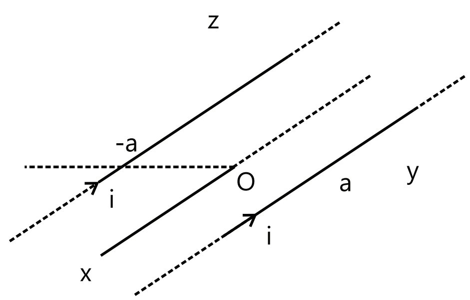
(A) x,y have the same dimensions

(B) y, z have the same dimension

(C) z, x have the same dimensions

(D) None of the three pairs have the same dimensions.

Q.20 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 an x-component.

Q.21 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

Q.22 Two identical charged particles enter a uniform magnetic field with same speed but at angles 30^0 and 60^0 with field. Let a, b and c be the ratio of their time periods, radii and pitches of the helical paths then

(A) abc=1 (B) abc > 1

(C) abc < 1 (D) a=bc

Q.23 Consider the following statements regarding a charged particle in a magnetic field. Which of the statement are true :

(A) Starting with zero velocity, it accelerates in a direction perpendicular to the magnetic field.

(B) While deflecting in magnetic field its energy gradually increases.

(C) Only the component of magnetic field perpendicular to the direction of motion

of the charged particle is effective in deflecting it.

(D) Direction of deflecting force on the moving charged particle is perpendicular to its velocity.

Assertion Reasoning Type

(A) Statement-I is true, statement-II is true and Statement-II is correct explanation for Statement-I.

(B) Statement-I is true, statement-II is true and statement-II is NOT the correct explanation for statement-I.

(C) Statement-I is true, statement-II is false.

(D) Statement-I is false, statement-II is true.

Q.24 Statement-I: A charged particle can never move along a magnetic field line in absence of any other force.

Statement-II: Force due to magnetic field is given by $\vec{F} = q\left(\vec{v} \times \vec{B}\right)$.

Q.25 Statement-I : It is not possible for a charged particle to move in a circular path around a long straight uncharged conductor carrying current under the influence of its magnetic field alone.

Statement-II: The magnetic force (if nonzero) on a moving charged particle is normal to its velocity.

Q.26 Statement-I: For a charged particle to pass through a uniform electro-magnetic field without change in velocity, its velocity vector must be perpendicular to the magnetic field.

Statement-II: Net Lorentz force on the particle is given by $F = q\left[E + \vec{v} \times B\right]$

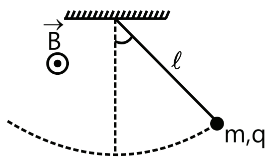
Q.27 Statement-I: Two long parallel conductors carrying current in the same direction experience a force of attraction.

Statement-II: The magnetic fields produced in the space between the conductors are in the same direction.

Q.28 Statement-I: Ampere law can be used to find magnetic field due to finite length of a straight current carrying wire.

Statement-II: The magnetic field due to finite length of a straight current carrying wire is symmetric about the wire.

Q.29 Statement-I: A pendulum made of a non-conducting rigid massless rod of length ℓ is attached to a small sphere of a mass m and charge q. The pendulum is undergoing oscillations of small amplitude having time period T. Now a uniform horizontal magnetic field out of plane of page is switched on. As a result of this change, the time period of oscillations will change.

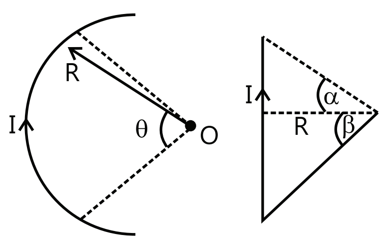


Statement-II: In the situation of statement-I, after the magnetic field is switched on the tension in string will change (except when the bob is at extreme position).

Comprehension Type

Paragraph 1: Magnetic field intensity (B) due to current carrying conductor can be calculated by use of Biot-Savart law. Which is

$$B = \frac{\mu_0}{4\pi}\frac{Idl x r}{r^3},$$



where dB is magnetic field due current element Idl at a position r from current element. For straight wire carrying current magnetic field at a distance R from wire is

$$B = \frac{\mu_0}{4\pi}\frac{I}{R}(\sin\alpha + \sin\beta)$$

And magnetic field due to a circular arc at its center is

$$B = \frac{\mu_0 I}{4\pi R}.\theta$$

where θ angle of circular arc at center, R is radius of circular arc.

Q.30 The magnetic field at C due to curved part is

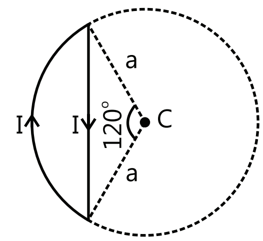
(A) $\frac{\mu_0 I}{6\alpha}$, directed into the plane of the paper

(B) $\frac{\mu_0 I}{6\alpha}$, directed towards you

(C) $\frac{\mu_0 I}{3\alpha}$, directed towards you

(D) $\frac{\mu_0 I}{3\alpha}$, directed up the plane of the paper

Q.31 A wire loop carrying a current I is shown in figure. The magnetic field induction at C due to straight part is



(A) $\frac{\sqrt{3}\mu_0 I}{2\pi\alpha}$, directed up the plane of the paper

(B) $\frac{\mu_0 I}{6\alpha}$, directed into the plane of the paper

(C) $\frac{\mu_0 I}{6\alpha}$, directed towards you

(D) $\frac{\mu_0 I}{2\alpha}\left(\frac{\sqrt{3}}{\pi} - \frac{1}{3}\right)$ towards you

Q.32 The net magnetic field at C due to the current carrying loop is directed into the plane of the paper

(A) Zero

(B) $\frac{\mu_0 I}{\alpha}$

(C) $\frac{\mu_0 I}{9\alpha}$

(D) $B = -\frac{\mu_0 I}{6a} + \frac{\sqrt{3}\mu_0 I}{2\pi a}$,

Paragraph 2: A current carrying coil behave like short magnet whose magnetic dipole moment M=nIA. Where direction of M is taking along the direction of magnetic fields on its axis and n is no of turns A is area of coil and I is current flowing through coil. When such a coil is put in magnetic field (B) magnetic torque (τ) acts on it as $\tau = -MxB$ and potential energy of the current loop in the magnetic field is u=–M.B.

Q.33 A current of 3A is flowing in a plane circular coil of radius 1cm and having 20 turns. The coil is placed in a uniform magnetic field of 0.5 Wbm^{-2}. Then, the dipole moment of the coil is

(A) $3000Am^2$ (B) $0.3Am^2$

(C) $75\,Am^2$ (D) $1.88x10^{-2}\,Am^2$

Q.34 A current of 3A is flowing in a plane circular coil of radius 1cm and having 20 turns. The coil is placed in a uniform magnetic field of 0.5 Wbm^{-2}. Then, the P.E. of the magnetic dipole in the position of stable equilibrium is

(A) -1500 J (B) -9.4 mJ

(C) +0.15 J (D) +1500 J

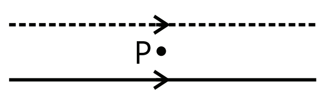
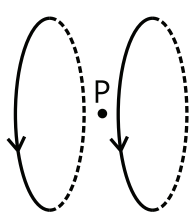
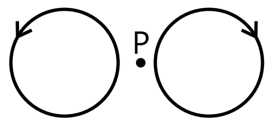
Q.35 In above question, to hold the current-carrying coil with the normal to its plane making an angle of 90^0 with the direction of magnetic induction, the necessary torque is

(A) 1500 Nm (B) 9.4×10^{-3} Nm

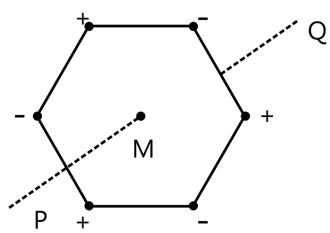
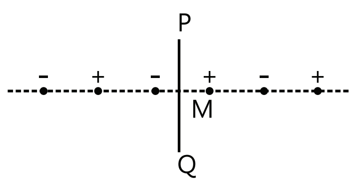
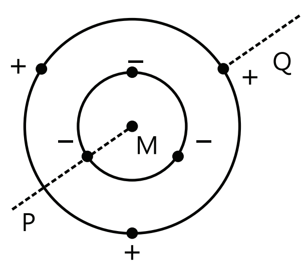
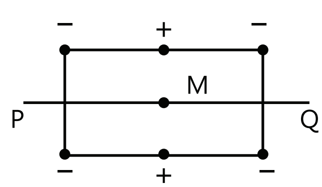
(C) 15 Nm (D) 150 Nm

Match the Column

Q.36 Two wires each carrying a steady current I are shown in four configuration in column I. Some of the resulting effects are described in column II. Match the statement in column I with the statements in column II and indicate your answer by darkening appropriate bubbles in the 4 x 4 matrix given in the ORS.

Column I	**Image**	**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 current 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.

Q.37 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 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.

Column-I	Image	Column-II
(A) $E=0$		Charges are at the corners of a regular hexagon. M is the center of the hexagon. PQ is perpendicular to the plane of the hexagon.
(B) $V \neq 0$		Charges are on a line perpendicular to PQ at equal intervals. M is the midpoint between the two innermost charges.
(C) $B=0$		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 center of the rectangle. PQ is parallel to the longer sides.
(D) $\mu \neq 0$		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 center of the rectangle. PQ is parallel to the longer sides.

Previous Years' Questions

Q.1 Statement I: The sensitivity of a moving coli galvanometer is increased by placing a suitable magnetic material as a core inside the coil. ***(2008)***

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

(A) Statement-I is true, statement-II is true and Statement-II is correct explanation for Statement-I.

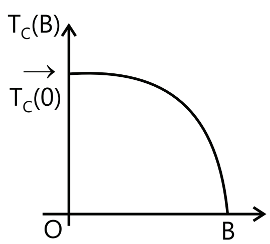
(B) Statement-I is true, statement-II is true and statement-II is NOT the correct explanation for statement-I.

(C) Statement-I is true, statement-II is false.

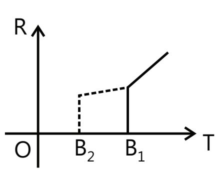
(D) Statement-I is false, statement-II is true.

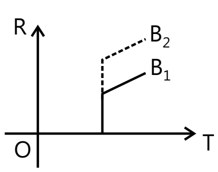
Passage: (Q.2-Q.3)

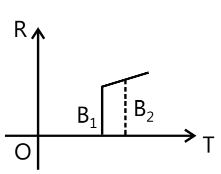
Electrical resistance of certain material, known as superconductors, changes abruptly from a non-zero value to zero as their temperature is lowered below a critical temperature $T_C(0)$. An interesting property of superconductors is that their critical temperature becomes smaller than $T_C(0)$ if they are placed in a magnetic field i.e., the critical temperature $T_C(B)$ is a function of the magnetic strength B. The dependence of $T_C(B)$ on B is shown in the Figure.

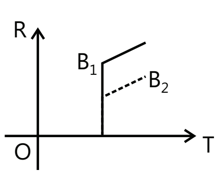


Q.2 In the graphs below, the resistance R of a superconductor is shown as a function of its temperature T for two different magnetic fields B_1 (solid line) and B_2 (dashed line). If B_2 is larger than B_1, which of the following graphs shows the correct variation of R with T in these fields? ***(2010)***

(A) 

(B) 

(C) 

(D) 

Q.3 A superconductor has $T_C(0)=100K$. When a magnetic field of 7.5 Tesla is applied, its T_C decreases to 75K. For this material one can definitely say that when (Note: T=Tesla) ***(1987)***

(A) B=5T, $T_C(B)=80K$

(B) B=5T, $75K < T_C(B) < 100K$

(C) B=10T, $75K < T_C(B) < 100K$

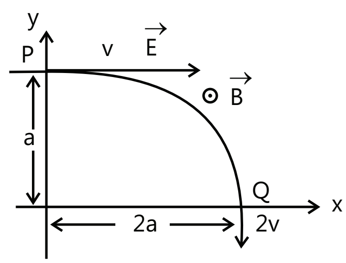
(D) B=10T, $T_C(B)=70K$

Q.4 A proton moving with a constant velocity passes through a region of space without any change in its velocity. If E and B represent the electric and magnetic fields respectively. Then, this region of space may have ***(1985)***

(A) E=0, B=0 (B) E=0, B≠0

(C) E≠0, B=0 (D) E≠0, B≠0

Q.5 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 $v\hat{i}$ and $-2\hat{j}$. Which of the following statement (s) is/are correct? ***(1991)***



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

(B) Rate of work done by the electric field at P is $\frac{3}{4}\left[\frac{mv^2}{a}\right]$

(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

Q.6 H^+, He^+ and O^{2+} all having the same kinetic energy pass through a region in which there is a uniform magnetic field perpendicular to their velocity. The masses of H^+, He^+ and O^{2+} are 1 amu, 4 amu and 16 amu respectively. Then ***(1994)***

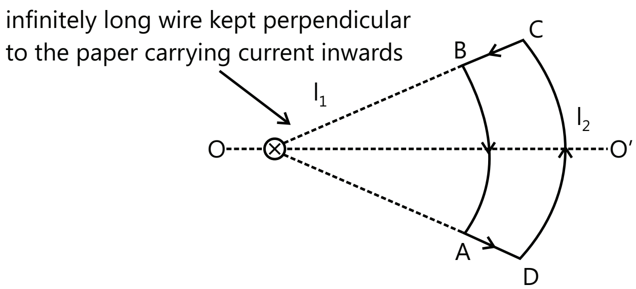
(A) H^+ will, be deflected most

(B) O^{2+} will be deflected most

(C) He^+ and O^{2+} will be deflected equally

(D) All will be deflected equally

Q.7 Which of the following statement is (are) correct in the given Figure? ***(2006)***



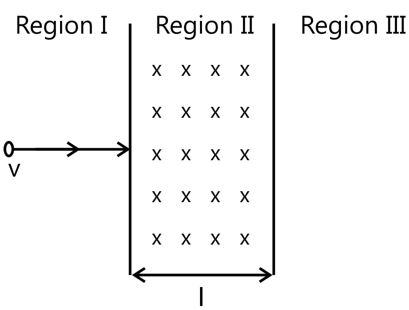
(A) Net force on the loop is zero.

(B) Net torque on the loop is zero.

(C) Loop will rotate clockwise about axis OO' when seen from O

(D) Loop will rotate anticlockwise about OO′ when seen from O

Q.8 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). ***(2008)***



(A) The particle enters Region III only if its velocity$>\frac{qlB}{m}$.

(B) The particle enters Region III only if its velocity $v<\frac{qlB}{m}$.

(C)Path length of the particle in Region II is maximum when velocity $v=\frac{qlB}{m}$.

(D) Time spent in Region II is same for any velocity v as long as the particle returns to Region I.

Q.9 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? ***(2011)***

(A) They will never come out of the magnetic field region

(B) They will come out travelling along parallel axis

(C) They will come out at the same time

(D) They will come out at different times.

Q.10 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 ? ***(2012)***

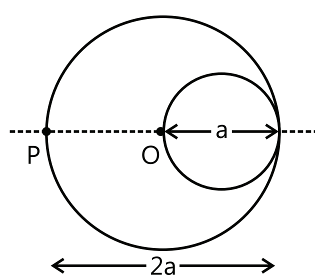
(A) If $\theta=0^o$, the charge moves in a circular path in the x-z plane.

(B) If $\theta=0^o$, the charge undergoes helical motion with constant pitch along the y-axis.

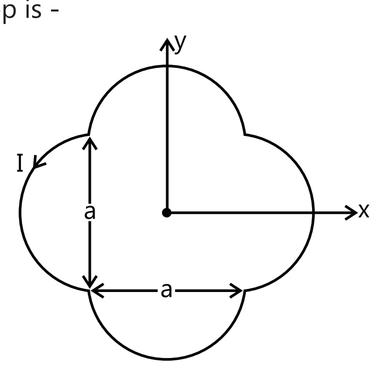
(C) If $\theta=10^o$, the charge undergoes helical motion with its pitch increasing with time, along the y-axis

(D) $\theta=90^o$, the charge undergoes linear but accelerated motion along the y-axis.

Q.11 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 $\frac{N}{12}\mu_0 aJ$, then the value of N is ***(2012)***



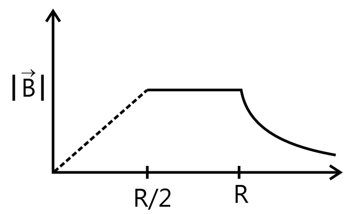
Q.12 A loop carrying current I lies in the x-y plane as shown in the figure. The unit vector $\hat{k}$ is coming out of the plane of the paper. The magnetic moment of the current loop is - ***(2012)***

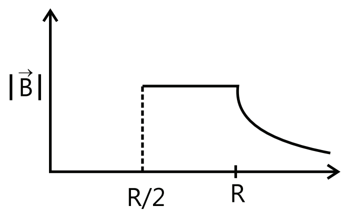


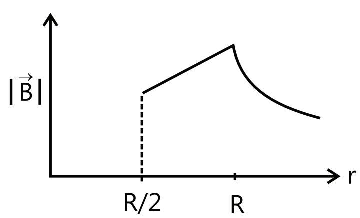
(A) $a^2 I\,\hat{k}$ (B) $\left(\frac{\pi}{2}+1\right)a^2 I\,\hat{k}$

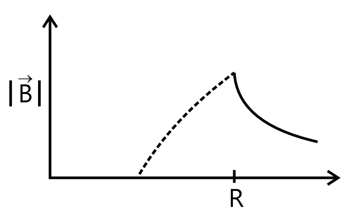
(C) $-\left(\frac{\pi}{2}+1\right)a^2 I\,\hat{k}$ (D) $(2\pi+1)a^2 I\,\hat{k}$

Q.13 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 ***(2012)***

(A)


(B)


(C)


(D)


Q.14 A particle of mass M and positive charge Q, moving with a constant velocity $u_1 = 4\hat{i}\,ms^{-1}$, 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 for all values of y. After passing through this region, the particle emerges on the other side after 10 milliseconds with a velocity $\vec{u}_2 = 2(\sqrt{3}\hat{i}+\hat{j})m/s^{-1}$. The correct statement(s) is (are) ***(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 $\frac{50\pi M}{3Q}$ units.

(D) The magnitude of the magnetic field is $\frac{100\pi M}{3Q}$ units

Q.15 Two bodies, each of mass M, are kept fixed with a separation 2L. A particle of mass m is projected from the midpoint of the line joining their centres, perpendicular to the line. The gravitational constant is G. The correct statement(s) is (are) ***(2013)***

(A) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $4\sqrt{\frac{GM}{L}}$

(B) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $2\sqrt{\frac{GM}{L}}$

(C) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $\sqrt{\frac{2GM}{L}}$

(D) The energy of the mass m remains constant.

Q.16 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 ***(2014)***

Q.17 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 ***(2014)***

(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 $h \approx 1.2a$

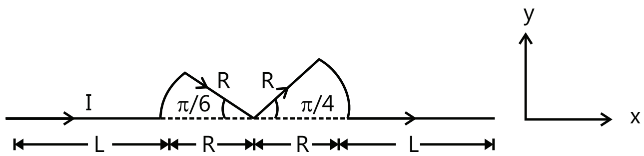
(D) Current in wire 1 and wire 2 is the direction PQ and RS, respectively and $h \approx 1.2a$

Q.18 Consider d >> 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) ***(2014)***

(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) $\frac{\sqrt{3}\mu_0 I^2 a^2}{2d}$

Q.19 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). **(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 $\hat{z}$, $F = 0$

Q.20 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) ***(2015)***

(A) If $w_1 = w_2$ and $d_1 = 2d$, 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 $V_2 = V_1$

Q.21 Consider two different metallic strips (1 and 2) of same dimensions (lengths ℓ, with w and thickness d) with carrier densities n1 and n2, respectively. Strip 1 is placed in magnetic field B1 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) ***(2015)***

(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 $V_2 = V_1$

MASTERJEE Essential Questions

JEE Main/Boards

Exercise 1

Q. 7	Q.8	Q.12
Q.20	Q.25	
Q.26	Q.27	

Exercise 2

Q.2	Q.5	Q.20

JEE Advanced/Boards

Exercise 1

Q.4	Q.5	Q.16	Q.19
Q.22	Q.25	Q.30	

Exercise 2

Q.1	Q.3	Q.11	Q.13
Q.15	Q.19	Q.20	Q.22
Q.40	Q.42	Q.44	Q.45
Q.48	Q.50		

Answer Key

JEE Main/Boards

Exercise 1

Q.1 $\pi \times 10^{-4}\,T \approx 3.1 \times 10^{-4}\,T$

Q.2 $3.5 \times 10^{-5}\,T$

Q.3 $4 \times 10^{-6}\,T$, vertically up

Q.4 $1.2 \times 10^{-5}\,T$, towards south

Q.5 $0.6N\ m^{-1}$

Q.6 4.2cm

Q.7 (i) 3.1 Nm, (ii) No

Q.8 $5\pi \times 10^{-4}\,T = 1.6 \times 10^{-3}\,T$ towards west

Q.9 (a) A horizontal magnetic field to magnitude 0.26T normal to the conductor in such a direction that Fleming's left-hand rule gives a magnetic force upward. (b) 1.176N

Q.10 $1.22N\ m^{-1}$

Q.11 (a) 2.1 N vertically downwards (b) 2.1N vertically downwards (c) 1.68N vertically downwards

Q.12 2:1

Q.13 (a) Zero (b) Zero (c) Force on each electron in evB=IB(nA)= $5 \times 10^{-25}\,N$.

Note: Answer (c) Denotes only the magnetic force.

Q.14 $B = \frac{\mu_0 I}{2R}$

Q.15 $B = \frac{\mu_0 I}{2\pi R}$

Q.16 $B = \mu_0 IN$ where N is the number of turns per unit length and I is the current flowing through the solenoid.

Q.17 2:1

Q.19 $\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$

Q.20 Circle

Q.21 $4 \times 10^{-5}\,T$

Q.22 B=14.1 Wb

Q.23 $1.57 \times 10^{-2}\,T$

Q.24 3×10^{-12}

Q.25 $6 \times 10^{-7}\,Nm^{-1}$

Q.26 $5.9 \times 10^{-6}\,N\ m$

Q.27 22.5V

Q.28 (i) 8A (ii) $3 \times 10^{-7}\,T$ (iii) $7.68 \times 10^{-6}\,Nm^{-1}$

Exercise 2

Q.1 D	**Q.2** C	**Q.3** A	**Q.4** A	**Q.5** A	**Q.6** A
Q.7 B	**Q.8** D	**Q.9** D	**Q.10** B	**Q.11** A	**Q.12** B
Q.13 C	**Q.14** C	**Q.15** A	**Q.16** A	**Q.17** A	**Q.18** C
Q.19 D	**Q.20** B	**Q.21** B			

Previous Years' Questions

Q.1 D	**Q.2** C	**Q.3** B	**Q.4** D	**Q.5** C	**Q.6** B
Q.7 A	**Q.8** B	**Q.9** B	**Q.10** C	**Q.11** D	**Q.12** A
Q.13 C	**Q.14** A	**Q.15** B	**Q.16** A	**Q.17** A	**Q.18** B

JEE Advanced/Boards

Exercise 1

Q.1 In the plane of the drawing from right to left

Q.2 (a) 0 (b) $1.41\times10^{-6}T, 45°$ in xz plane, (c) $5\times10^{-6}T$, +x-direction

Q.3 $\frac{(1-2\sqrt{2})\mu_0 I}{\pi a}\hat{k}$

Q.4 zero

Q.5 $\frac{\mu_0 I}{4R}\left(\frac{3}{4}\hat{k}+\frac{1}{\pi}\hat{j}\right)$

Q.6 $\frac{\mu_0 i}{4\pi R}\left[\frac{3}{2}\pi+1\right]$

Q.7 $B=\frac{\mu_0 i}{4\pi R}\sqrt{2\left(2\pi^2-2\pi+1\right)}$

Q.8 $B_1=\frac{\mu_0 b r_1^2}{3}, B_2=\frac{\mu_0 b r^3}{3r_2}$

Q.9 $\frac{\mu_o iqv}{2\pi a}$

Q.10 $10\hat{k}$

Q.11 $\frac{2mv_0}{qB}$

Q.12 $\frac{mEI}{Be}$

Q.13 Zero

Q.14 $\sqrt{2}IRB\hat{j}$

Q.15 $F=\alpha a^2\hat{i}\hat{j}$

Q.16 (a) $\frac{3mv^2}{4qa}$, (b) $\frac{3mv^3}{4a}$, (c) zero

Q.17 $T_0=2\pi\sqrt{\frac{m}{6IB}}=0.57s$

Q.18 $\frac{\mu_0 II'c}{2\pi}\left[\frac{1}{a}-\frac{1}{b}\right]$ to the left

Q.19 (i) z=0, $x=\pm\frac{d}{\sqrt{3}}$ (ii) $\frac{I}{2\pi d}\sqrt{\frac{\mu_0}{\pi\lambda}}$

Q.20 $\frac{Q_\omega}{4}h^2\tan^2\theta$

Q.21 (i) $\frac{\mu_0}{4\pi}\left(\frac{4I}{a}\right)$ along Y-axis, (ii) $\frac{\mu_0}{4\pi}\left(\frac{I^2}{2a}\right)\sqrt{10}, \tan^4\left(\frac{1}{3}\right)+\pi$ with positive axis

Q.22(a) $\frac{Qv\mu_0 I}{m\,6a}\left(\frac{3\sqrt{3}}{\pi}-1\right)$ (b) $\vec{\tau}=BI\left(\frac{\pi}{3}-\frac{\sqrt{3}}{4}\right)a^2\hat{j}$

Q.23 (a) $I=\frac{mg}{\pi r\left(B_x^2+B_y^2\right)^{1/2}}$ (b) $I=\frac{mg}{\pi r B_x}$

Q.24 $\frac{\mu_0 iJ_0}{\pi}\tan^{-1}\left(\frac{d}{2h}\right)\left(-\hat{k}\right)$

Q.25 0.62N<F<0.88N

Q.26 $B_{min}=4.7\times10^3T$

Q.27 $i_1=0.1110A, i_2=0.096A$

Q.28 $\frac{\mu_0 I_1 I_2}{4\pi}$ In (3) along –ve z direction

Q.29 (b) Yes

Q.30 $F=\frac{\mu_0 I^2}{2\pi}In\left(\frac{a^2}{L^2+a^2}\right)$, zero

Exercise 2

Single Correct Choice Type

Q.1 C **Q.2** A **Q.3** C **Q.4** C **Q.5** C **Q.6** D

Q.7 C **Q.8** D **Q.9** B **Q.10** A **Q.11** A **Q.12** A
Q.13 A **Q.14** C **Q.15** C

Multiple Correct Choice Type

Q.16 B, C **Q.17** A **Q.18** B, D **Q.19** A, B, C **Q.20** A, B, C, D **Q.21** A, B
Q.22 A, D **Q.23** C, D

Assertion Reasoning Type

Q.24 D **Q.25** B **Q.26** D **Q.27** C **Q.28** D **Q.29** D

Comprehension Type

Paragraph 1:

Q.30 A **Q.31** A **Q.32**D

Paragraph 2:

Q.33D **Q.34** B **Q.35** B

Matric Match Type or Match the Column

Q.36 A $\to$ q, r; B $\to$ p; C $\to$ q, r; D $\to$ q, or; A $\to$ q, r; B $\to$ p; C $\to$ q, r; D $\to$ q, s

Q.37 A $\to$ p, r, s; B $\to$ r, s; C $\to$ p, q; D $\to$ r,s

Previous Years' Questions

Q.1 C **Q.2** C **Q.3** B **Q.4** A, B, D **Q.5** A, B, D **Q.6** A, C
Q.7 A, C **Q.8** A, C, D **Q.9** B, D **Q.10** C, D **Q.11** 5 **Q.12** B
Q.13 D **Q.14** A, C **Q.15** B **Q.16** 3 **Q.17** C **Q.18** B
Q.19 A, B, C **Q.20** A, D **Q.21** A, C

Solutions

JEE Main/Boards

Exercise 1

Sol 1: $B = \frac{\mu_0 NI}{2R} = \frac{\mu_0 \times 100 \times 0.4}{2 \times 8 \times 10^{-2}} = 3.1 \times 10^{-4}$T

Sol 2: $B = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 \times 35}{2\pi \times \frac{1}{5}} = 3.5 \times 10^{-5}$T

Sol 3: $B = \frac{\mu_0 I}{2\pi r}\hat{k} = \frac{\mu_0 \times 50}{2\pi \times \frac{5}{2}}\hat{k} = 4 \times 10^{-6}$T,

vertically upward.

Sol 4: $B = \frac{\mu_0 \times 90}{2\pi \times \frac{3}{2}} = \frac{\mu_0}{\pi} \times 30 = 1.2 \times 10^{-5}$T,

towards south.

Sol 5: $F = I\ell \times B = 8 \times 1 \times 0.15 \times \frac{1}{2} = 0.6\ \text{Nm}^{-1}$

Sol 6: $F = \frac{\mu_0 I}{4\pi\sqrt{x^2 + \frac{a^2}{4}}} \cdot \frac{a}{\sqrt{x^2 + \frac{a^2}{2}}}$

Since force is always perpendicular to velocity so path will be a circle

$R = \frac{mv}{qB} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^{6}}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2$ cm

Sol 7: (i) $\tau = M \times B$; $M = INA$

$\tau = 6 \times 30 \times \pi(0.08)^2 \times 1 \times \sin 60^o = 3.1$ Nm

(ii) No

Sol 8: $B = \dfrac{-\mu_0 \times 20 \times 16}{2 \times \dfrac{16}{100}} + \dfrac{\mu_0 \times 25 \times 18}{2 \times \dfrac{10}{100}}$

$= 5\pi \times 10^{-4}$T toward west

Sol 9: For tension to be zero

(a) $F = I\ell \times B = mg$

$= 5 \times 0.45 \times B = \dfrac{\sqrt{2mKE}}{qB}$

$B = \dfrac{0.6}{5 \times 0.45} = 0.26$ T

(b) By force equilibrium

$2T = Mg + F$

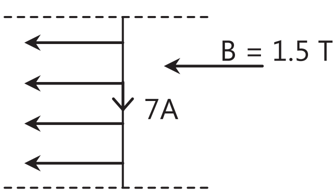
$= 0.06 \times 9.8 + 0.06 \times 9.8 = 1.176$ N

Sol 10: I = 300A; Force per unit length = F

$F = \dfrac{\mu_0 i_1 i_2}{2\pi d} = \dfrac{\mu_0 \times (300)^2}{2\pi \times \dfrac{3}{2} \times 10^{-2}} = 1.2$ Nm^{-1}

Since the direction of the current is in opposite direction in the wire, the force will be repulsive in nature.

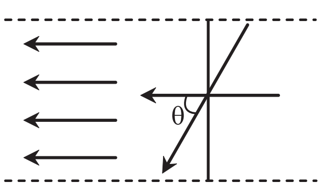
Sol 11: B = 1.5T; r = 0.1m



(a) $F = i\,\ell \times \vec{B}$

$= 7 \times 0.2 \times 1.5 = 2.1$ N vertically downwards.

(b)



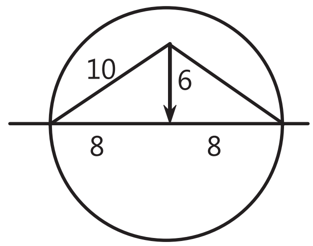
$F = i\,\ell_1 \times \vec{B}$

$= i\ell_1 \vec{B} \sin\theta$

$= i\,B \times \left(\dfrac{20}{100}\right)$

$= 7 \times 0.2 \times 1.5 = 2.1$ N vertically downwards.

(c)



Effective length of wire is 16 cmin the magnetic field so

$F = i\ell \times \vec{B}$

$= 7 \times 0.16 \times 1.5$

$= 1.68$ N downwards

Sol 12: Length of wire $= N \times 2\pi R$

Final no. of turns $= \dfrac{N \times 2\pi R}{2\pi \dfrac{R}{2}} = 2N$

Magnetic moment $\mu = INA$

$\dfrac{\mu_1}{\mu_2} = \dfrac{N_1 A_1}{N_2 A_2} = \dfrac{N \times \pi R^2}{2N \times \pi \left(\dfrac{R}{2}\right)^2} = \dfrac{2}{1}$

Sol 13: N = 20

r = 0.1 m

B = 0.1 T

I = 5 A

(a) $\tau = M \times \vec{B} = MB \sin 0^o = 0$

(b) $F = i\ell \times \vec{B}$

F = Total force is zero as $\vec{\ell}$ is zero for a closed loop

(c) Force on each electron $= q\vec{v} \times \vec{B}$

$= eVB = \dfrac{IB}{nA} = 5 \times 10^{-25}$ N

Sol 14: Refer page 21.11 to 21.14

Sol 15: Refer page 21.11 and 21.12

Sol 16: B at the centre is $B = \mu_0 NI$

N - number of turns

I - current

Sol 17: $R = \dfrac{mv}{qB}$

$v = \dfrac{RqB}{m}$

$\dfrac{v_p}{v_d} = \dfrac{RqB}{m_p}\dfrac{m_d}{RqB} = 2$

Sol 18: Refer page 21.25 to 21.26

Sol 19: $F = q\vec{E} + q\vec{v}\times\vec{B}$

Sol 20: Its path will be a circle.

Sol 21: Magnetic field due to side BC is B_{BC}

$B_{BC} = \dfrac{\mu_0 I}{4\pi R}\left(\dfrac{\sqrt{3}}{2}+\dfrac{\sqrt{3}}{2}\right)$; $B_{BC} = \dfrac{3\sqrt{3}\mu_0 I}{4\pi R}$

Magnetic field due to all sides will be equal so

$B_{net} = \dfrac{3\sqrt{3}\mu_0 I}{4\pi R}$

Sol 22: Electron moving in a circle will act like a loop carrying current I.

$So, I = \dfrac{q}{t} = \dfrac{q\omega}{2\pi} = \dfrac{qv}{2\pi R}$

So magnetic field at centre = $B = \dfrac{\mu_0 I}{2R} = \dfrac{\mu_0 qv}{4\pi R^2}$

$$\text{Thus } B = \frac{9\times10^{9}\times1.6\times10^{-19}\times2.2\times10^{6}}{\left(0.5\times10^{-10}\right)^{2}} = 14.1 \text{ Wb}$$

Sol 23: $B = \mu_0 ni$

$= 4\pi\times10^{-7}\times\dfrac{5000}{2}\times 5 = 1.57\times10^{-2}T$

Sol 24: B = 2.5 T

$v = 1.5\times10^{7}$ m/s

$F = q\vec{v}\times\vec{B} = q\times1.5\times10^{7}\times2.5\times\dfrac{1}{2}$

$= 1.6\times10^{-19}\times1.5\times10^{7}\times\dfrac{2.5}{2}\times3\times10^{-12}$

Sol 25: Force per unit length

$F = \dfrac{\mu_0 i^2}{2\pi d} = 6\times10^{-7}$ N/m

Sol 26: Magnetic field inside the solenoid is

$B = \mu_0 NI = \mu_0\times\dfrac{400}{0.4}\times3$

$= 4\pi\times10^{-7}\times3\times1000 = 12\pi\times10^{-4}$ T

Torque on the coil is $\tau = M\times\vec{B} = MB$

$= 0.4\times10\times\pi(0.01)^2\times12\pi\times10^{-4} = 5.9\times10^{-6}$ Nm

Sol 27: Let the resistance of the voltmeter be R

Voltage across $300\,\Omega$ = 60 – 30 V= 30 V

$I = \dfrac{30}{300} = 0.1$ A

Let equivalent resistance of voltmeter and 400Ω be R_{eq}

$IR_{eq} = 30V$

$0.10\,R_{eq} = 30$ V

$R_{eq} = 300\,\Omega = \dfrac{R\times400}{R+400}$

3R + 1200 = 4R

Resistance of voltmeter = R = $1200\,\Omega$

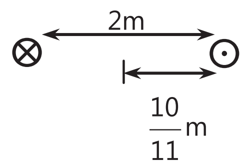
When voltmeter is connected to $300\,\Omega$

$R_{eq} = \dfrac{1200\times300}{1500} = 240\,\Omega$

$i = \dfrac{60}{640}A = \dfrac{6}{64}A$

Voltage measured = $\dfrac{6}{64}\times240 = 22.5$ V

Sol 28: (i) i = 9.6A



B at $\dfrac{10}{11}$ m from wire B is

$$B = \frac{\mu_0\times9.6}{2\pi\left(\frac{12}{11}\right)} - \frac{\mu_0 I}{2\pi\times\frac{10}{11}} = 0$$

$I = \frac{9.6\times10}{12} = 8A$

(ii) Force per unit length $F = \frac{\mu_0 i_1 i_2}{2\pi\times2}$

$= \frac{\mu_0\times9.6\times8}{4\pi} = 7.68\times10^{-6}\ Nm^{-1}$

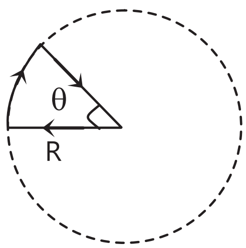
Exercise 2

Sol 1: (D) Total magnetic field at point O

$$B = \frac{\mu_0\ell}{2R'}\frac{3}{4} + \frac{\mu_0\ell}{2R}\frac{1}{4}$$

$$= \frac{\mu_0\ell}{8}\left[\frac{3}{R'}+\frac{1}{R}\right]$$

Sol 2: (C)



Magnetic field $B = \frac{\mu_0 I}{2R}\left(\frac{\theta}{2\pi}\right)(-\hat{k})$

Sol 3: (A) $\vec{B} = \frac{\mu_0}{4\pi}\frac{q\,\vec{V}\times\vec{r}}{r^3} = \frac{\mu_0}{4\pi}\frac{qV\sin\theta}{r^2}$

$= \frac{\mu_0}{4\pi}\times\frac{2\times100\times\sin30^o}{4} = 10^{-7}\times25 = 2.5\mu T$

Sol 4: (A) Magnetic field at the common centre is

$$\frac{\mu_0 I}{2R}\hat{i} + \frac{\mu_0 I}{2R}\hat{j} + \frac{\mu_0 I}{2R}\hat{k}$$

$$= \frac{\mu_0 I}{2R}\sqrt{3}$$

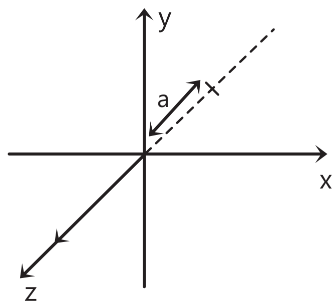
Sol 5: (A) Magnitude of magnetic field at the centre

$$= +\frac{\mu_0\times20\times16}{2\times16\times10^{-2}} - \frac{\mu_0\times25\times18}{2\times10\times10^{-2}}$$

$$= -\mu_0\times10^3 + \mu_0\times2250$$

$$= \mu_0\times1250 = \frac{\mu_0}{4\pi}\times5000\pi = 5\pi\times10^{-4}\,T$$

Sol 6: (A)



Magnetic field $= B = -\frac{\mu_0 i}{2\pi a}\hat{i} + \frac{\mu_0 i}{2\pi a}\hat{j}$

Sol 7: (B) $\vec{E} = -K_1\hat{j}$;

K_1 is some constant

$\vec{V} = K_2\hat{i}$

$F = q\vec{V}\times\vec{B} + q\vec{E} = 0$

$\Rightarrow \vec{V}\times\vec{B} = -\vec{E} \Rightarrow \vec{B} = -\hat{k}$

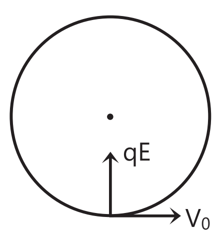
Sol 8: (D) Final velocity of the particle

$$= v = \sqrt{v_0^2 + \left(\frac{qEt}{m}\right)^2} = 2v_0$$

$$v_0^2 + \left(\frac{qEt}{m}\right)^2 = 4v_0^2$$

$$\left(\frac{qEt}{m}\right)^2 = 3v_0^2 \Rightarrow t = \frac{\sqrt{3}mv_0}{qE}$$

Sol 9: (D)



When electric field is applied

$$\frac{mv_0^2}{R_1} = qE$$

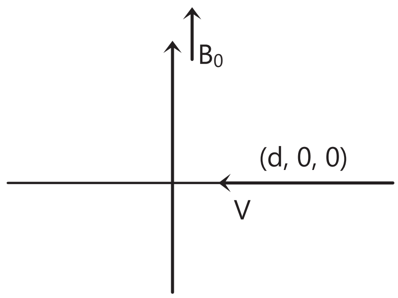
$$R_1 = \frac{mv_0^2}{qE}$$

When magnetic field is applied

$$R_2 = \frac{mv_0}{qB}$$

$$\frac{R_1}{R_2} = \frac{mv_0^2\, qB}{qEmv_0} = \frac{v_0\, B}{E}$$

Sol 10: (B)



For the particle to not hit y-z plane radius of the particle should be less than equal to d

$$R = \frac{mv}{qB_0} \le d$$

$$v_{max} = \frac{qB_0 d}{m}$$

Sol 11: (A) Electric force Fe$= \frac{kq_1q_2}{r^2} = \frac{kq^2}{r^2}$

Magnetic force $= qv\left(\frac{\mu_0}{4\pi} \times \frac{qv}{r^2}\right)$

$$F_m = q^2v^2\left(\frac{\mu_0}{4\pi}\right)\frac{1}{r^2}$$

$$\frac{Fe}{F_m} = \frac{k}{v^2\left(\frac{\mu_0}{4\pi}\right)} = \frac{1}{v^2\varepsilon_0\mu_0} = \frac{c^2}{v^2}$$

Sol 12: (B) $R = \frac{mv}{qB} = \frac{\sqrt{2mKE}}{qB}$

$$R_{H^+} = \sqrt{\frac{2KE \times 1 \times m_p}{eB}}\ (m_p = \text{mass of proton})$$

$$R_{He^+} = \sqrt{\frac{2KE \times 4 \times m_p}{eB}}$$

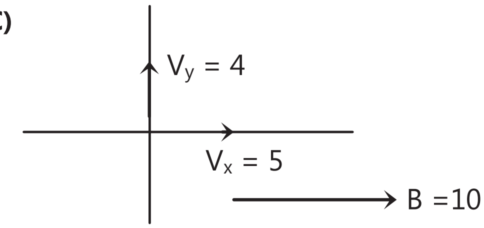
$$R_{O^{+2}} = \sqrt{\frac{2KE \times 16 \times m_p}{2eB}}$$

So, $R_{He^+} = R_{O^{+2}}$

Sol 13: (C) $R = \frac{mv}{qB} = \frac{\sqrt{2mKE}}{qB}$

$$R' = \frac{\sqrt{2m(2KE)}}{q(3B)} = R\sqrt{\frac{2}{9}}$$

Sol 14: (C)



Y-component of velocity will make the particle to move in circle whereas x-component of velocity will make particle move along x-axis.

So motion is helical.

Sol 15: (A) Force on a particle moving in magnetic field is $q\vec{v} \times \vec{B}$.

$(4\hat{i} + 3\hat{j}) \times 10^{-13} = 1.6 \times 10^{-19} \times 2.5 \times 10^7 (\vec{K} \times \vec{B})$

Force will be zero if direction of magnetic field and velocity is same.

So $\vec{B} = (0.6\hat{i} \times -0.8\hat{j})\ B$

$\Rightarrow (4\hat{i} + 3\hat{j}) = 1.6 \times 25\ (\hat{k} \times (0.6\hat{i} - 0.8\hat{j})\ B$

$\Rightarrow \vec{B} = -0.075\hat{i} + 0.1\hat{j}$

Sol 16: (A) Force acting on particle $= q.\vec{v} \times \vec{B}$

$\Rightarrow q.2\hat{i} \times \vec{B} = -2\hat{j}$

$\Rightarrow \vec{B}$ is in +ve z direction ($\hat{k}$)

Electric force on the particle is zero.

So when $v_3 = 2\hat{k}$, force is zero.

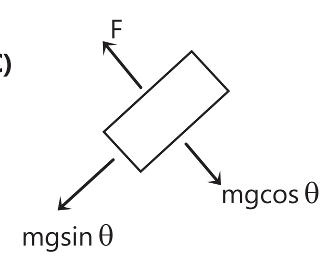
Sol 17: (A) Magnetic field is in ($-\hat{k}$) direction

So direction of force

$\vec{F} = q\vec{v} \times \vec{B}$

$\hat{F} = -[-\hat{i} \times (-\hat{k})] = \hat{j}$

Sol 18: (C)



$F = qVB$

Particle will leave the inclined plane when

$F = mg\cos\theta \Rightarrow qvB = mg\cos\theta$

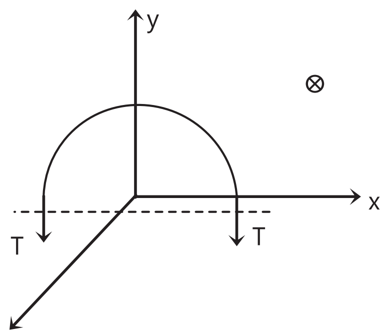
$$v = \frac{mg\cos\theta}{qB}$$

Time taken to reach v is t

$v = g\sin\theta\, t$

$$t = \frac{v}{g\sin\theta} = \frac{mg\cot\theta}{qgB} = \frac{m\cot\theta}{qB}$$

Sol 19: (D)



$F = I\int d\vec{\ell} \times \vec{B}$

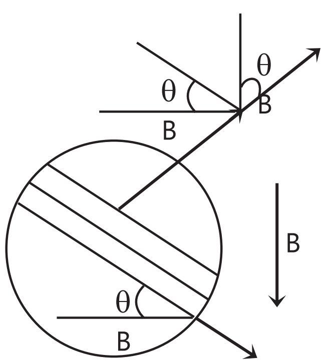
$= I\,(2r\,\hat{i}) \times (-0.2\,\hat{k}) = 20\,\hat{j}$

Magnetic force is in +ve y direction

So balancing force on semi-circular ring we get

$2T = 20 \Rightarrow T = 10N$

Sol 20: (B)



Torque due to magnetic field will be balanced by gravity.

$mg\sin\theta\, R = I \times \pi R^2 \times B\sin\theta$

$$B = \frac{mg}{\pi i R}$$

Sol 21: (B) Magnetic field = I × A

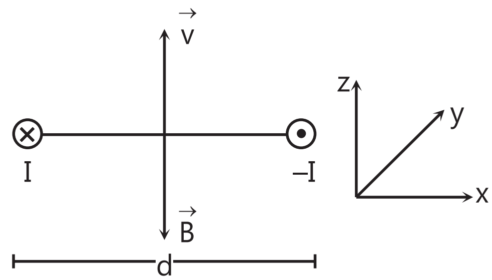
$$M = \frac{q.\pi r^2}{t}$$

$$t = \frac{2\pi}{\omega} = \frac{2\pi r}{v}$$

$$M = \frac{q.\pi r^2 v}{2\pi r} = \frac{qrv}{2}$$

Previous Years' Questions

Sol 1: (D) Net magnetic field due to both the wires will be downward as shown in the figure.



Since, angle between $\vec{v}$ and $\vec{B}$ is 180°.

Therefore, magnetic force

$\vec{F}_m = q(\vec{v} \times \vec{B}) = 0$

Sol 2: (C) H_1 = Magnetic field at M Due to PQ + magnetic field at M due to QR

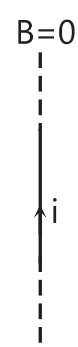
But magnetic field at M due to QR = 0

∴ Magnetic field at M due to PQ (or due to current I in PQ)= H_1

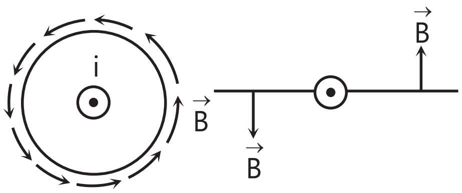
Now H_2 = Magnetic field at M due to PQ (current I) + magnetic field at M due to QS (current I/2) + magnetic field at M due to QR

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

Note: Magnetic field at any point lying on the current carrying straight conductor is zero.



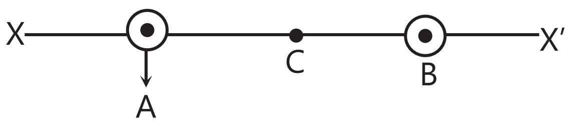
Sol 3: (B) If the current flows out of the paper, the magnetic field at points to the right of the wire will be upwards and to the left will be downwards as shown in figure.



Now, let us come to the problem.

Magnetic field at C = 0

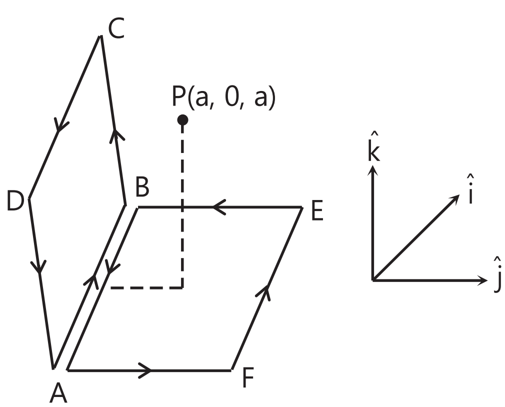
Magnetic field in region BX′ will be upwards (+ve) because all points lying in this region are to the right of both the wires.



Magnetic field in region AC will be upwards (+ve),because points are closer to A, compared to B. Similarly magnetic field in region BC will be downwards (–ve).

Graph (B) satisfies all these conditions. Therefore, correct answer is (B).

Sol 4: (D) The magnetic field at P(a, 0, a) due to the loop is equal to the vector sum of the magnetic fields produced by loops ABCDA and AFEBA as shown in the figure.



Magnetic field due to loop ABCDA will be along $\hat{i}$ and due to loop AFE BA, along $\hat{k}$. Magnitude of magnetic field due to both the loops will be equal. Therefore, direction of resultant magnetic field at P will be $\frac{1}{\sqrt{2}}$ $(\hat{i}+\hat{k})$.

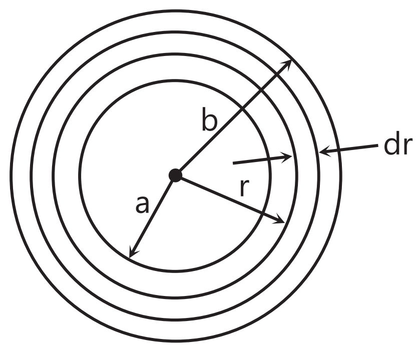
Note: This is a common practice, when by assuming equal currents in opposite directions in an imaginary wire (here AB) loops are completed and solution becomes easy.

Sol 5: (C) Consider an element of thickness dr at a distance r from the centre. The number of turns in this element,$dN = \left(\frac{N}{b-a}\right)dr$

Magnetic field due to this element at the centre of the coil will be

$$dB = \frac{\mu_0 (dN) I}{2r} = \frac{\mu_0 I}{2}\frac{N}{b-a}\cdot\frac{dr}{r}$$

$$\therefore B = \int_{r=a}^{r=b} dB = \frac{\mu_0 NI}{2(b-a)}\ln\left(\frac{b}{a}\right)$$



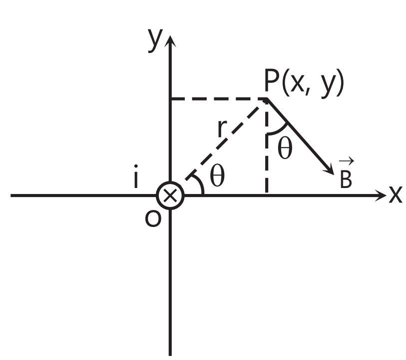
Note: The idea of this question is taken from question number 3.245 of IE Irodov.

Sol 6: (B) Radius of the circle = $\frac{mv}{Bq}$

or radius $\propto$ mv if B and q are same.

$(\text{Radius})_A > (\text{Radius})_B$; $\therefore m_A v_A > m_B v_B$

Sol 7: (A) Magnetic field at P is $\vec{B}$, perpendicular to OP in the direction shown in figure.



So, $\vec{B} = B\sin\theta\,\hat{i} - B\cos\theta\,\hat{j}$

Here, $B = \dfrac{\mu_0 I}{2\pi r}$

$\sin\theta = \dfrac{y}{r}$ and $\cos\theta = \dfrac{x}{r}$

$\therefore \vec{B} = \dfrac{\mu_0 I}{2\pi}\cdot\dfrac{1}{r^2}(y\hat{i} - x\hat{j}) = \dfrac{\mu_0 I(y\hat{i} - x\hat{j})}{2\pi(x^2+y^2)}$

(as $r^2 = x^2 + y^2$)

Sol 8: (B) If $(b - a) \geq r$

(r = radius of circular path of particle)

The particle cannot enter the region $x > b$.

So, to enter in the region $x > b$

$r > (b - a)$ or $\dfrac{mv}{Bq} > (b - a)$ or $v > \dfrac{q(b-a)B}{m}$

Sol 9: (B) Electric field can deviate the path of the particle in the shown direction only when it is along negative y-direction. In the given options $\vec{E}$ is either zero or along x-direction. Hence, it is the magnetic field which is really responsible for its curved path. Options (a) and (c) cannot be accepted as the path will be circular in that case. Option (d) is wrong because in that case component of net force on the particle also comes in $\hat{k}$ direction which is not acceptable as the particle is moving in x-y plane. Only in option (b) the particle can move in x-y plane.

In option (d) $\vec{F}_{net} = q\vec{E} + q(\vec{v} \times \vec{B})$

Initial velocity is along x-direction. So, let

$\vec{v} = v\hat{i}$

$\vec{F}_{net} = qa\hat{i} + q[(v\hat{i}) \times (c\hat{k} + b\hat{j})]$

$= qa\hat{i} - qvc\hat{j} + qvb\hat{k}$

In option (b) $\vec{F}_{net} = q(a\hat{i}) + q[(v\hat{i}) \times$

$(c\hat{k} + a\hat{i})] = qa\hat{i} - qvc\hat{j}$

Sol 10: (C) $\vec{U} = -\vec{M}\vec{B} = -MB\cos q$

Here, $\vec{M}$ = magnetic moment of the loop

θ = angle between $\vec{M}$ and $\vec{B}$

U is maximum when $\theta = 180°$ and minimum when $\theta = 0°$. So, as θ decreases from 180° to 0° its PE also decrease.

Sol 11: (D) Magnetic force does not change the speed of charged particle. Hence, $v = u$. Further magnetic field on the electron in the given condition is along negative y-axis in the starting. Or it describes a circular path in clockwise direction. Hence, when it exits from the field, $y < 0$.

Therefore, the correct option is (D)

Sol 12: (A) $\vec{F}_m = q(\vec{v} \times \vec{B})$

$\therefore$ Correct option is (A)

Sol 13: (C) Correct answer is (C), because induced electric field lines (produced by change in magnetic field) and magnetic field lines form closed loops.

Sol 14: (A) If we take a small strip of dr at distance r from centre, then number of turns in this strip would be, $dN = \left(\dfrac{N}{b-a}\right)dr$

Magnetic field due to this element at the centre of the coil will be

$dB = \dfrac{\mu_0 (dN) I}{2r} = \dfrac{\mu_0 NI}{(b-a)}\dfrac{dr}{r}$

$\therefore B = \displaystyle\int_{r=a}^{r=b} dB = \dfrac{\mu_0 NI}{2(b-a)}\ln\left(\dfrac{b}{a}\right)$

Sol 15: (B)

$r = \dfrac{\sqrt{2mK}}{Bq} \Rightarrow r \propto \dfrac{\sqrt{m}}{q}$

$r_\alpha = r_p < r_d$

Sol 16: (A) $B_{net} = B_{M_1} + B_{M_2} + B_H$

$= \dfrac{\mu_0 M_1}{4\pi x^3} + \dfrac{\mu_0 M_2}{4\pi x^3} + B_H$

$= \dfrac{\mu_0}{4\pi x^3}(M_1 + M_2) + B_H$

$= \dfrac{10^{-7}}{10^{-3}} \times 2.2 + 3.6 \times 10^{-5}$

$= 2.56 \times 10^{-4}\ \text{Wb}/\text{m}^2$

Sol 17: (A) $\mu_0 H = \mu_0 ni$

$$3\times10^3 = \frac{100}{0.1}\times i \Rightarrow i = 3A$$

Sol 18: (B) Since $\vec{B}$ is uniform, only torque acts on a current carrying loop. $\vec{\tau} = (I\vec{A})\times\vec{B}$

$\vec{A} = A\hat{k}$ for (b) and $\vec{A} = -A\hat{k}$ for (d).

$\therefore\ \vec{\tau} = 0$ for both these cases.

The energy of the loop in the $\vec{B}$ field is: $U = -I\vec{A}\cdot\vec{B}$, which is minimum for (b).

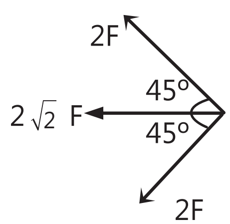
JEE Advanced /Boards

Exercise 1

Sol 1: $I_1 = I_2 = I_3 = I_4$

$\Rightarrow F_1 = F_2 = F_3 = F_4 = F$

$\Rightarrow 2F$



Resultant force will be $2\sqrt{2}$ F from right to left

Sol 2: Let magnetic field due to wire be B_w

(a)x = 0, z = 2m;

$$B = B_0 + B_w = -\frac{\mu_0 I\hat{i}}{2\pi\times2} + 10^{-6}\hat{i}$$

$$= -10^{-7}\times10\hat{i} + 10^{-6}\hat{i}$$

$$= 0$$

(b)x = 2m, z = 0

$$B = B_0 + B_w = \frac{\mu_0 I}{2\pi\times2}\hat{k} + 10^{-6}\hat{i}$$

$$B = 10^{-6}\hat{k} + 10^{-6}\hat{i} = \sqrt{2}\times10^{-6}\text{ T}$$

(c)x=0, z=–0.5m

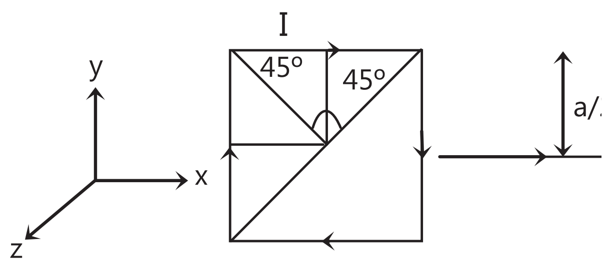
$$B = B_0 + B_w$$

$$= 10^{-6}\hat{i} + \frac{\mu_0\times10}{2\pi\times\frac{1}{2}}$$

$$= 10^{-6}\hat{i} + 4\times10^{-7}\times10\hat{i}$$

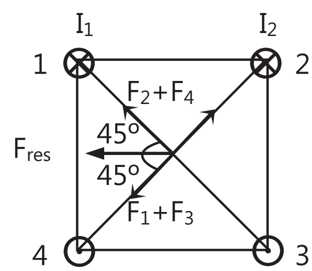
$$= 5\times10^{-6}\hat{i}\text{ T}$$

Sol 3: Magnetic field can be found as the super position of both given below.



Magnetic field due to loop = B_l

$$= -\left[\frac{\mu_0 I}{4\pi\left(\frac{a}{2}\right)}\left(\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{2}}\right)\right]\times4\hat{k}$$



$$= -\frac{\mu_0 I}{2\pi a}\times\sqrt{2}\times4\hat{k}$$

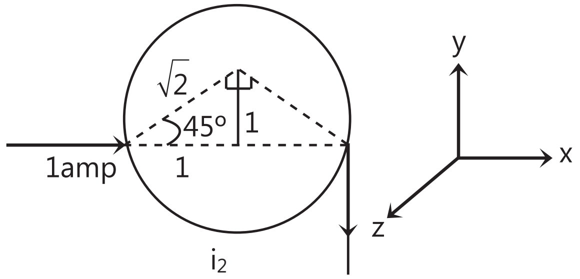
$$= -\frac{2\sqrt{2}\mu_0 I}{\pi a}\hat{k}$$

Magnetic field due to infinite length wire = $B_w = \dfrac{\mu_0 I\hat{k}}{2\pi\left(\frac{a}{2}\right)}$

$$= \frac{\mu_0 I}{\pi a}\hat{k}$$

Net magnetic field = $\dfrac{(1-2\sqrt{2})\mu_0 I}{\pi a}\hat{k}$

Sol 4:



$i_1 = \dfrac{\frac{\pi}{2}}{2\pi}\times 1 = \dfrac{1}{4}$amp

$i_2 = 1 - \dfrac{1}{4} = \dfrac{3}{4}$ amp

Magnetic field due to $i_1 = B_1 = -\dfrac{\mu_0\left(\frac{1}{4}\right)}{2\sqrt{2}}\left(\dfrac{\frac{3\pi}{2}}{2\pi}\right)\hat{k}$

$$= -\frac{\mu_0}{8\sqrt{2}}\times\frac{3}{4}\hat{k}$$

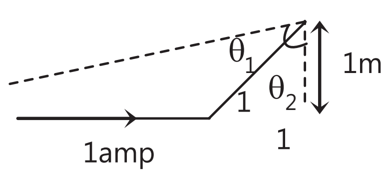
Magnetic field due to $i_2 = B_2 = \dfrac{\mu_0\left(\frac{3}{4}\right)\left(\frac{\pi}{2}\right)}{2\sqrt{2}\;\;2\pi}\hat{k}$

$$= \frac{3\mu_0}{8\sqrt{2}}\times\frac{1}{4}\hat{k}$$

Magnetic field due to wire in x-direction = B_3

$B_3 = \dfrac{\mu_0\times 1}{4\pi\times 1}(\sin(-45°)+\sin 90°)\,\hat{k}$

$B_3 = \dfrac{\mu_0}{4\pi}\left(1-\dfrac{1}{\sqrt{2}}\right)\hat{k}$



Magnetic field due to wire in negative y-direction =B_y

$B_y = -\left(\dfrac{\mu_0\times 1}{4\pi\times 1}(\sin(-45°)+\sin 90°)\right)\hat{k}$

$= -\dfrac{\mu_0}{4\pi}\left(1-\dfrac{1}{\sqrt{2}}\right)\hat{k}$

Net magnetic field = B = $B_1 + B_2 + B_3 + B_4 = 0$

Sol 5: Magnetic Induction

$\vec{B} = \dfrac{\mu_0 I}{2(2R)}\left(\dfrac{1}{4}\right)\hat{k} + \dfrac{\mu_0 I}{2R}\left(\dfrac{1}{4}\right)\hat{k} + \dfrac{\mu_0 I}{4\pi R}\hat{j}$

$= \dfrac{\mu_0 I}{4R}\left[\dfrac{3}{4}\hat{k} + \dfrac{1}{\pi}\hat{j}\right]$

Sol 6: Magnetic Induction

$\vec{B} = \dfrac{\mu_0 I}{2R}\left(\dfrac{3\frac{\pi}{2}}{2\pi}\right)\hat{k} + \dfrac{\mu_0 I}{4\pi R}\hat{k}$

$= \dfrac{\mu_0 I}{2R}\times\dfrac{3}{4}\hat{k} + \dfrac{\mu_0 I}{4\pi R}\hat{k} \;\; = \dfrac{\mu_0 I}{4\pi R}\left[\dfrac{3\pi}{2}+1\right]\hat{k}$

Sol 7: Magnetic Induction

$\vec{B} = \dfrac{\mu_0 I}{2R}\hat{i} - \dfrac{\mu_0 I}{4\pi R}\hat{i} - \dfrac{\mu_0 I}{4\pi R}\hat{k}$

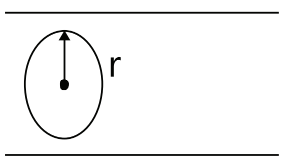
$= \dfrac{\mu_0 I}{4\pi R}[2\pi - 1]\,\hat{i} - \dfrac{\mu_0 I}{4\pi R}\hat{k}$

$= \dfrac{\mu_0 I}{4\pi R}\sqrt{\left[4\pi^2 + 1 - 4\pi + 1\right]}$

$= \dfrac{\mu_0 I}{4\pi R}\sqrt{2\left(2\pi^2 - 2\pi + 1\right)}$

Sol 8: We will find magnetic field B by ampere's law.

$\oint \vec{B}.\vec{dl} = \mu_0 I_{IN}$



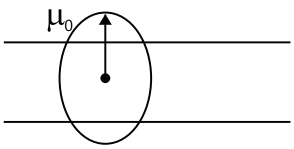
(a)For $r_1 < R$

$B\times 2\pi r_1 = \mu_0\left(\int JdA\right)$

$= \mu_0\left(\int_0^{r_1} br2\pi r\,dr\right)$

$B\times 2\pi r_1 = \mu_0\dfrac{2\pi b r_1^3}{3}$

$B = \dfrac{\mu_0 b r_1^2}{3}$

(b) 

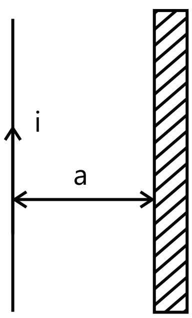
By ampere's law

$$B\times 2\pi r_2 = \mu_0\int (JdA) = \mu_0\left(\int_0^{r_0} br2\pi r\, dr\right)$$

$$B\times 2\pi r_2 = \mu_0 2\pi b\frac{r_0^3}{3}$$

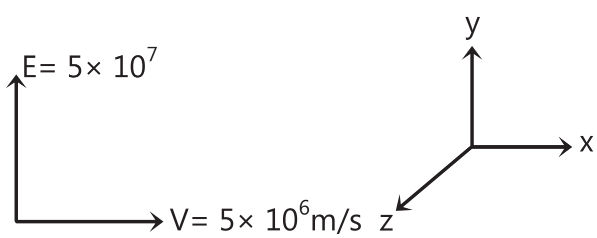
$$B = \frac{\mu_0 b r_0^3}{3r_2}$$

Sol 9:



Magnetic Force = qVB = $qV\left(\frac{\mu_0 I}{2\pi a}\right)$

Sol 10:



Magnetic force = qVB

Electric force = qE

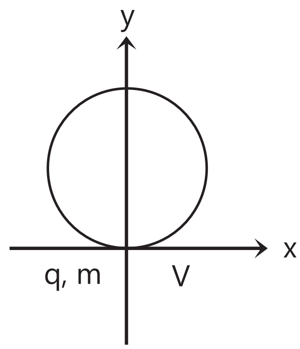
When both forces are equal in magnitude and opposite in direction then net force on charged particle is zero.

qVB = qE

$$B = \frac{E}{V} = \frac{5\times 10^7}{5\times 10^6} = 10\text{ T}$$

and direction is in positive $\hat{k}$ direction

Sol 11:



y coordinate is equal to twice the radius of the circle

y = 2R

$$R = \frac{mV_0}{qB} \Rightarrow y = \frac{2mV_0}{qB}$$

Sol 12: We know that velocity of charged particle = v = $\frac{E}{B}$

Force = Change in momentum per sec= $\frac{mv}{t}$

$$I = \frac{e}{t} \Rightarrow F = \frac{mEI}{B\cdot e}$$

Sol 13: Force acting on a wire carrying current

$F = I\int d\vec{\ell}\times\vec{B}$

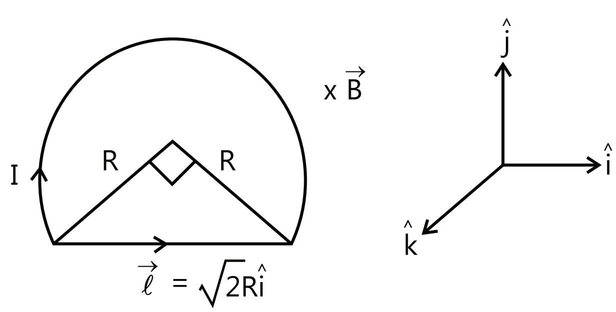
Since $\vec{B}$ is uniform so

$F = I\,(\int d\vec{\ell})\times\vec{B}$

For a loop $\int d\vec{\ell} = 0$

So F = 0

Sol 14:



Force = $I\int d\vec{\ell}\times\vec{B}$

Since $\vec{B}$ is constant so

$F = I\,(\int d\vec{\ell})\times\vec{B}$

$F = I\cdot\vec{\ell}\times\vec{B}$

$F = I\left(\sqrt{2}R\hat{i} \times (-B\hat{k})\right)$

$= I\sqrt{2}RB\hat{j} = \sqrt{2}IRB\hat{j}$

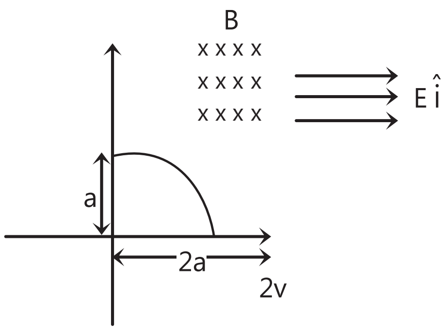
Sol 15: $F = F_1 + F_2 + F_3 + F_4$

$= i\int(d\ell_1 \times B_1) + i\int(d\ell_2 \times B_2) + i\int(d\ell_3 \times B_3) + i\int(d\ell_4 \times B_4)$

$$= \left(i\int_0^a dy\hat{j} \times (\alpha y)(-\hat{k})\right) + i(a\hat{i} \times \alpha y(-\hat{k})) + i\int_0^a dy\hat{j} \times (\alpha y)\hat{k} + I \times 0$$

$$F_1 = -i\alpha\frac{a^2}{2}\hat{i} + i\,\alpha a^2\hat{j} + i\frac{\alpha a^2}{2}\hat{i} = i\alpha a^2\hat{j}$$

Sol 16:



(a) Work done by Electric Field = Change in Kinetic Energy

$$\int F.dx = \frac{1}{2}m(2v)^2 - \frac{1}{2}mv^2$$

$$qE \times 2a = \frac{3}{2}mv^2$$

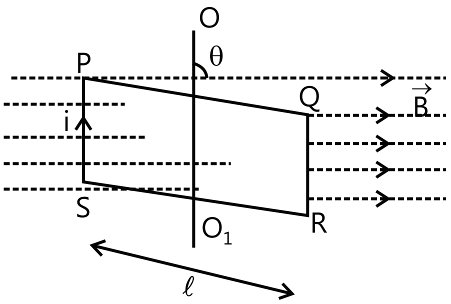
$$E = \frac{3mv^2}{4qa}$$

(b) Rate of work done = F.v = qE.v= $\frac{3}{4a}mv^3$

(c) Work done by magnetic field is always zero.

Work done by electric field = $\vec{F}.\hat{v} = qE\hat{i}.(-2v\hat{j}) = 0$

Sol 17:



Consider a loop PQRS placed in uniform magnetic field B in such a way that the normal to coil subtends an angle θ to the direction of B when a current I flows through the loop clockwise.

The sides PQ and RS are perpendicular to the field and equal and opposite forces of magnitude I and B act upwards and downwards respectively. Equal and opposite forces act on sides QR and PS towards right and left of coil.

The resultant force is zero but resultant torque is not zero. The forces on sides PQ and RS produce a torque due to a single turn which is given by

$\tau = I\ell^2 B\sin\theta$

for small θ, $\sin\theta \approx \theta$

$\tau = I\ell^2 B\theta$ ... (i)

$\tau = I\alpha$

$$= \left(\frac{m}{4}\frac{\ell^2}{12} \times 2 + \frac{m}{4}\frac{\ell^2}{4} \times 2\right)\alpha$$

$$= m\ell^2\left[\frac{1}{24} + \frac{1}{8}\right]\alpha = \frac{m\ell^2}{8}\left[\frac{4}{3}\right] = \frac{m\ell^2}{6} \quad \text{... (ii)}$$

By (i) and (ii)

$$I\ell^2 B\theta = \frac{m\ell^2}{6}\alpha$$

$$\alpha = \frac{6IB}{m}\theta$$

$$\omega^2 = \frac{6IB}{m}$$

$$\text{Time period} = 2\pi\sqrt{\frac{m}{6IB}} = 2\pi\sqrt{\frac{10^{-2}}{6 \times 2 \times 10^{-1}}}$$

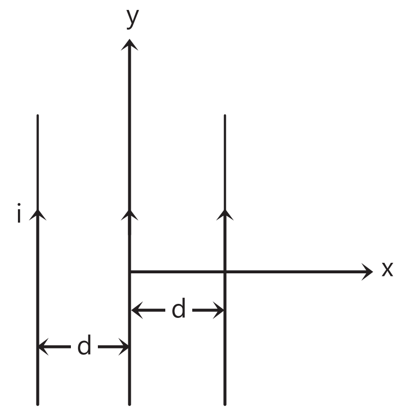
$$= 2\pi\sqrt{\frac{1}{120}} = 0.57 \text{ sec}$$

Sol 18: Net force acting on the loop = F

$$F = \frac{\mu_0 II'c}{2\pi a} - \frac{\mu_0 II'c}{2\pi b} = \frac{\mu_0 II'c}{2\pi}\left[\frac{1}{a} - \frac{1}{b}\right]$$

This loop will experience attractive forces.

Sol 19: (i)



Net Force at some point x, y is

$$F_{net} = \frac{\mu_0 I}{2\pi(x+d)} + \frac{\mu_0 I}{2\pi x} + \frac{\mu_0 I}{2\pi(x-d)} = 0$$

$$\Rightarrow \frac{1}{n+d} + \frac{1}{x} + \frac{1}{x-d} = 0$$

$$\frac{2x}{x^2-d^2} + \frac{1}{x} = 0$$

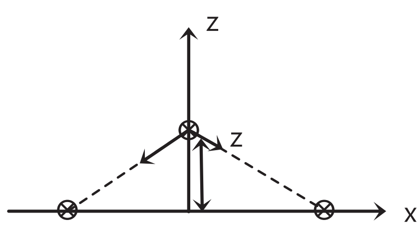
$$\frac{2x^2+x^2-d^2}{x(x^2-d^2)} = 0 \Rightarrow 3x^2 = d^2$$

$$x = \pm\sqrt{\frac{d}{3}}$$

Net force will be zero only in x–y plane

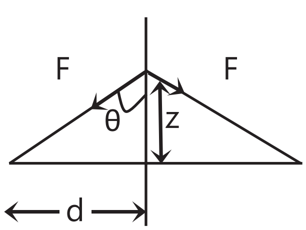
i.e. when z = 0 and $x = \pm\sqrt{\frac{d}{3}}$

(ii)



Let the middle wire is displaced by z distance in positive z-direction.

Attractive force acting on wire is F



$$\cos\theta = \frac{z}{\sqrt{d^2+z^2}}$$

$$F = \frac{\mu_0 i^2 \ell}{2\pi\sqrt{d^2+z^2}}$$

Resultant force is downward

$$F_{net} = -2F\cos\theta = \frac{-2\mu_0 i^2 \ell}{2\pi\sqrt{d^2+z^2}} \cdot \frac{z}{\sqrt{d^2+z^2}}$$

$$F_{net} = \frac{-\mu_0 i^2 z\ell}{\pi(d^2+z^2)}$$

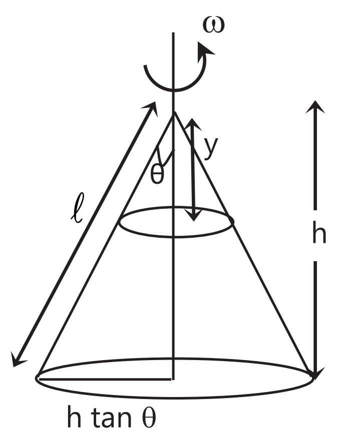
For small z

$$F_{net} = \frac{-\mu_0 i^2 z\ell}{\pi d^2} = \lambda a$$

$$\omega = \sqrt{\frac{\mu_0 i^2 \ell}{\lambda\pi d^2}}$$

$$F = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{\mu_0 i^2}{\lambda\pi d^2}} = \frac{i}{2\pi d}\sqrt{\frac{\mu_0}{\lambda\pi}}$$

Sol 20: $l\cos\theta = h$



Take a ring at distance y from the top point of the cone.

Magnetic moment M = IA

dM=

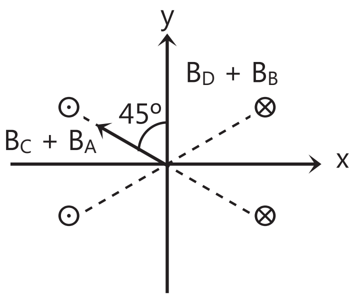
$$\left(\frac{Q}{\pi(h\tan\theta)\frac{h}{\cos\theta}} \cdot \frac{2\pi y\,dy\tan\theta}{\cos\theta}\right)\frac{\omega}{2\pi} \cdot \pi(y\tan\theta)^2$$

$$= \int_0^h \frac{Q\omega\tan^3\theta}{h^2\tan\theta} \cdot y^3 dy = \frac{Q\omega\tan^2\theta}{h^2} \cdot \frac{h^4}{4}$$

$= \frac{1}{4} Q\omega \tan^2\theta\, h^2$

Sol 21: (i)$B_C = B_A = B_B = B_D = B$

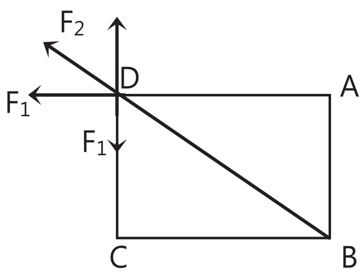
$B = \frac{\mu_0 I \times 2}{2\pi\sqrt{2}\,a}$



Net magnetic field is

$B_{net} = B\sqrt{2} = \frac{\mu_0 I \times 2}{2\pi a}$ along y-axis

(ii)



$F_1 = \frac{\mu_0 I^2 \ell}{2\pi(2a)}$

$F_2 = \frac{\mu_0 I^2 \ell}{2\pi(2\sqrt{2}a)}$

$F_x = F_1 + \frac{F_2}{\sqrt{2}} = \frac{\mu_0 I^2 \lambda}{4\pi a}\left[1+\frac{1}{2}\right] = \frac{3\mu_0 I^2 \lambda}{8\pi a}$

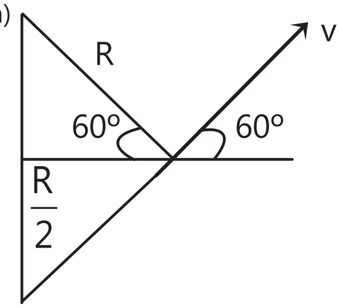
$F_y = F_1 - \frac{F_2}{\sqrt{2}} = \frac{\mu_0 I^2 \lambda}{4\pi a}\left[1-\frac{1}{2}\right] = \frac{\mu_0 I^2 \lambda}{8\pi a}$

Net force $= \frac{\mu_0 I^2 \ell}{8\pi a}\sqrt{1+3^2}$; $\ell = 1$

$= \left(\frac{\mu_0}{4\pi}\right)\left(\frac{I^2}{2a}\right)\sqrt{10}$

Radius = R = a

Sol 22: (a)



$\vec{v} = v\left(\frac{1}{2}\hat{i} + \frac{\sqrt{3}}{2}\hat{j}\right)$

$B = \left(\frac{\mu_0 I}{2R}\left(\frac{\frac{2\pi}{3}}{2\pi}\right) - \frac{\mu_0 I}{4\pi\frac{R}{2}}\left(\frac{\sqrt{3}}{2}+\frac{\sqrt{3}}{2}\right)\right)\hat{k}$

$B = \left(\frac{\mu_0 I}{6R} - \frac{\sqrt{3}\mu_0 I}{2\pi R}\right)\hat{k} = \frac{\mu_0 I}{2R}\left[\frac{1}{3} - \frac{\sqrt{3}}{\pi}\right]\hat{k}$

Force $= qv\times B = \frac{qv}{2}\left[\left(\hat{i} + \sqrt{3}\,\hat{j}\right) \times \frac{\mu_0 I}{2R}\left(\frac{1}{3} - \frac{\sqrt{3}}{\pi}\right)\hat{k}\right]$

$= \frac{Qv}{m}\,\frac{\mu_0 I}{6a}\left[\frac{3\sqrt{3}}{\pi} - 1\right]$

(b)Net Torque $= \vec{M}\times\vec{B} = I\,AB\,\hat{j}$

$= I\left(\frac{\pi}{3}a^2 - \frac{\sqrt{3}a^2}{4}\right)B\,\hat{j}$

$= B\,I\left(\frac{\pi}{3} - \frac{\sqrt{3}}{4}\right)a^2\,\hat{j}$

Sol 23: (a) Net Torque on the loop is

$\tau = -MB_x\hat{j} + MB_y\hat{i} = I\pi r^2\sqrt{B_x^2 + B_y^2}$ ...(i)

By Torque balance mgr = τ ...(ii)

By (i) and (ii)

$I = \frac{mg}{\pi r\sqrt{B_x^2 + B_y^2}}$

(b) Net Torque is $\tau = -MB_x\hat{j}$

$|\tau| = I\pi r^2 B_x$

By torque balance

$mgr = t \Rightarrow mgr = I\pi r^2 B_x$

$I = \frac{mg}{\pi r B_x}$

Sol 24: Magnetic field due to sheet of width d and infinite length at a distance h is given by

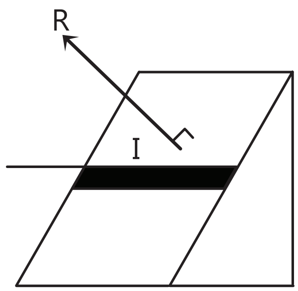
$$B = \frac{\mu_0 j_0}{\pi}\tan^{-1}\left(\frac{d/2}{h}\right)\hat{i}$$

$$\vec{\ell} = \hat{j}$$

$$F = i\,\vec{\ell}\times\vec{B}$$

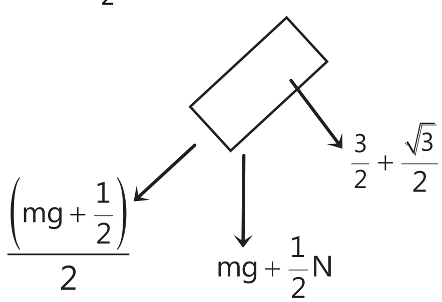
$$F = \frac{i\mu_0 j_0}{\pi}\tan^{-1}\left(\frac{d}{2n}\right)(-\hat{k})$$

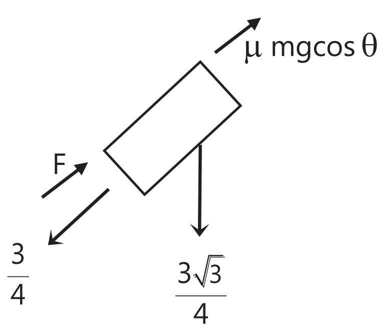
Sol 25:



Force= $I\,\vec{\ell}\times\vec{B}$ = 10 × 0.5 × 0.1

Force = $\frac{1}{2}$N upward on inclined plane





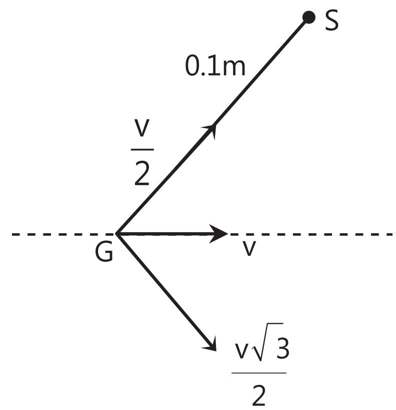
$$\mu.1 + F = \frac{3}{4} \Rightarrow F = \frac{3}{4} - \frac{3\sqrt{3}}{40}$$

$$F_{min} = \frac{3}{4}\left[1-\frac{\sqrt{3}}{10}\right] = 0.62 \text{ N}$$

$$F = \frac{3}{4} + \frac{3\sqrt{3}}{40}$$

$$F_{max} = 0.88 \text{ N}$$

Sol 26:



Electron will move in helical path with pitch = 0.1 m. For minimum value of B particle should reach at point S in a single revolution.

Time period $T = \frac{2\pi m}{qB}$

So $0.1 = \frac{v}{2}T$

$$0.1 = \frac{v\cdot 2\pi m}{2\cdot qB}$$

$$B' = \frac{20\pi mv}{2q}$$

$$= \frac{20\pi\sqrt{2\times 9.1\times10^{-31}\times 2000\times 1.6\times 10^{-19}}}{2\times 1.6\times 10^{-19}}$$

$$= 10\pi\sqrt{\frac{2\times 9.1\times 10^{-31}\times 2000}{1.6\times 10^{-19}}}$$

$$B = 10\pi\sqrt{2.275}\times 10^{-4}$$

$$B = 4.7 \times 10^{-3} \text{ T}$$

Sol 27: To neutralize the magnetic field, current in vertical ring should be such that the magnitude of magnetic field is 3.49×10^{-5} T and current in horizontal ring should be such that the magnitude of magnetic field is $\frac{1}{\sqrt{3}}\times 3.49\times 10^{-5}$

For vertical ring

$$B = \frac{\mu_0 NI}{2r} = \frac{\mu_0\times 100\times I}{2\times 0.2}$$

$$3.49\times10^{-5} = \mu_0\times 250\,I$$

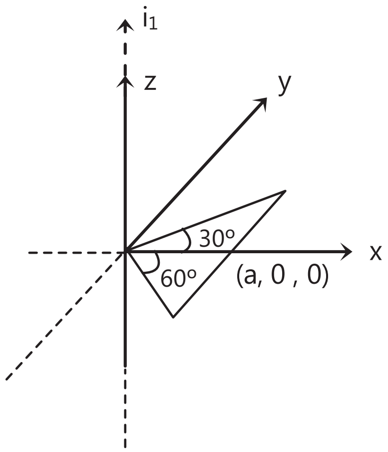
$$I = \frac{3.49\times10^{-5}}{\mu_0\times250} = \frac{3.49\times10^{-5}}{4\pi\times10^{-7}\times250} = 0.111\text{ A}$$

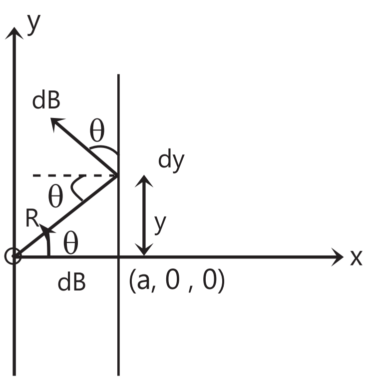
For horizontal ring

$$B = \frac{\mu_0 NI}{2r} \Rightarrow \frac{1}{\sqrt{3}}\times3.49\times10^{-5} = \frac{\mu_0\times100\text{ I}}{2\times0.3}$$

$$\Rightarrow \text{ I} = 0.096\text{ A}$$

Sol 28:





Force on dy element in x direction is

$$\int dF = \int i_2 dy\, B\sin\theta$$

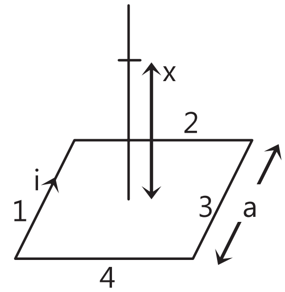
$$F = \int i_2 \frac{Rd\theta}{\cos\theta}\cdot\frac{\mu_0 i_1}{2\pi R}\sin\theta$$

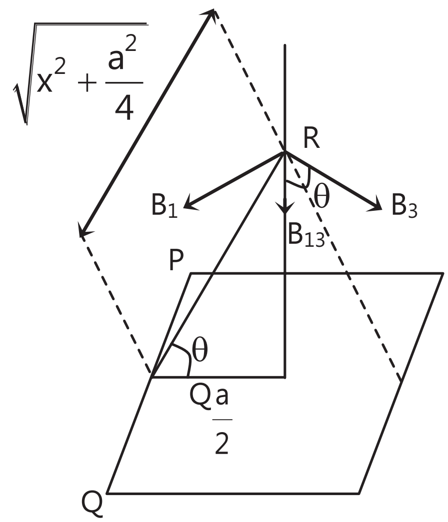
$$= \frac{\mu_0 i_1 i_2}{2\pi}\int_{-60}^{30}\tan\theta\, d\theta$$

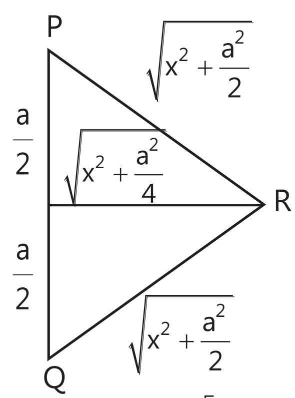
$$F = \frac{\mu i_1 i_2}{2\pi}[\log\cos]_{-60}^{30}$$

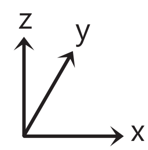
$$= \frac{\mu i_1 i_2}{2\pi}\log\sqrt{3} = \frac{\mu i_1 i_2}{4\pi}\log 3$$

Sol 29: (a) $|B_1| = |B_2| = |B_3| = |B_4|$









$$B_1 = \frac{\mu_0 I}{4\pi\sqrt{x^2+\frac{a^2}{4}}}\left[\frac{a}{2\sqrt{x^2+\frac{a^2}{2}}}+\frac{a}{2\sqrt{x^2+\frac{a^2}{2}}}\right]$$

$$B_1 = \frac{\mu_0 I}{4\pi\sqrt{x^2+\frac{a^2}{4}}}\cdot\frac{a}{\sqrt{x^2+\frac{a^2}{2}}}$$

Resultant of B_1 and B_3 is $B_{13} = 2B_1\cos\theta$

$$B_{13} = \frac{2\times\mu_0 I}{4\pi\sqrt{x^2+\frac{a^2}{4}}}\frac{a}{\sqrt{x^2+\frac{a^2}{2}}}\cdot\frac{\frac{a}{2}}{\sqrt{x^2+\frac{a^2}{4}}}$$

$$= \frac{\mu_0 I a^2}{4\pi\left(x^2+\frac{a^2}{4}\right)\left(x^2+\frac{a^2}{2}\right)^{\frac{1}{2}}}$$

$$B_{13} = \frac{\mu_0 I\, a^2}{\pi(4x^2+a^2)\left(x^2+\frac{a^2}{2}\right)^{\frac{1}{2}}}$$

Similarly $B_{24} = \dfrac{\mu_0 I a^2}{\pi(4x^2+a^2)\left(x^2+\frac{a^2}{2}\right)^{\frac{1}{2}}}$

Net resultant = B_{13} + B_{24}

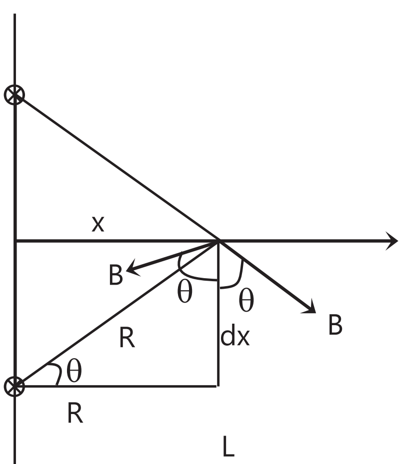
$$= \frac{2\mu_0 I a^2}{\pi(4x^2+a^2)\left(x^2+\frac{a^2}{2}\right)^{\frac{1}{2}}}$$

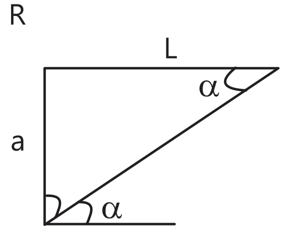
(b) Yes

Sol 30: $B_{res} = 2B\cos\theta$

$$F_{res} = I\int d\vec{\ell}\times B_{res}$$

$$= \int I\times\frac{R\,d\theta}{\sin\theta}\,\frac{2\,\mu_0 I}{2\pi R}\cos\theta;\ \sin\alpha = \frac{a}{\sqrt{L^2+a^2}}$$





$$= \frac{\mu_0 I^2}{\pi}\int_{\pi/2}^{\alpha}\cot\theta\,d\theta = \frac{\mu_0 I^2}{\pi}\ln(\sin\theta)_{90}^{\alpha}$$

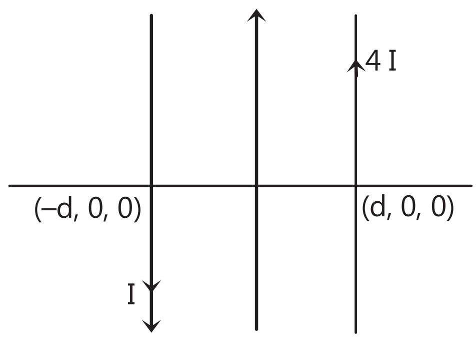
$$= \frac{\mu_0 I^2}{2\pi}\ln\left(\frac{a}{\sqrt{L^2+a^2}}-1\right)$$

If direction of current in B is reversed then resultant magnetic field will become horizontal and so net force will be zero.

Exercise 2

Single Correct Choice Type

Sol 1: (C) Magnetic field at some x is given by

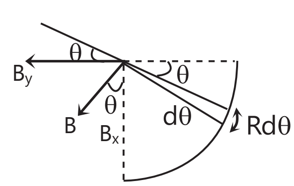


$$\frac{\mu_0(4I)}{2\pi(d-x)}\hat{k} + \frac{\mu_0 I}{2\pi(d+x)}\hat{k}$$

$$= \frac{\mu_0 I}{2\pi}\left[\frac{4}{d-x}+\frac{1}{d+x}\right] = \frac{\mu_0 I}{2\pi}\left[\frac{5d+3x}{d^2-x^2}\right]$$

It corresponds to graph (c)

Sol 2: (A) Magnetic field at the centre due to Rdθ component is



$$B_x = \int dB_x = \int\frac{\mu_0\left(\frac{I}{2\pi R}\cdot Rd\theta\right)}{2\pi R}\cos\theta = \frac{\mu_0 I}{4\pi^2 R}$$

$$B_y = \int dB_y = \int\frac{\mu_0\left(\frac{I}{2\pi R}\cdot Rd\theta\right)}{2\pi R}\sin\theta = \frac{\mu_0 I}{4\pi^2 R}$$

$$B = \frac{\mu_0 I}{4\pi^2 R}\sqrt{1+1}$$

Sol 3: (C) $V = \frac{E}{B}$ for no deflection to occur

$$V = \frac{3.2\times10^5}{2\times10^{-3}} = 1.6\times10^8 \text{ m/s}$$

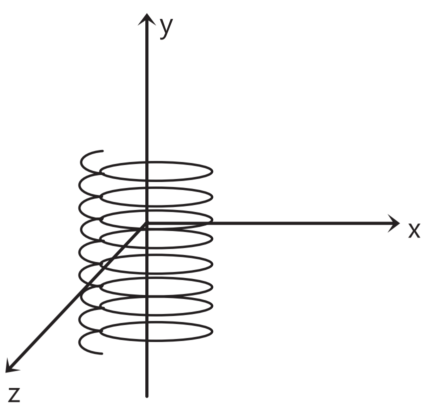
$$R = \frac{mv}{qB} = \frac{9.1\times10^{-31}\times1.6\times10^8}{1.6\times10^{-19}\times2\times10^{-3}} = 0.45 \text{ m}$$

Sol 4: (C) $\frac{q}{m} = \alpha$

Work done by electric field = $qE_0x_0 = \frac{1}{2}m(25-0)$

$$x_0 = \frac{25m}{2qE_0} = \frac{25}{2\alpha E_0}$$

Sol 5: (C) Particle is moving in helix along y-axis. So the time taken by particle to reach in x-z plane should be integral multiple of time taken to complete one revolution.



Helical motion of the particle

$$\Rightarrow \frac{2mv}{qE} = \left(\frac{2\pi m}{qB}\right)n$$

$$n = \frac{Bv}{\pi E}$$

So $\left[\frac{Bv}{\pi E}\right]$ should be an integer

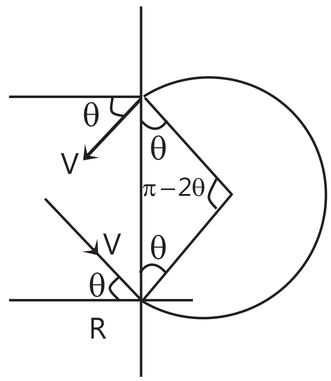
Sol 6: (D) Both particles will move in helix. They will meet for the first time when mass m will complete two revolutions and mass 2m will complete one revolution. Time taken to complete one rotation.

$$t_1 = \frac{2\times2\pi M}{QB};\ t_2 = \frac{2\pi 2M}{QB}$$

Distance from the point of projection = tv cosθ

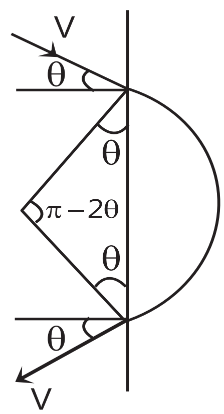
$$= v\cos\theta\frac{4\pi M}{QB} = \frac{4\pi Mv\cos\theta}{QB}$$

Sol 7: (C)



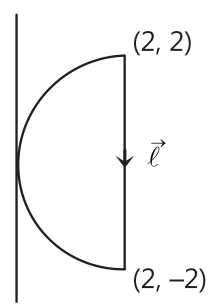
Time taken = $\left(\frac{\pi+2\theta}{\omega}\right) = \left(\frac{\pi+2\theta}{2\pi}\right)T$

Sol 8: (D)



Time taken = $\left(\frac{\pi-2\theta}{\omega}\right) = \left(\frac{\pi-2\theta}{2\pi}\right)T$

Sol 9: (B)



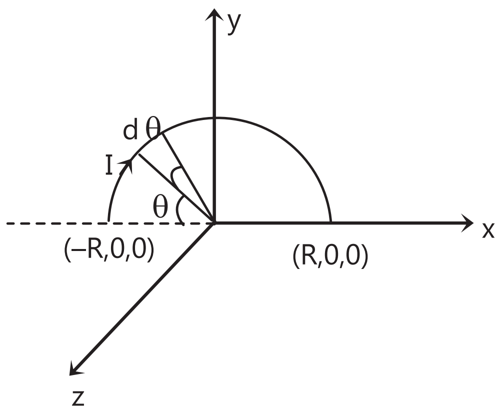
Magnetic force is given by

$dF_m = i\int d\vec{\ell}\times\vec{B} = i\int d\ell\,(-\hat{j})\times(-4\hat{k}) = 4i\int d\ell\ \hat{i}$

since ℓ and B are perpendicular so

$df_m = 8\int d\ell\ \hat{i} = 8 \times 4\hat{i} = 32\hat{i}$

Sol 10: (A)



$$F = I\int Rd\theta(\sin\theta\ \hat{i} + \cos\theta\ \hat{j}) \times \frac{B_0}{2R}(-R\cos\theta)\hat{k}$$

$$= \frac{IB_0R}{2}\int_0^{\pi}(\sin\theta\,\hat{i}+\cos\theta\,\hat{j})\times(-\cos\theta\,\hat{k})\,d\theta$$

$$= \int_0^{\pi}(\sin\theta\cos\theta\,\hat{j}-\cos^2\theta\,\hat{i})\,d\theta$$

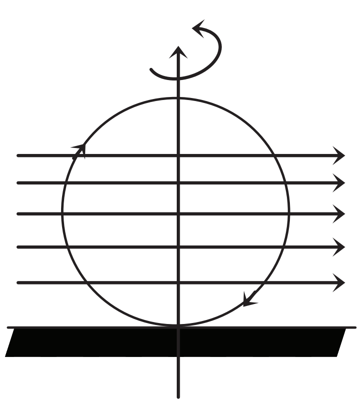
$$= \int_0^{\pi}\left(\frac{\sin2\theta\,\hat{j}}{2}-\frac{(1+\cos2\theta)\hat{i}}{2}\right)d\theta$$

$$= \left[\frac{-\cos2\theta}{4}\right]_0^{\pi}\hat{j} - \left[\frac{\theta}{2}\right]_0^{\pi}\hat{i} - \left[\frac{\sin2\theta}{4}\right]_0^{\pi}\hat{i}$$

$$= 0 - \frac{\pi}{2}\hat{i} - 0 = -\frac{\pi}{2}\hat{i}$$

Sol 11: (A) Refer Q.18 Exercise-I JEE Advanced.

Sol 12: (A) Torque on the ring due to magnetic field is



$\tau = MB\sin\theta$

$\tau = I \times \pi R^2 \times B = I\alpha$

$$I\pi R^2 \times B = \frac{MR^2\alpha}{2}$$

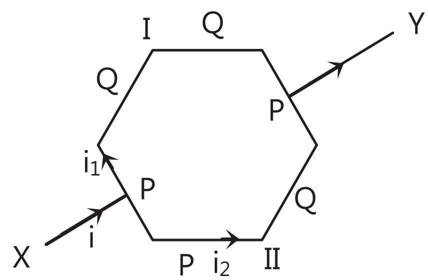
$$\alpha = \frac{2\times4\times\pi\times10}{2}$$

$= 40\pi$ rad/sec^2

Sol 13: (A) Let us assume that resistance of p material is ρ and that of Q is q.

$$i_1 = \frac{2\rho+q}{3(\rho+q)}i,\quad i_2 = \frac{2q+\rho}{3(\rho+q)}i$$

$$\frac{i_1}{i_2} = \frac{2\rho+q}{2q+\rho}$$



We know that $B \propto i$

SoB_1 = magnetic field due to I part

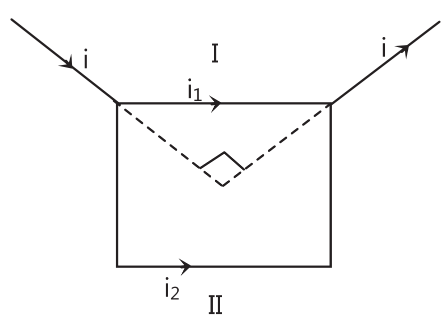
B_2 = magnetic field due to II part

For the magnetic field to be zero $B_1 = -B_2$ should hold.

$$\text{But } \frac{B_i}{B_i} \propto \frac{i_1}{i_2} = \frac{2\rho+q}{2q+\rho} \neq -1$$

So magnetic field will not be zero at centre.In (B), (C) and (D) $i_1 = i_2$ so magnetic field is zero at centre.

Sol 14: (C)

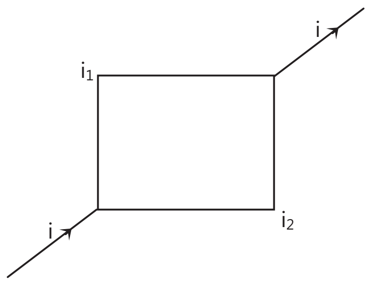


In (A)

$$i_1 = \frac{3}{4}i \quad ; \quad i_2 = \frac{i}{4}$$

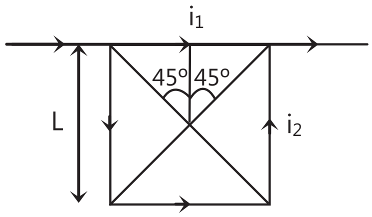
$$B = \frac{-\mu_0 i_1}{4\pi \frac{l}{2}}(\sin\theta_1 + \sin\theta_2) + \frac{3\mu_0 i_2}{4\pi \frac{\ell}{2}}(\sin\theta_1 + \sin\theta_2)$$

(B)



By symmetry $i_1 = i_2$ and magnetic field will be cancelled out by both the parts.

(C)



$i_1 = \frac{3}{4}i$; $i_2 = \frac{i}{4}$

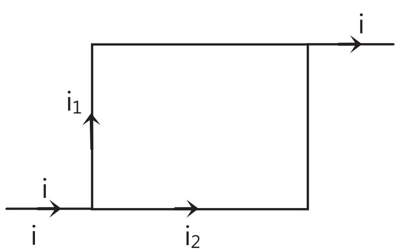
Let magnetic field due to sides of square be B_s

$$B_s = \frac{-\mu_0 \frac{3}{4} i_1}{4\pi \frac{L}{2}}\left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right)\hat{k} + \frac{3\mu_0 \frac{i}{4}}{4\pi \frac{L}{2}}\left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right)$$

$B_s = 0$

But magnetic field due to 2 infinitely long wires is not zero so net magnetic field is zero.

(D)

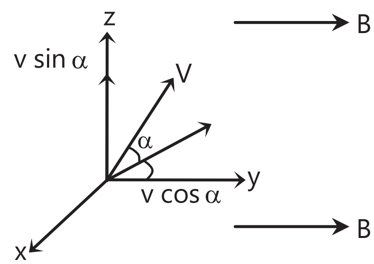


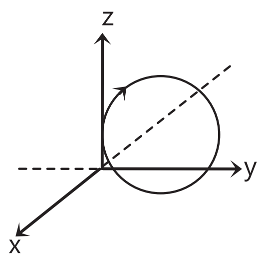
By symmetry $i_1 = i_2 = \frac{i}{2}$

So magnetic field due to four sides of square will cancel out. Magnetic field due to two infinitely long wires will also cancel out as they are equal in magnitude and opposite in direction.

So net magnetic field is zero.

Sol 15: (A) So its x coordinate cannot be positive.





Its x- and z- coordinate will be zero when particle will complete one revolution.

y - Coordinate = $v\cos\alpha\, t$

Multiple Correct Choice Type

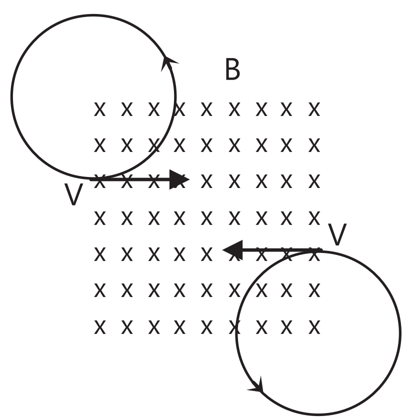
Sol 16: (B, C) (A)Motion is helical in nature

(B) They will follow circular path with radius

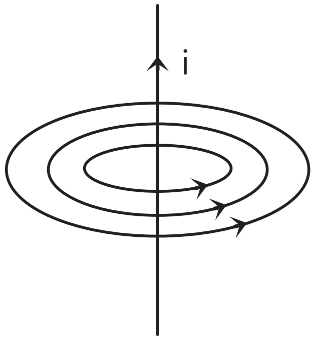
$$R = \frac{\sqrt{2mKE}}{qB}$$

(C) Work done by magnetic force is always zero.

(D)



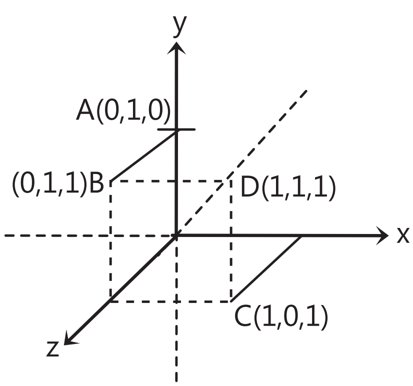
Sol 17: (A, B, C) $B = \frac{\mu_0 I}{2\pi r}(\sin\theta_1 + \sin\theta_2)$



By ampere's law magnetic field on a ring with centre as wire is same.

B $\not\propto \frac{1}{r}$ as θ_1 and θ_2 are also dependent on r.

Sol 18: (B, D) Magnetic field



at A = $B_A = \frac{\mu_0 I}{2\pi \times 1}; B_B = \frac{\mu_0 I}{2\pi\sqrt{2}}$

$B_C = \frac{\mu_0 I}{2\pi \times 1}; B_D = \frac{\mu_0 I}{2\pi \times \sqrt{2}}$

Sol 19: (A, B, C) $\frac{1}{\mu_0 \varepsilon_0} = c^2$

Sodimension of y is m/s

$v = \frac{E}{B}$ when E and B are both perpendicular and perpendicular to velocity

So dimension of x m/s

Dimension of RC = sec

So $\quad Z = \frac{\ell}{CR}$ has dimension m/s

So $\quad$ x, y, z have same dimensions.

Sol 20: (A, B, C, D) On x-axis

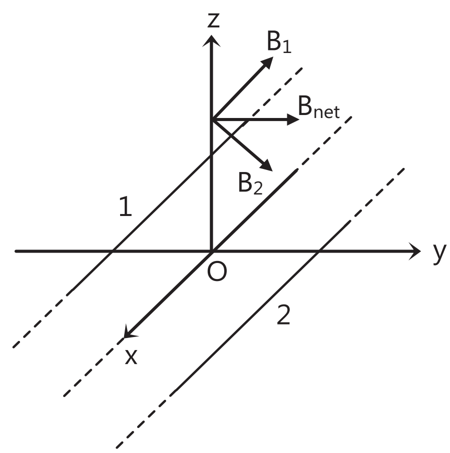
(A) $B = \frac{\mu_0 I}{2\pi a} - \frac{\mu_0 I}{2\pi a} = 0$

(B) On y-axis say at (y, 0, 0)

$B = \frac{-\mu_0 I}{2\pi(a+y)}\hat{k} + \frac{\mu_0 I}{2\pi(a-y)}\hat{k}$

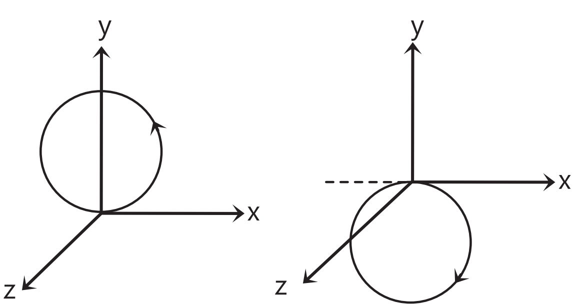
So except at origin, B has only z-components

(C)

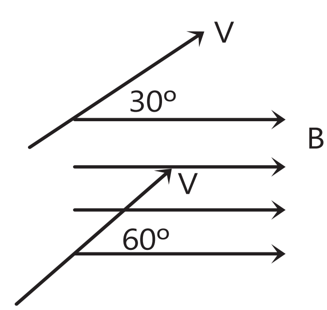


(D) B cannot has x-component as B is perpendicular to direction of I.

Sol 21: (A, B) This can be done by applying magnetic field in y-axis or z-axis.



Sol 22: (A, D)



Time period $T = \frac{2\pi m}{qB}$; $\qquad a = \frac{T_1}{T_2} = 1$

radii $R = \frac{mv\sin\theta}{qB}$

$$\frac{R_1}{R_2} = \frac{\sin(30^o)}{\sin(60^o)} = \frac{1}{\sqrt{3}}$$

pitch = $v\cos\alpha\, t$

$$\frac{P_1}{P_2} = \frac{v\cos(30^o)}{v\cos(60^o)} = \sqrt{3}$$

abc = 1; a = bc

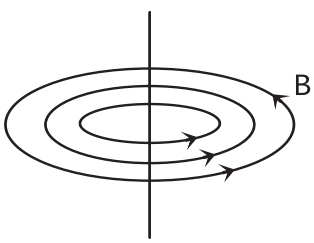
Sol 23: (C, D) If velocity is zero, then magnetic force is zero.Energy cannot increase in magnetic field as work done by magnetic force is zero.

$F = q\vec{v}\times\vec{B}$;So force is perpendicular to its velocity.

Assertion Reasoning Type

Sol 24: (D) If initially velocity of charged particle is in the direction of magnetic field then force acting on it is zero and particle will continue to move in the same direction. So statement 1 is false.

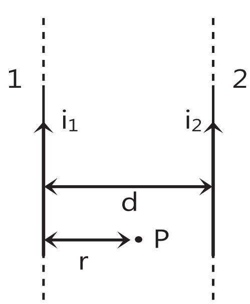
Sol 25: (B) Magnetic field at any point is in tangential direction. So it is not possible for a particle to move in tangential direction by the action of magnetic force.



Sol 26: (D) It's velocity vector must be perpendicular to both magnetic field and electric field.

Sol 27: (C) $F = I\int d\vec{\ell}\times\vec{B}$

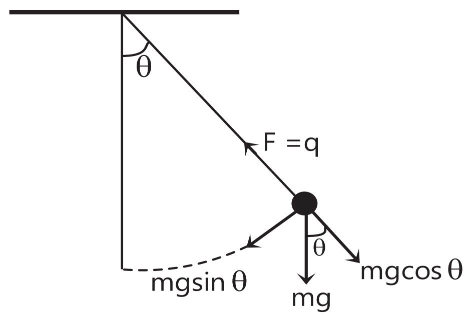
So force acting is attractive



Consider a point P in space between two wires at a distance r from one wire. The magnetic force due to wire 1 is in positive z-axis direction whereas due to wire 2 is in negative z-axis direction.

Sol 28: (D) Statement 1 is false as Ampere's circuital law holds good for a closed path of any size and shape around a current carrying conductor only if the relation is independent of distance.

Sol 29: (D) Since angular acceleration of the mass will not change so time period will also remain the same.



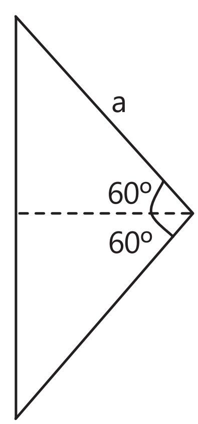
Comprehension Type

Paragraph 1

Sol 30: (A) Magnetic field due to curved part is

$$B = \frac{\mu_0 I}{4\pi a}\left(\frac{2\pi}{3}\right) = \frac{\mu_0 I}{6a}$$

Sol 31: (A)



$$B = \frac{\mu_0 I}{4\pi\frac{a}{2}}(\sin60^o + \sin60^o) = \frac{\sqrt{3}\mu_0 I}{2\pi a}$$

Sol 32: (D) Net magnetic field at C is

$$B = -\frac{\mu_0 I}{6a} + \frac{\sqrt{3}\mu_0 I}{2\pi a}$$

Paragraph 1

Sol 33: (D) I = 3A

r = 0.04m

N = 20

B = 0.5 T

Dipole moment M = INA= $3\times 20\times \pi(0.01)^2$

$= 1.88\times 10^{-2}\ Am^2$

Sol 34: (B) PE = $-1.88\times 10^{-2}\times \frac{1}{2}$

= –9.4mJ

Sol 35: (B) Torque, τ = in AB sin 90°

$$= 3\times 20\times \pi\times\left(\frac{1}{100}\right)^2\times 0.5\times 1$$

$$= 3\times 3.14\times 10^{-3}\,\text{Nm} = 9.4\times 10^{-3}\,\text{Nm}$$

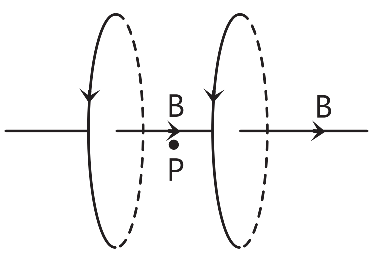
Match the Columns

Sol 36: A $\to$ q, r; B$\to$ p; C $\to$ q, r; D $\to$ q, or; A $\to$ q, r; B$\to$ p; C $\to$ q, r; D$\to$ q, s

τ = MB sin 90°= 9.4×10^{-3} Nm

(A) Magnetic field is in opposite direction. Since current is in same direction so they will attract each other. Magnetic field is equal in magnitude at P so magnetic field at P is zero.

(B)



Magnetic field at P is in the same direction.

Wires will attract as the current is in the same direction.

(C) Magnetic field at P is in opposite direction due to two wires and has same magnitude. So net magnetic field is zero at P. Wires will attract each other as current is in the same direction.

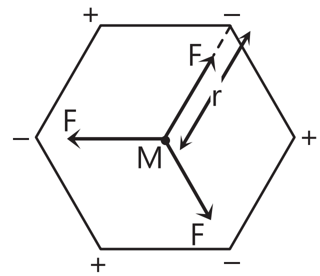
(D) Magnetic field will be in opposite direction and wires will repel each other as current is in opposite sense.

Sol 37: A $\to$ p, r, s; B$\to$ r, s; C $\to$ p, q; D$\to$ r, s

Electric field is zero at point M

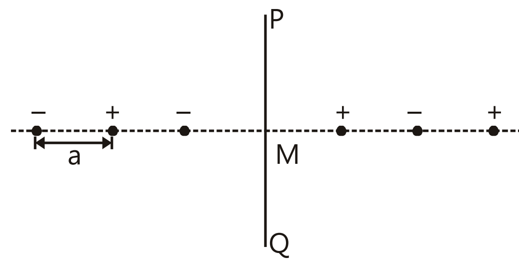
Electric potential = $\frac{3Kq}{r}-\frac{3Kq}{r}=0$

Magnetic field is zero as current due to rotating charge is zero.



Magnetic moment= INA= 0 × NA = 0

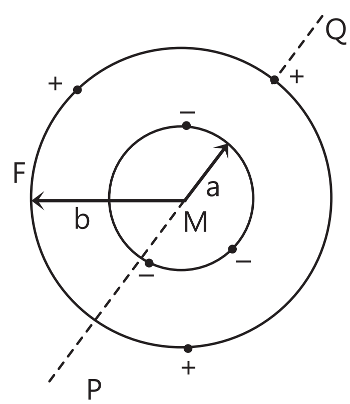
$$E=-\frac{Kq}{\left(\frac{5a}{2}\right)^2}-\frac{Kq}{\left(\frac{5a}{2}\right)^2}+\frac{Kq}{\left(\frac{3a}{2}\right)^2}+\frac{Kq}{\left(\frac{3a}{2}\right)^2}-\frac{Kq}{\left(\frac{a}{2}\right)^2}-\frac{Kq}{\left(\frac{a}{2}\right)^2}\neq 0$$



$$V=\frac{Kq}{\frac{5a}{2}}-\frac{Kq}{\frac{5a}{2}}+\frac{Kq}{\frac{3a}{2}}-\frac{Kq}{\frac{3a}{2}}+\frac{Kq}{\frac{a}{2}}-\frac{Kq}{\frac{a}{2}}=0$$

B = 0 as current due to rotating charge is zero.

μ = 0 as current due to rotating charge is zero.



E = 0

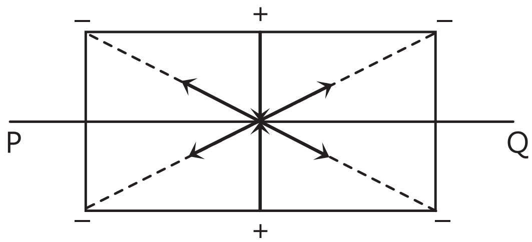
Electric field will cancel out due to symmetry

$$V=-\frac{Kq}{a}\times 3+\frac{Kq}{b}\times 3\neq 0$$

B is not zero as current due to rotating charge is non-zero.

μ = INA

as $I \neq 0 \Rightarrow \mu \neq 0$



Electric field is zero.By symmetry electric field will cancel out each other.

$$V = \frac{-Kq}{\left(\frac{\sqrt{5}\,a}{2}\right)} \times 4 + \frac{Kq}{\frac{a}{2}} \times 2 \neq 0$$

Let I be the current due to moving charge

$$\text{So } B = \frac{\mu_0 I}{2a} - \frac{2x\mu_0 Ia^2}{2\left(2a^2\right)^{\frac{3}{2}}} \neq 0$$

μ = INA

$\mu = 2\times Ia^2 - Ia^2 = Ia^2$

Previous Years' Questions

Sol 1: (C) $c\phi$ = BINA

$$\therefore\ \phi = \left(\frac{BNA}{c}\right) I$$

Sol 2: (C) If $B_2 > B_1$, critical temperature, (at which resistance of semiconductors abruptly becomes zero) in case 2 will be less than compared to case1.

Using iron core, value of magnetic field increases. So, deflection increases for same current. Hence, sensitivity increases.

Soft iron can be easily magnetized or demagnetized.

Sol 3: (D) With increase in temperature, T_C is decreasing.

$T_C(0)$ = 100 K

T_C = 75 K at B = 7.5 T

Hence, at B = 5 T, T_C should lie between 75 K and 100 K.

Hence, the correct option should be (b).

Sol 4: (A, B, D) If both E and B are zero, then $\vec{F}_e$ and $\vec{F}_m$ both are zero. Hence, velocity may remain constant. Therefore, option (a) is correct.

If E = 0, B ≠ 0 but velocity is parallel or antiparallel to magnetic field, then also $\vec{F}_e$ and $\vec{F}_m$ both are zero. Hence, option (b) is also correct.

If E ≠ 0, B ≠ 0 but $\vec{F}_e + \vec{F}_m = 0$, then also velocity may remain constant or option (d) is also correct.

Sol 5: (A, B, D) Magnetic force does not do work. From work-energy theorem:

$$\overrightarrow{W}_{Fe} = \Delta KE \text{ or } (qE)(2a) = \frac{1}{2} m[4v^2 - v^2]$$

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

At P, rate of work done by electric field

$$= \vec{F}_e \cdot \vec{v} = (qE)(v)\cos 0°$$

$$= q\left(\frac{3}{4}\frac{mv^2}{qa}\right) v = \frac{3}{4}\left(\frac{mv^3}{a}\right)$$

Therefore, option (b) is also correct. Rate of work done at Q: of electric field = $\vec{F}_e \cdot \vec{v}$ = (qE)(2v)cos 90° = 0 and of magnetic field is always zero. Therefore, option (d) is also correct.

Note that $\vec{F}_e = qE\,\hat{i}$

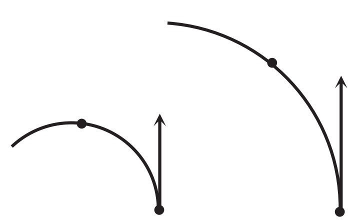
Sol 6: (A, C) $r = \frac{mv}{Bq} = \frac{P}{Bq} = \frac{\sqrt{2km}}{Bq}$

i.e., $r \propto \frac{\sqrt{m}}{q}$

If K and B are same.

i.e., $r_{H^+} : r_{He^+} : r_{O^{2+}} = \frac{\sqrt{1}}{1} : \frac{\sqrt{4}}{1} : \frac{\sqrt{16}}{2} = 1 : 2 : 3$

Therefore, He^+ and O^{2+} will be deflected equally but H^+ having the least radius will be deflected most.



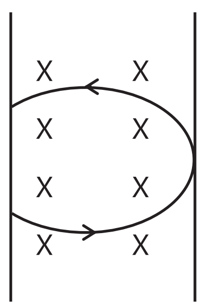
Sol 7: (A, C) $\vec{F}_{BA} = 0$, because magnetic lines are parallel to this wire.

$\vec{F}_{CD} = 0$, because magnetic lines are antiparallel to this wire.

$\vec{F}_{CB}$ is perpendicular to paper outwards and $\vec{F}_{AD}$ is perpendicular to paper inwards. These two forces (although calculated by integration)cancel each other but produce a torque which tend to rotate the loop in clockwise direction about an axis OO'.

Sol 8: (A, C, D) $v = \frac{BqI}{m}$

$\vec{v} \perp \vec{B}$ in region II. Therefore, path of particle is circle in region II.



Particle enters in region III if, radius of circular path, r >I

or $\frac{mv}{Bq} > I$

or $v > \frac{BqI}{m}$

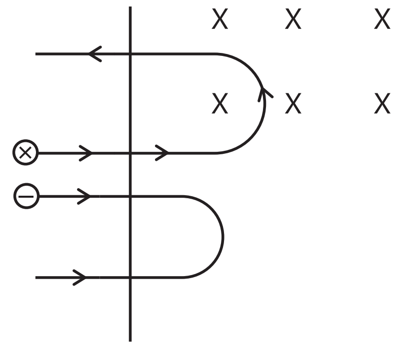
If $v = \frac{BqI}{m}$, $r = \frac{mv}{Bq} = I$, particle will turn back and path length will be maximum. If particle returns to region I, time spent in region II will be:

$t = \frac{T}{2} = \frac{\pi m}{Bq}$, which is independent of v.

Sol 9: (B, D) $r = \frac{mv}{Bq}$ or $r \propto m$

$\therefore r_e < r_p$ as $m_e < m_p$

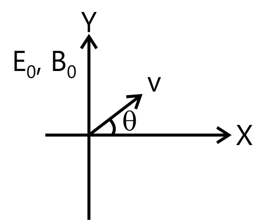
Further, $T = \frac{2\pi m}{Bq}$ or $T \propto m$



$\therefore T_e < T_p$, $t_e = \frac{T_e}{2}$ and $t_p = \frac{T_p}{2}$

or $t_e < t_p$

Sol 10: (C, D)

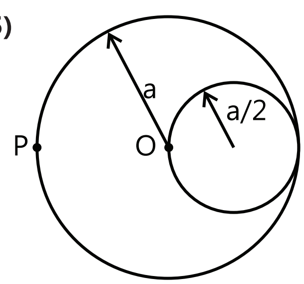


If $\theta = 0$ or 10^o

then particle moves in helical path with increasing pitch along Y-axis.

If $\theta = 90^o$ then magnetic force on the particle is zero and particle moves along Y-axis with constant acceleration.

Sol 11: (5)



$I = J \times \pi a^2$

$$B = \frac{\mu_0 J \times \pi a^2}{2\pi a} - \frac{\mu_0 J \times \pi}{2\pi \times \frac{3a}{2}} \times \frac{a^2}{4}$$

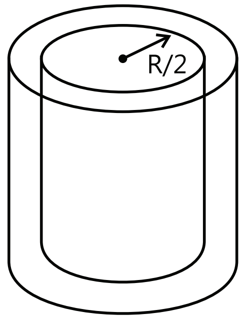
$$\Rightarrow B = \mu_0 Ja\left[\frac{1}{2} - \frac{1}{12}\right]$$

$$\Rightarrow B = \mu_0 Ja \times \frac{5}{12}$$

Sol 12: (B) $M = I \times$ Area of loop $\hat{k}$

$$= I \times \left[a^2 \times \frac{\pi a^2}{4 \times 2} \times 4\right]\hat{k} = I \times a^2\left[\frac{\pi}{2} + 1\right]\hat{k}$$

Sol 13: (D)



$r < \frac{R}{2}$; $B = 0$

B at $r = \frac{R}{2}$

$$\Rightarrow B = \frac{\mu_0 JR}{2 \times 2} - \frac{\mu_0 JR}{2 \times 2} = 0$$

B at $r > \frac{R}{2}$

$$\Rightarrow B = \frac{\mu_0 JR}{2} - \frac{\mu_0 J \times \pi}{2\pi r} \times \frac{R^2}{4}$$

$$B = \frac{\mu_0 L}{2}\left[r - \frac{R^2}{4r}\right]$$

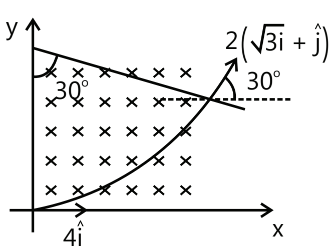
If we put $r = \frac{R}{2}$, B = 0

$\therefore$ B is continuous at r = R/2

Sol 14: (A, C) So magnetic field is along –ve, z-direction.

Time taken in the magnetic field $= 10 \times 10^{-1} = \frac{\pi M}{6QB}$

$$B = \frac{\pi M}{60 \times 10^{-3} Q} = \frac{1000\pi M}{60Q} = \frac{50\pi M}{3Q}$$



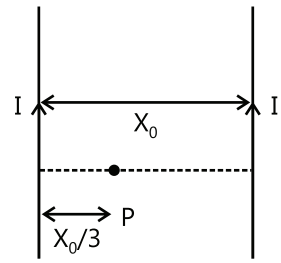
Sol 15: (B)

$$\frac{-2GMm}{L} + \frac{1}{2}mv^2 = 0 \Rightarrow v = 2\sqrt{\frac{GM}{L}}$$

Note: The energy of mass 'm' means its kinetic energy (KE) only and not the potential energy of interaction between m and the two bodies (of mass M each) – which is the potential energy of the system.

Sol 16: (3) Case – I

Case-I

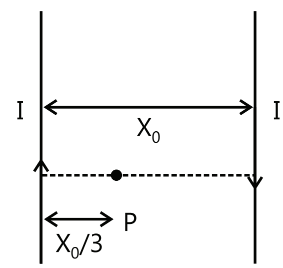


$$B_1 = \frac{1}{2}\left(\frac{\mu_0}{2\pi}\right)\left(\frac{3I}{x_0}\right)$$

$$R_1 = \frac{mv}{qB_1}$$

Case - II

Case-II



$$R_1 = \frac{mv}{qB_2}$$

$$\Rightarrow \frac{R_1}{R_2} = \frac{B_2}{B_1} = \frac{1/3}{1/9} = 3$$

Sol 17: (C) The net magnetic field at the given point will be zero if.

$|\vec{B}_{wires}| = |\vec{B}_{loop}|$

$$\Rightarrow 2\frac{\mu_0 I}{2\pi\sqrt{a^2 + h^2}} \times \frac{a}{\sqrt{a^2 + h^2}} = \frac{\mu_0 Ia^2}{2(a^2 + h^2)^{3/2}}$$

$$\Rightarrow h \approx 1.2a$$

The direction of magnetic field at the given point due to the loop is normally out of the plane. Therefore, the net magnetic field due the both wires should be into the plane. For this current in wire I should be along PQ and that in wire RS should be along SR.

Sol 18: (B)

$$\tau = MB \sin\theta = I\pi a^2 \times 2 \times \frac{\mu_0 I}{2\pi d} \sin 30^\circ = \frac{\mu_0 I^2 a^2}{2d}$$

Sol 19: (A, B, C) $\vec{F} = 2I(L+R)[\hat{i} \times \hat{B}]$

Sol 20: (A, D) $I_1 = I_2$

$\Rightarrow \; neA_1v_1 = neA_2v_2$

$\Rightarrow \; d_1w_1v_1 = d_2w_2v_2$

Now, potential difference developed across MK

V = Bvw

$$\Rightarrow \; \frac{V_1}{V_2} = \frac{v_1w_1}{v_2w_2} = \frac{d_2}{d_1}$$

Sol 21: (A, C) As $I_1 = I_2$

$n_1w_1d_1v_1 = n_2w_2d_2v_2$

Now $\dfrac{V_2}{V_1} = \dfrac{B_2v_2w_2}{B_2v_1w_1} = \left(\dfrac{B_2w_2}{B_1w_1}\right)\left(\dfrac{n_1w_1d_1}{n_2w_2d_2}\right) = \dfrac{B_2n_1}{B_1n_2}$