

Synopsis:

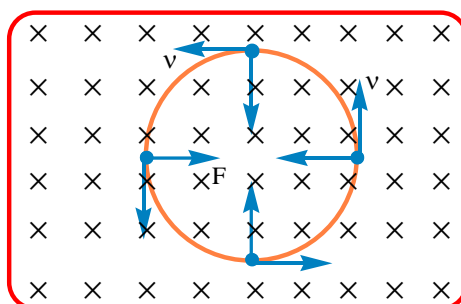
➤ **Force acting on a charged particle moving in a uniform magnetic field:**

- (i) If charge $+q$ is moving with velocity \vec{v} , making an angle θ with the direction of field. Force acting on the charge is,

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

Magnitude of force is $F = Bqv \sin \theta$, direction of \vec{F} is perpendicular to plane containing both \vec{v} and \vec{B}

- (ii) If $\theta = 0^\circ$ or 180° , then the force acting on the particle is zero. And the particle keeps moving in the same path. i.e., undeviated.
- (iii) If the charged particle enters normal to the magnetic field, the force acting on it is maximum. i.e., F_{\max}
- (iv) This force acts right angles to \vec{B} and \vec{v} . It acts as centripetal force and the path of particle will be circular.



Then the radius of the circular path is given by

$$r = \frac{mv}{Bq} \Rightarrow r = \frac{P}{Bq} \text{ (from } Bqv = \frac{mv^2}{r} \text{)}$$

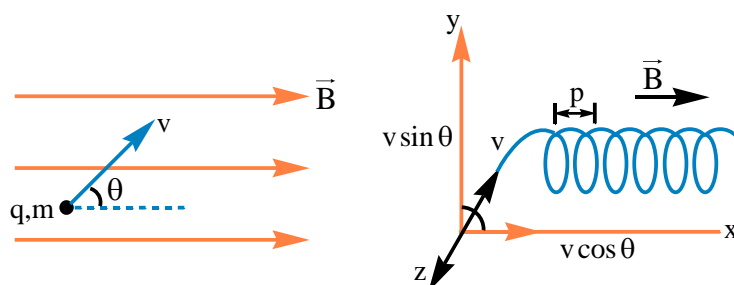
Where P = momentum

- (v) $r = \frac{\sqrt{2mK}}{qB}$ where K is kinetic energy of the particle
- (vi) If charged particle is accelerated through a potential difference of V volts before it enters into the magnetic field normally then $r = \frac{\sqrt{2mqV}}{qB}$
- (vii) Speed, kinetic energy remains constant, but velocity, acceleration, momentum and force are variable since their directions are continuously changing.
- (viii) The time period of rotation is $T = \frac{2\pi r}{v} \therefore T = \frac{2\pi m}{qB}$
 Angular frequency of rotation is $\omega = \frac{Bq}{m}$
 $\therefore T$ and ω are independent of v and r of charged particle.
- (ix) When the particle enters the magnetic field at angle θ with \vec{B} , such that $\theta \neq 0^\circ, \theta \neq 90^\circ, \theta \neq 180^\circ$ then the path followed by the particle will be helical.

(Physics)

MEGNETICS

- (x) Radius of circular path of the helix is given by $r = \frac{mv \sin \theta}{qB}$



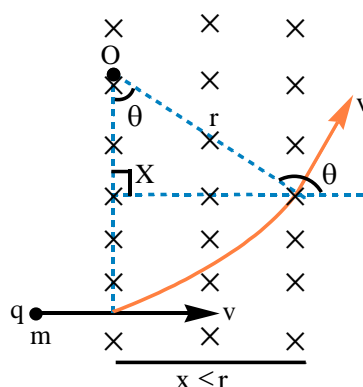
- (xi) Time period of rotation is $T = \frac{2\pi m}{qB}$

- (xii) Distance travelled by the particle along magnetic field in one complete rotation or pitch of helix is given by $P = (v \cos \theta)T; = \frac{2\pi m v \cos \theta}{qB}$

- (xiii) Work done by the magnetic field on the charged particle is zero.

➤ **Deviation of charged particle in uniform magnetic field :**

Case 1 : Suppose a charged particle enters perpendicular to the uniform magnetic field if the magnetic field extends to a distance 'x' which is less than or equal to radius of the path.



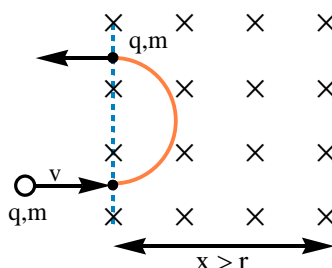
In this case, $r = \frac{mv}{Bq}$,

Angle of deviation ' θ ' can be determined by using the formula $\sin \theta = \frac{x}{r} = \frac{xqB}{mv}$

$$\therefore \theta = \sin^{-1} \left(\frac{xqB}{mv} \right)$$

The above relation can be used only when $x \leq r$.

Case 2 : For $x > r$,



In this case, $r = \frac{mv}{Bq}$,

In this case, deviation = 180° .

➤ **Fleming's left hand rule :**

Stretch the fore finger, central finger and thumb of left hand in mutually perpendicular directions, such that if fore finger indicates direction of magnetic field, central finger indicates direction of current, then thumb indicates direction of force on conductor.

➤ **Lorentz Force :**

(i) When a charge enters a region where both electric and magnetic fields exists simultaneously, force acting on it is called Lorentz force and is given by $\vec{F} = \vec{F}_e + \vec{F}_m = q[\vec{E} + (\vec{V} \times \vec{B})]$.

(ii) **Cyclotron :**

(a) The cyclotron is a machine to accelerate charged particles or ions to high energies using both electric and magnetic fields in combination.

(b) Cyclotron uses the fact that the frequency of revolution of the charged particle in a magnetic field is independent of its energy.

(c) Centripetal force is provided by the magnetic force $\frac{mv^2}{r} = Bqv$

(d) Radius of circular path is $r = \frac{mv}{Bq}$

(e) Time period of charged particle is $T = \frac{2\pi r}{v}$

$T = \frac{2\pi m}{Bq} f = \frac{1}{f} = \frac{Bq}{2\pi m} = \text{cyclotron frequency.}$

(f) K.E of charged particles is $K.E = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{Bqr}{m}\right)^2 = \frac{B^2q^2r^2}{2m}$

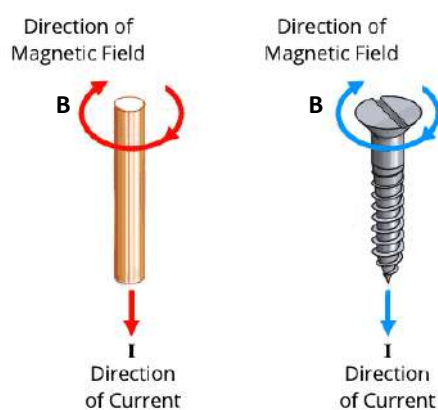
Introduction:

A current-carrying wire produces a magnetic field of its own. This was first observed by Oersted.

When current is flowing through a conductor, only magnetic field is produced around it, which is nonconservative. The direction of magnetic lines of force due to a straight current-carrying conductor will be concentric circles around the conductor in a plane that is always perpendicular to the length of the conductor. The direction of the magnetic field can be found by using:

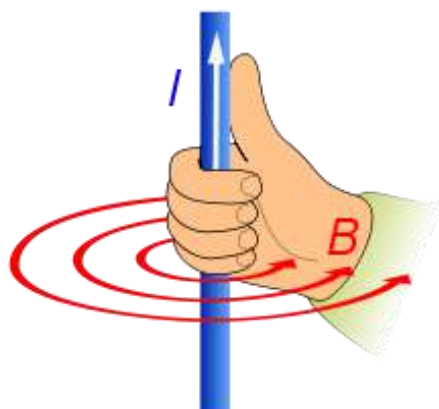
(i) **Maxwell's Cork screw rule:**

Imagine a right-handed cork screw advancing in the direction of current, then the direction of rotation of the screw head gives the direction of magnetic lines of force,

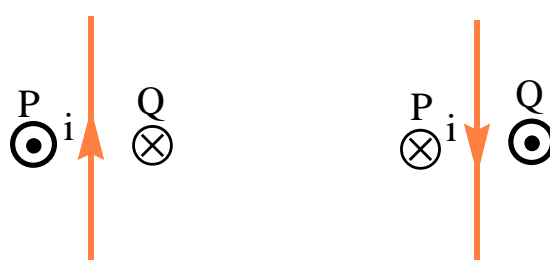


(ii) **Ampere's right-hand thumb rule:**

When a straight conductor carrying current is held in the right hand such that the thumb is pointing along the direction of current, then the direction in which fingers curl around it gives the direction of magnetic lines of force.



The direction of magnetic field for current carrying conductor is as given below.

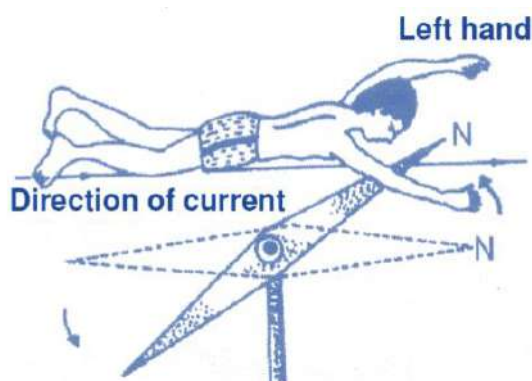


⊗ indicates \vec{B} into the plane of paper

⊙ indicates \vec{B} out of the plane of paper

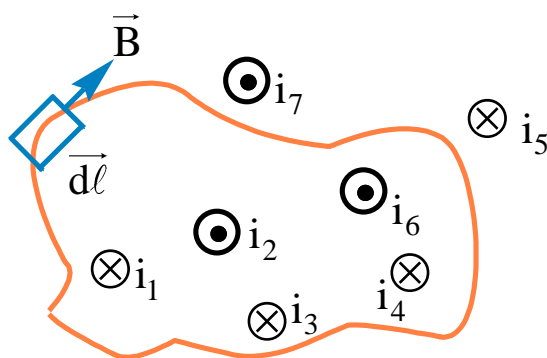
(iii) **Ampere's Swimming Rule:**

Imagine a person swimming along a current carrying wire in the direction of the current facing a magnetic needle below the wire, then the magnetic north pole of the needle deflects towards his left hand.



Ampere's circuital law:

Statement: The line integral of the magnetic induction field (B) along any closed path in air (or) vacuum is equal to μ_0 times the net current across the area bounded by this path. $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 i_{\text{net}}$



Consider a closed plane curve as shown in figure. $d\vec{\ell}$ is a small length element on the curve. Let \vec{B} be the resultant magnetic field at the position of $d\vec{\ell}$. If the scalar product $\vec{B} \cdot d\vec{\ell}$ is integrated by varying $d\vec{\ell}$ on the closed curve it is called line integral of \vec{B} along the curve and it is represented by $\oint \vec{B} \cdot d\vec{\ell}$

The rule for deciding whether an enclosed current is positive or negative:

The fingers of the right hand are to be taken in the direction of integration around the path. If a current pierces the membrane stretched across the area in the direction of the thumb, then it is positive current. If the current pierces the membrane in the opposite direction, then it is negative. For the above closed path

$$\oint B \cdot d\ell = \mu_0 (i_1 - i_2 + i_3 + i_4 - i_6)$$

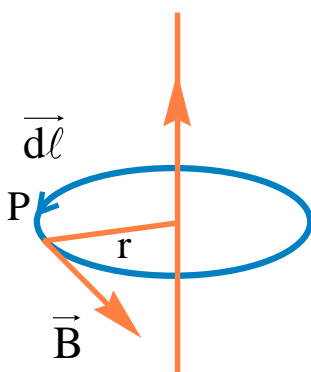
Important points regarding Ampere's law:

1. The line integral does not depend on the shape of the closed path or on the position of the current carrying wire in the loop
2. If a conductor carrying current is outside the closed path, the line integral of B due to that conductor is zero i.e., we need not consider the currents that do not pierce the area of the closed path.

3. Ampere's circuital law is always true no matter how distorted the path or how complicated may be the magnetic field. In most cases even though Ampere's circuital law is true it is inconvenient because it is impossible to perform the path integral. However in few special symmetric cases it is easy to perform path integral using ampere's law.
4. Ampere's circuital law is applicable for conductors carrying steady current.
5. Ampere's circuital law is analogous to Gauss law.
6. Ampere's circuital law is not independent of Biot-Savart's law. It can be derived from Biot-Savart's law. Its relation with Biot-Savart's law is similar to the relation between Gauss law and Coulomb's law in electrostatics.

Intensity of magnetic induction (**B**) near a long straight conductor:

From Ampere's circuital law



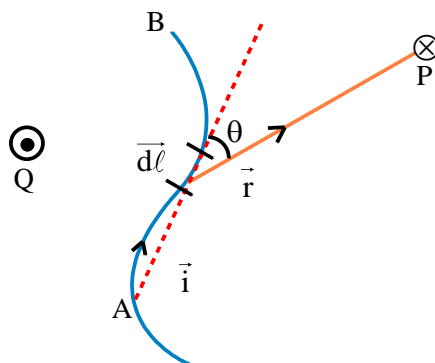
$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 i \oint B d\ell \cos 0^\circ = \mu_0 i$$

$$B \oint d\ell = \mu_0 i B(2\pi r) = \mu_0 i \Rightarrow B = \frac{\mu_0 i}{2\pi r}$$

Here r must be much less than the length of conductor.

Magnetic induction at any point along the axis of conductor is zero.

Magnetic field due to a current element (Biot-Savart law):



According to Biot-Savart's law, the magnitude of magnetic induction dB .

(a) is directly proportional to the current i flowing through the element i.e.,

$$dB \propto i \rightarrow (i)$$

(b) is directly proportional to the length $d\ell$ of the element i.e.,

$$dB \propto d\ell \rightarrow (ii)$$

(c) is directly proportional to the sine of the angle (θ) between length of the element and the line joining the element to the point P.

$$dB \propto \sin \theta \rightarrow (iii)$$

(d) is inversely proportional to the square of the distance (r) of the point from the element.

$$dB \propto \frac{1}{r^2} \rightarrow (iv)$$

- ❖ If the conductor is in vacuum (or) air then $dB = \frac{\mu_0 i d\ell \sin \theta}{4\pi r^2}$
- ❖ Here $\frac{\mu_0}{4\pi}$ is the proportionality constant and μ_0 is called as permeability of free space or air. The value of μ_0 is $4\pi \times 10^{-7}$ tesla – m/A
- ❖ The above equation gives the magnitude of the magnetic field produced due to small current element at a distance 'r' from it.
- ❖ If current flows in the direction as shown in the figure, the direction of dB at P is directed perpendicular to the plane of the paper in the inward direction.
- ❖ In vector form the above equation can be written $\vec{dB} = \frac{\mu_0 i d\vec{\ell} \times \vec{r}}{4\pi r^3}$
- ❖ The resultant field at P due to the entire conductor can be obtained by integrating the above equation. $B = \int_A^B \frac{\mu_0 i d\vec{\ell} \times \vec{r}}{4\pi r^3}$

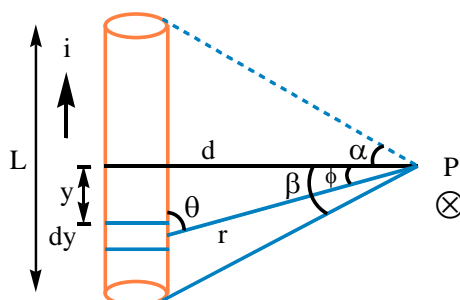
➤ Magnetic field due to a straight current carrying wire:

Consider a straight conductor carrying current 'i'. let 'P' be a point at a perpendicular distance 'd' from the conductor.

Let 'dy' be a small current element at a distance 'r' from 'P'.

- According to Biot-Savart's law, the magnetic induction at P due to the small element is $dB = \frac{\mu_0 i dy \sin \theta}{4\pi r^2}$

- As every element of the wire contributes to \vec{B} in the same direction, the magnetic induction due to the entire conductor is $B = \int dB = \frac{\mu_0 i}{4\pi} \int \frac{dy \sin \theta}{r^2}$



$$\tan \phi = y/d$$

$$y = d \tan \phi \Rightarrow dy = d(\sec^2 \phi) d\phi$$

$$\frac{r}{d} = \sec \phi \quad r = d \sec \phi$$

$$B = \frac{\mu_0 i}{4\pi} \int \frac{d(\sec^2 \phi) \cdot d\phi \sin(90^\circ - \phi)}{d^2 \sec^2 \phi}$$

$$[\because \theta = (90 - \phi)]$$

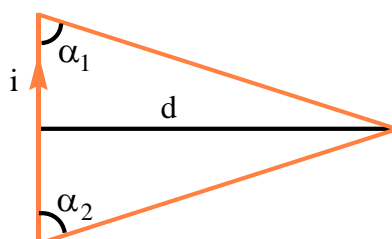
$$B = \frac{\mu_0 i}{4\pi} \int_{-\beta}^{\alpha} \frac{d(\sec^2 \phi) d\phi \cos \phi}{d^2 \sec^2 \phi}$$

$$B = \frac{\mu_0 i}{4\pi d} \int_{-\beta}^{\alpha} \cos \phi d\phi$$

($-\beta$ is taken because the angle is measured anti clockwise)

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

Similarly B is given as



$$B = \frac{\mu_0 i}{4\pi d} [\cos \alpha_1 + \cos \alpha_2]$$

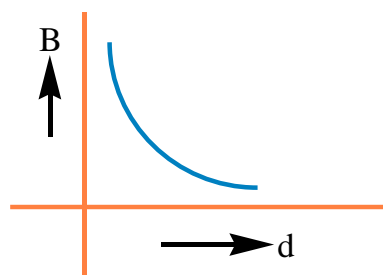
❖ Special Cases:

- (i) If the point is along the length of the wire (but not on it then as $\vec{d\ell}$ and \vec{r} will be either parallel or anti parallel i.e., $\theta = 0$ (or) π

$$\text{So, } \vec{d\ell} \times \vec{r} = 0 \text{ and hence } \vec{B} = \int_A^B \vec{dB} = \vec{0}$$

- (ii) If a point is at a perpendicular distance d from the wire then the magnetic field B varies inversely with distance d.

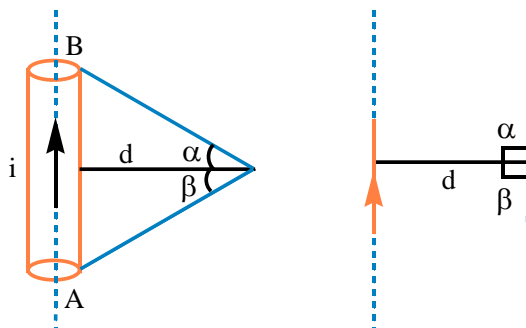
$$B \propto \frac{1}{d}$$



- (iii) If the wire is of finite length 'L' and the point is on its perpendicular bisector, at a distance 'd' from the wire, i.e., $\alpha = \beta$

$$B = \frac{\mu_0}{4\pi} \frac{2i}{d} \sin \alpha \text{ with } \sin \alpha = \frac{L}{\sqrt{L^2 + 4d^2}}$$

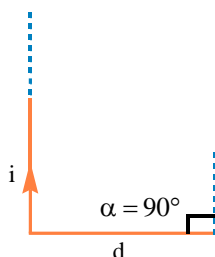
- (iv) If wire is of infinite length and the point P lies at a distance 'd' from the wire which is at a large distance from its ends as shown in figure, $\alpha = \beta = \pi/2$



$$B = \frac{\mu_0}{4\pi} \frac{i}{d} (2) = \frac{\mu_0}{4\pi} \frac{2i}{d} = \frac{\mu_0 i}{2\pi d}$$

- (v) At a point away from the conductor and near the edge of conductor

$$\alpha = 90^\circ, \beta = 0^\circ; B = \frac{\mu_0}{4\pi} \frac{i}{d}$$

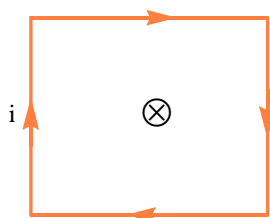


- (vi) (a) Magnetic induction at the centre of current carrying wire bent in the form of square of side 'a' is

$$B_{\text{net}} = 4B_{\text{side}}$$

$$B_{\text{net}} = 4 \frac{\mu_0}{4\pi} \times \frac{i}{a/2} (\sin 45^\circ + \sin 45^\circ)$$

$$B = 8\sqrt{2} \left(\frac{\mu_0 i}{4\pi a} \right) \otimes$$



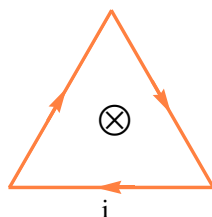
- (vi) (b) Magnetic induction at the centroid of current carrying wire bent in the form of equilateral triangle of side 'a' is

$$B_{\text{net}} = 3B_{\text{side}}$$

$$B_{\text{net}} = 3 \frac{\mu_0}{4\pi} \times \frac{i}{r} (\sin 60^\circ + \sin 60^\circ)$$

$$\left(\text{where } r = \frac{a}{2\sqrt{3}} \right)$$

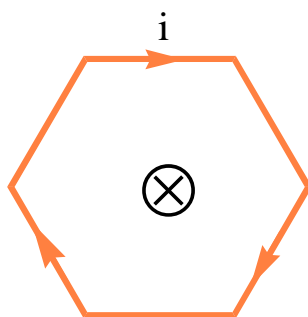
$$B = 18 \frac{\mu_0 i}{4\pi a} \otimes$$



- (vi) (c) Magnetic induction at the centre of current carrying wire bent in the form of hexagon of side 'a' is given by

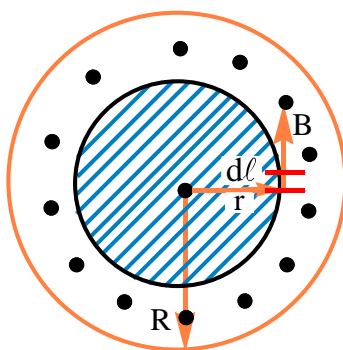
$$B_{\text{net}} = 6B_{\text{side}}$$

$$\text{Here, } \alpha = \beta = 30^\circ; B = 4\sqrt{3} \frac{\mu_0 i}{4\pi a}$$



The magnetic field due to along straight current carrying conductor:

- (a) Taking a circular ampere loop centered to the wire of radius $r < R$. To find B inside the conductor using ampere's circuital law (ACL), we have $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 i'$, here $i' = J \cdot \pi r^2$



$$\text{Or } B \oint d\ell = \mu_0 J \pi r^2 \text{ or } B 2\pi r = \mu_0 J \pi r^2$$

$$\text{or } B = \frac{\mu_0 J}{2} r; r \leq R; B \propto r$$

- (b) At a point outside the wire ($r > R$)

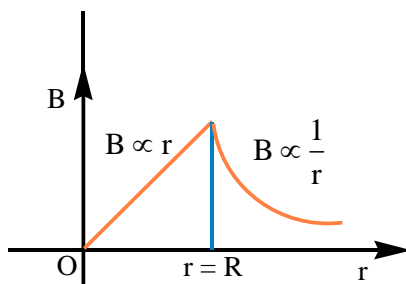
$$\oint B \cdot d\ell \cos 0^\circ = \mu_0 i'$$

Where $i' = i$ because the amperian loop encloses total current or

$$B \oint d\ell = \mu_0 i \text{ or } B 2\pi r = \mu_0 i$$

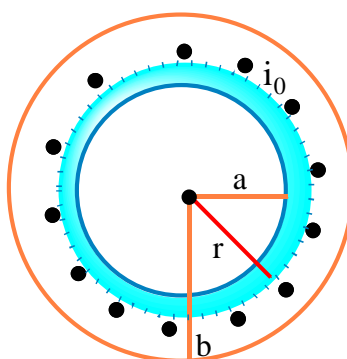
$$\Rightarrow B = \frac{\mu_0 i}{2\pi r}; r \geq R; B \propto \frac{1}{r}$$

- (c) B varies linearly inside the conductor and hyperbolically outside the conductor.



Magnetic induction is maximum at the periphery of the wire

- (d) The variation of \vec{B} as the function of radial distance r due to a hollow cylinder carrying a current i_0 .



Taking a circular amperian loop of radius $r(> a)$ and applying ACL,

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 i; \quad B 2\pi r = \mu_0 i$$

$$\text{Where, } i = \frac{i_0}{\pi(b^2 - a^2)} \cdot \pi(r^2 - a^2)$$

$$= \frac{i_0(r^2 - a^2)}{b^2 - a^2}$$

$$\text{Then } B = \frac{\mu_0 i_0 (r^2 - a^2)}{2\pi(b^2 - a^2)r}$$

$$a \leq r \leq b$$

$$B = 0 \text{ for } r \leq a \text{ (as because } i = 0)$$

$$\text{For } r > b$$

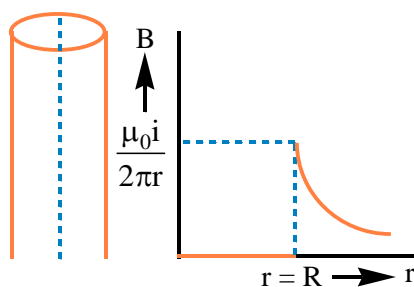
$$B = \frac{\mu_0 i_0}{2\pi r}$$

- (e) For thin hollow cylinder

$$(i) B_{\text{inside}} = 0$$

$$(ii) B_{\text{surface}} = \frac{\mu_0 i}{2\pi R} \text{ (} r = R \text{)}$$

$$(iii) B_{\text{outside}} = \frac{\mu_0 i}{2\pi r} \text{ (} r > R \text{)}$$



- (f) Work done to move a unit north pole through a small distance ' $d\ell$ ' along the tangent at a distance ' r ' away from current carrying conductor

$$\Rightarrow dw = \vec{F} \cdot d\vec{\ell}$$

$$\vec{F} = m\vec{B} = \vec{B} (\because m = 1)$$

$$\text{But, } dw = \vec{F} \cdot d\vec{\ell} \Rightarrow dw = \vec{B} \cdot d\vec{\ell}$$

Total work done in moving it once around the conductor: $W = \oint dw$

$$W = \oint \vec{B} \cdot d\vec{\ell}$$

But from Ampere's circuital law

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 i \Rightarrow W = \mu_0 i$$

If a pole of strength ' m ' is rotated for ' n ' times around the current carrying conductor, then the work done is

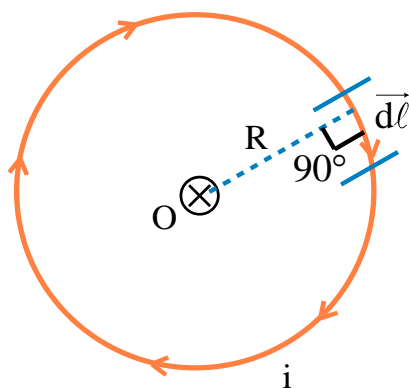
$$W = \mu_0 i \times nm$$

Here $W \neq 0$, the magnetic field produced by current carrying conductor is a non-conservative field.

- Magnetic field at the center of a circular coil carrying current:

Consider a circular coil of radius R carrying a current i in clockwise direction. Consider any small element $d\ell$ of the wire. The magnetic field at the center O due to the current element $id\vec{\ell}$ is $dB =$

$$\frac{\mu_0}{4\pi} \frac{i d\vec{\ell} \times \vec{R}}{R^3}$$



Where \vec{R} is the vector joining the element to the center O . The direction of this field is

perpendicular to the plane of the diagram and is going into it.

The magnitude of the magnetic field is $dB = \frac{\mu_0 i d\ell}{4\pi R^2}$ (i)

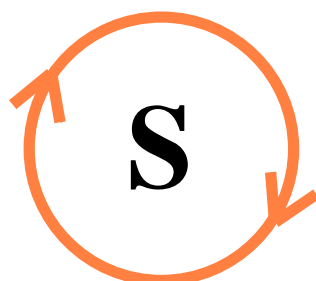
As the fields due to all such elements have the same direction, the net field is also in this direction. It can, therefore, be obtained by integrating equation(i) under proper limits.

$$\text{Thus, } B = \int dB = \int \frac{\mu_0 i}{4\pi R^2} d\ell$$

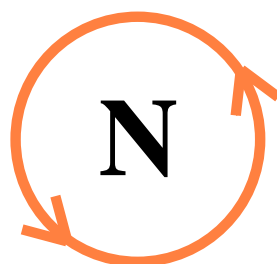
If the coil has N turns $\int d\ell = 2\pi RN$

$$B = \frac{\mu_0 i}{4\pi R^2} \int d\ell = \frac{\mu_0 i}{4\pi R^2} \times 2\pi RN = \frac{\mu_0 i N}{2R} \otimes$$

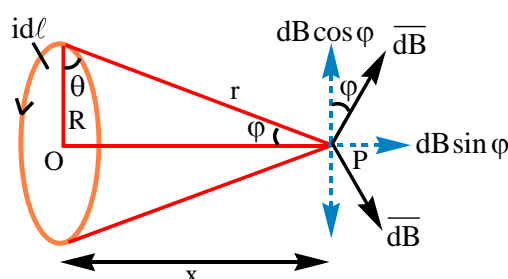
If the current is in clock wise direction, then the magnetic field produced is normally inwards and the face of the coil behaves as south pole.



If the current is in anti clock wise direction, then the magnetic field produced is normally outwards and the face of the coil behaves as north pole.



➤ Field at an axial point of a circular loop:



Consider a circular loop of radius R, carrying current in yz plane with center at origin O. Let P be a point on the axis of the loop at a distance 'x' from the center 'O' of the loop.

Consider a conducting element $d\ell$ of loop.

According to Biot-Savart's law, the magnitude of magnetic field due to the current element is

$$|\vec{dB}| = \frac{\mu_0}{4\pi} \frac{|\vec{dl} \times \vec{r}|}{r^3} \text{ where } r = \sqrt{x^2 + R^2}$$

Here the element $d\ell$ is in yz plane where as the displacement vector \vec{r} from \vec{dl} to the point p is in xy plane. So $|\vec{dl} \times \vec{r}| = dl \times r$

$$|\vec{dB}| = \frac{\mu_0}{4\pi} \frac{dl \times r}{r^3} = \frac{\mu_0}{4\pi} \frac{dl}{r^2}$$

The direction of \vec{dB} is perpendicular to the plane formed by \vec{r} and \vec{dl}

In case of a point P on the axis of circular coil, for every current element ' $id\ell$ ' there is a symmetrically situated opposite element. The component of the field \vec{dB} perpendicular to the axis cancel each other while component of the field \vec{dB} along the axis add up and contributes to the net magnetic field.

$$\text{i.e., } B = \int dB \sin \phi = \frac{\mu_0}{4\pi} \int \frac{id\ell \sin \theta}{r^2} \sin \phi$$

Here angle θ between the element \vec{dl} and \vec{r} is $\pi/2$ everywhere and r is same for all elements and also $\sin \phi = (R/r)$ so,

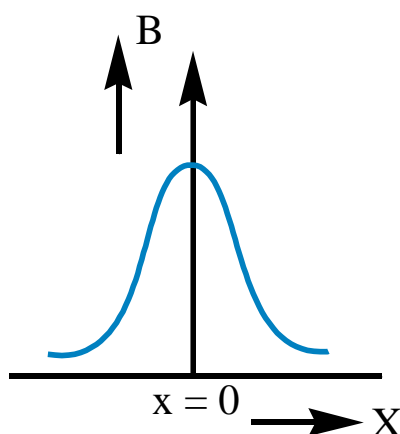
$$B = \frac{\mu_0}{4\pi} \int \frac{id\ell \sin \theta}{r^2} \sin \phi = \frac{\mu_0}{4\pi} \int \frac{id\ell \sin 90^\circ R}{r^3} \\ = \frac{\mu_0}{4\pi} \frac{iR}{r^3} \int d\ell$$

For a loop $\int d\ell = 2\pi R$ and as $r^3 = (x^2 + R^2)^{3/2}$;

$$B = \frac{\mu_0}{4\pi} \frac{2\pi i R^2}{(x^2 + R^2)^{3/2}} = \frac{\mu_0 i R^2}{2(x^2 + R^2)^{3/2}}$$

The direction of magnetic field B is along the axis of the loop.

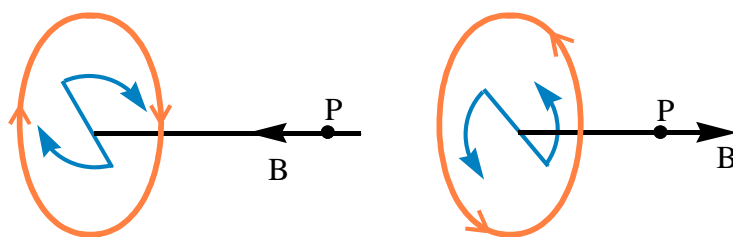
- (i) The magnetic field B varies non linearly with distance x from centre as shown in figure.



For a coil having N turns, $\int d\ell = 2\pi RN$

$$\text{So, } B = \frac{\mu_0 Ni R^2}{2(x^2 + R^2)^{3/2}}$$

It is maximum when $x^2 = 0$ i.e., at the center of the coil whose value is given by



(ii) If $x \gg R$; $B = \frac{\mu_0}{4\pi} \frac{2\pi N I R^2}{x^3} = \frac{\mu_0}{4\pi} \frac{2 N I A}{x^3}$

Where $A = \pi R^2$, area of the coil.

➤ Circular current loop as magnetic dipole:

From the above expression $B = \frac{\mu_0}{4\pi} \frac{2 N I A}{x^3}$

Comparing with $B = \frac{\mu_0}{4\pi} \frac{2 M}{x^3}$

(a) Magnetic moment of the circular current carrying coil is $M = N i A$

(b) M is independent of shape of the coil

∴ Current loop behaves like a magnetic dipole with poles on either side of its face and it is known as “magnetic shell”

(c) SI unit of magnetic moment (M) is $A - m^2$ and dimensional formula is IL^2 .

(d) Magnetic moment of a current loop is a vector perpendicular to the plane of the loop and the direction is given by right hand thumb rule.

➤ Magnetic dipole moment of a revolving electron:

Consider an electron revolving in a circular path of radius r around a nucleus with uniform speed v .

The current in the orbit is $i = \frac{e}{T} = \frac{e}{2\pi r/v} = \frac{ev}{2\pi r}$

Magnetic dipole moment of a revolving electron is

$\mu = iA = \frac{ev}{2\pi r} \times \pi r^2 = \frac{evr}{2}$

Magnetic dipole moment of a revolving electron in first orbit of hydrogen atom is called Bohr magneton (μ).

From Bohr second postulates, for an electron revolving in first orbit of hydrogen atom.

$m_e v r = \frac{h}{2\pi} (n = 1)$

Where h = Planck's constant, m_e = mass of electron

$\mu = \frac{evr}{2} = \frac{e}{2} \frac{h}{2\pi m_e} = \frac{eh}{4\pi m_e}$

$(\mu) \frac{e}{4\pi m_e \text{min}}$

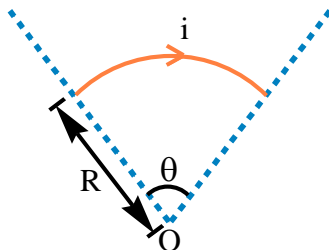
$= \frac{1.60 \times 10^{-19} \times 6.63 \times 10^{-34}}{4 \times 3.14 \times 9.11 \times 10^{-31}}$

$$= 9.27 \times 10^{-24} \text{Am}^2$$

This value is called the Bohr magneton.

❖ Special cases:

(i) For an arc shaped conductor carrying current subtending an angle θ at the center.



$$B = \frac{\mu_0 i}{2R} \frac{\theta}{2\pi} \otimes$$

$$\therefore \text{Magnetic induction at the center } B = \frac{\mu_0 i \theta}{4\pi R} \otimes$$

(ii) For a quadrant circular wire carrying current.

$$\theta = 90^\circ$$

$$\text{Magnetic induction at the center } B = \frac{\mu_0 i}{8R} \otimes$$

(iii) If B_0 is magnetic induction at the center of a circular current carrying coil of radius R having N turns and B_A is magnetic induction at a point on the axis of it at a distance x from center then

$$B_A = \frac{B_0}{\left(1 + \frac{x^2}{R^2}\right)^{3/2}}$$

$$\text{Proof: } B_0 = \frac{\mu_0 Ni}{2R} \text{ and } B_A = \frac{\mu_0 Ni R^2}{2(R^2 + x^2)^{3/2}}$$

$$\Rightarrow B_A = \frac{\mu_0 Ni}{2R \left(1 + \frac{x^2}{R^2}\right)^{3/2}} \Rightarrow B_A = \frac{B_0}{\left(1 + \frac{x^2}{R^2}\right)^{3/2}}$$

$$B_A = B_0 \left[1 - \frac{3x^2}{2R^2}\right]$$

(iv) If a particle of charge q moves in a circular path of radius r with a velocity v , then the magnetic induction at the center of circular loop

$$B = \frac{\mu_0 i}{2r} = \frac{\mu_0}{2r} \times \frac{qv}{2\pi r} = \frac{\mu_0}{4\pi} \frac{qv}{r^2}$$

$$\text{If } f \text{ is the frequency of rotation } B = \frac{\mu_0}{2r} \times qf$$

If ω is the angular velocity, then

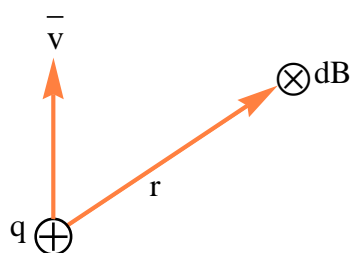
$$B = \frac{\mu_0}{2r} \times \frac{q\omega}{2\pi} = \frac{\mu_0}{4\pi} \frac{q\omega}{r}$$

(v) A charge ' q ' is moving with a velocity of ' v '. Then the expression of magnetic induction due to this charge at a position vector \vec{r} from the charge is (Biot -Savart law for a current element) $d\vec{B} =$

$$\frac{\mu_0 i d\vec{\ell} \times \vec{r}}{4\pi r^3}.$$

If a charged particle of charge q and undergoes a displacement $\vec{d\ell}$ during a time dt .

$$\text{Put } i = \frac{q}{dt} \text{ or } i \vec{d\ell} \times \vec{r} = \frac{q \vec{d\ell}}{dt} \times \vec{r}$$



$$\text{Putting } \frac{d\ell}{dt} = v; \quad i \vec{d\ell} \times \vec{r} = q(\vec{v} \times \vec{r})$$

$$\text{Using the above equations, } d\vec{B} = \frac{\mu_0 q (\vec{v} \times \vec{r})}{4\pi r^3}$$

- (vi) (a) When a wire of length ' ℓ ' carrying current ' i ' is bent in a circular loop of ' n ' turns then the magnetic induction at the centre of the loop is

$$B = \frac{\mu_0 n i}{2r} = \frac{\mu_0 \pi n^2 i}{\ell} (\because n \times 2\pi r = \ell)$$

- (vi) (b) The same wire of length ' ℓ ' carrying current ' i ' is first bent into a circular coil with n_1 turns and then into another circular coil with n_2 turns. If B_1, B_2 are magnetic inductions at their centers in the two cases, then

$$(vi) \quad (c) \quad \frac{B_1}{B_2} = \left(\frac{n_1}{n_2}\right)^2$$

- (vi) (d) If r_1 and r_2 are radii of turns of the coil in the above case, then ratio of magnetic induction is

$$\frac{B_1}{B_2} = \left(\frac{r_2}{r_1}\right)^2$$

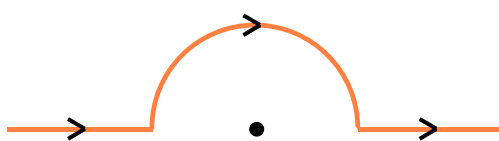
- (vi) (e) If two circular coils are connected in series, then the ratio of magnetic induction at their centers is $\frac{B_1}{B_2} = \left(\frac{n_1}{n_2}\right) \left(\frac{r_2}{r_1}\right)$

- (vi) (f) If the two coils are made up of same wire and connected in parallel, then the ratio of the magnetic induction at their centers is $\frac{B_1}{B_2} = \left(\frac{r_2}{r_1}\right)^2$

- (vii) (a) For semi circular wire carrying current.

$$\theta = 180^\circ$$

$$\text{Magnetic induction at the center } B = \frac{\mu_0 i}{4R} \otimes$$



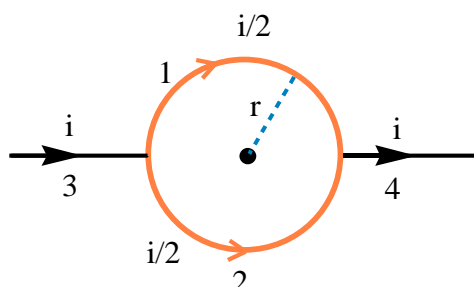
- (vii) (b) To a circular wire, two straight wires are attached as shown.

When current is passed through it the magnetic field at the centre is zero.

$$B_1 = \frac{\mu_0 \left(\frac{i}{2}\right)}{4R} \otimes; B_3 = B_4 = 0$$

$$B_2 = \frac{\mu_0 \left(\frac{i}{2}\right)}{4R} \odot$$

$\therefore B_{\text{net at } O}$ is zero

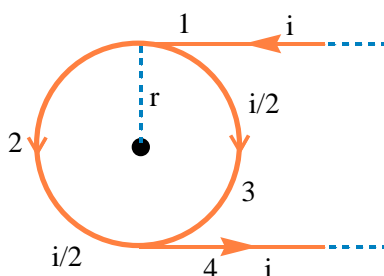


- (vii) (c) To a circular wire, two straight wires are attached as shown. When current is passed through it the magnetic field at the centre.

$$B_1 = \frac{\mu_0 i}{4\pi r} \odot$$

$$B_2 = \frac{\mu_0 \left(\frac{i}{2}\right)}{4R} \odot; B_3 = \frac{\mu_0 \left(\frac{i}{2}\right)}{4R} \otimes; B_4 = \frac{\mu_0 i}{4\pi r} \odot$$

$$\vec{B}_{\text{net}} = \vec{B}_1 + \vec{B}_2 + \vec{B}_3 + \vec{B}_4; B_{\text{net}} = \frac{\mu_0 i}{2\pi r} \odot$$



- (vii) (d) The upper and lower halves of the ring have resistances R_1 and R_2 . Two straight wires are connected to it as shown.

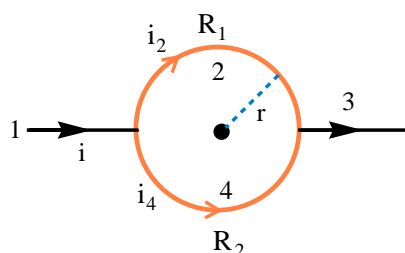
The magnetic induction at the centre of the ring is

$$B_1 = B_3 = 0 \quad B_2 = \frac{\mu_0 i_2}{4r} \otimes \quad B_4 = \frac{\mu_0 i_4}{4r} \odot$$

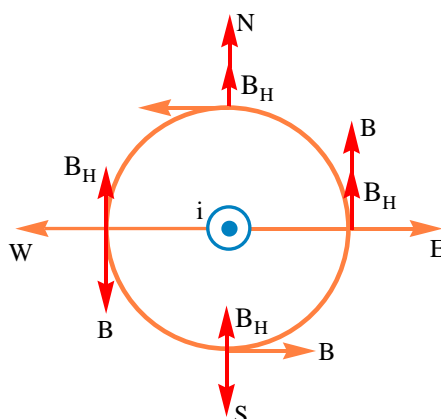
Since R_1 and R_2 are parallel to each other

$$i_2 R_1 = i_4 R_2; i_2 = \frac{i}{R_1 + R_2} \times R_2; i_4 = \frac{i}{R_1 + R_2} \times R_1$$

$$\vec{B}_{\text{net}} = \vec{B}_1 + \vec{B}_2 + \vec{B}_3 + \vec{B}_4; \vec{B}_{\text{net}} = \frac{\mu_0}{4r} (i_2 - i_4)$$



- (vii) (e) A straight current carrying conductor is held vertically in earth's magnetic field. It carries current in the upward direction, then the direction of magnetic field (B) due to it
- (viii) (a) due north of the conductor is towards west $B_{net} = \sqrt{B^2 + B_H^2}$
- (viii) (b) due west of the conductor is towards south $B_{net} = B - B_H$
- (viii) (c) due south of the conductor is towards east $B_{net} = \sqrt{B^2 + B_H^2}$



➤ Tangent Galvanometer:

- (i) Tangent galvanometer works on the principle of Tangent law i.e.,
 $B = B_H \tan \theta$
 Here B = Magnetic induction at the centre of the current carrying coil = $\frac{\mu_0 n i}{2r}$
- (ii) It is a moving magnet type galvanometer
- (iii) During experiment, plane of the coil should be along the magnetic meridian [to fulfill the requirement of tangent law]
- (iv) Current measured by tangent galvanometer is $i = \left(\frac{2r B_H}{\mu_0 n} \right) \tan \theta = K \tan \theta$; r = Radius of coil,
 K = reduction factor; n = number of turns of coil
- (v) SI unit of reduction factor is ampere
- (vi) Reading is more accurate when $\theta = 45^\circ$ since relative error $\frac{d\theta}{\theta} \propto \frac{1}{\sin^2 \theta}$ and it is minimum for 45°
- (vii) Sensitivity is maximum when $\theta = 0^\circ$ since $\frac{d\theta}{di} \propto \cos^2 \theta$, which is maximum for $\theta = 0^\circ$
- (viii) Reduction factor K depends on horizontal component of earth's magnetic field.
- (ix) T.G gives different readings at different places for same current

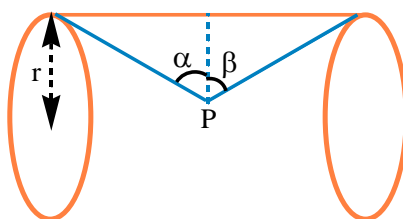
- (x) T.G cannot be used at magnetic poles, since $B_H = 0$ at magnetic poles.
 (xi) T.G is used to measure the current of the order of 10^{-6} A

➤ **Solenoid and Toroid:**

(i) Solenoid:

(a) If many turns of an insulated wire are wound around a cylinder the resulting coil is called a solenoid

(b) Field at a point on the axis of a solenoid is $B = \frac{\mu_0 ni}{2} (\sin \alpha + \sin \beta)$



Where 'n' is number of turns per unit length of solenoid.

(c) For a long solenoid magnetic induction on the axis is $B = \mu_0 ni$ ($\because \alpha = \beta \cong 90^\circ$)

(d) At one end of a long solenoid magnetic induction is $B = \frac{\mu_0 ni}{2}$ ($\because \alpha = 0^\circ, \beta \cong 90^\circ$)

(ii) Toroid:

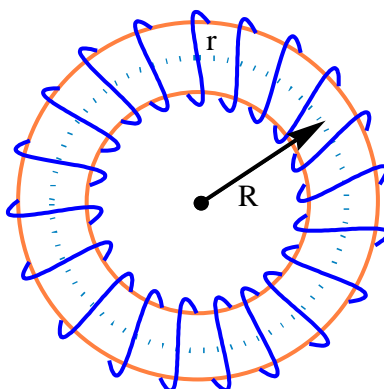
(a) If a solenoid is bent in a circular shape and the ends are joined then it is known as toroid.

Let N be the total number of turns in the toroid of radius joined then it is known as toroid.led a

$$n = \frac{N}{2\pi r}$$

Applying Ampere's law

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 Ni; \quad B = \frac{\mu_0 Ni}{2\pi r} = \mu_0 ni$$



➤ **Force on a current carrying conductor kept in uniform magnetic field :**

i) A conductor carrying current i is placed in a uniform magnetic field of induction B at an angle θ with the field direction. The force acting on it is given by $\vec{F} = i(\vec{\ell} \times \vec{B})$; $|\vec{F}| = Bi\ell \sin \theta$

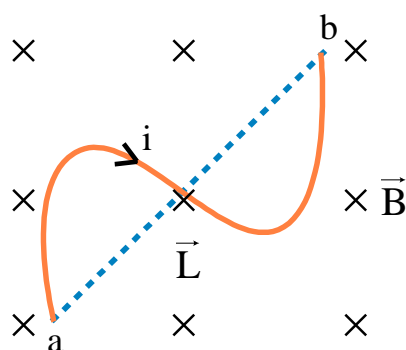
ii) If B and ℓ are parallel or anti-parallel $F = 0$

iii) If B and ℓ are perpendicular, then F_{max} .

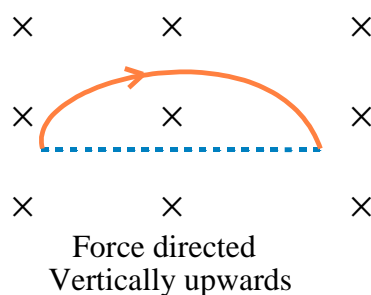
iv) Direction of force can be found using Fleming's left hand rule.

(iii) Special Cases :

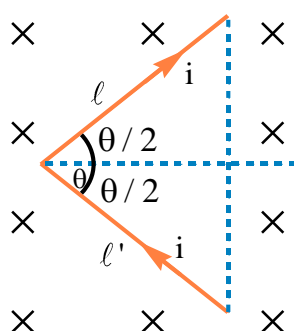
- (a) The force acting on curved wire joining points a and b as shown in the figure is the same as that on a straight wire joining these points. It is given by $\vec{F} = i(\vec{L} \times \vec{B})$ where $\vec{L} = ab$



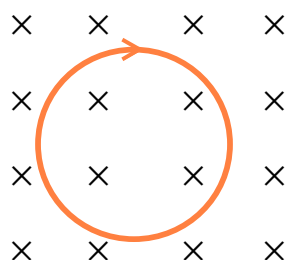
- (b) The force experienced by a semi circular wire of radius 'r' when it is carrying a current 'i' and is placed in a uniform external magnetic field of induction B as shown in the figure is given by $F = BI(2r)$.



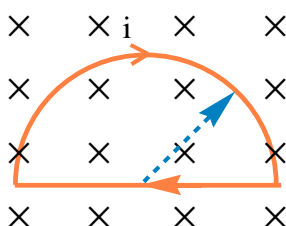
- (c) The force on the wire shown $F = Bi\ell \sin \frac{\theta}{2}$ towards left = $\ell_{\text{eff}} = 2\ell \sin \frac{\theta}{2}$



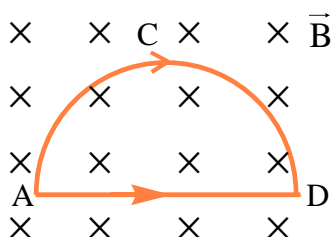
- (d) The force on a closed loop of any shape carrying current in a uniform magnetic field is always zero. Since $\ell_{\text{eff}} = 0$



- (e) The net force experienced by a closed current loop and current completes the loop in a uniform field is zero.



- (f) In case of a closed loop but current does not complete the loop the net force is not zero.



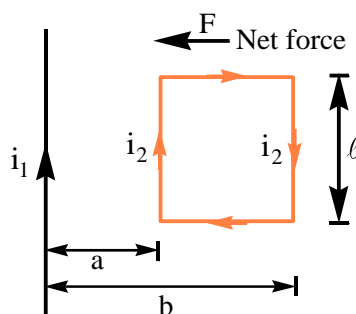
$$\vec{F}_{ACD} = \vec{F}_{AD}$$

$$\therefore \vec{F}_{loop} = \vec{F}_{ACD} + \vec{F}_{AD} = 2\vec{F}_{AD}$$

$$\therefore |\vec{F}_{loop}| = 2|\vec{F}_{AD}|$$

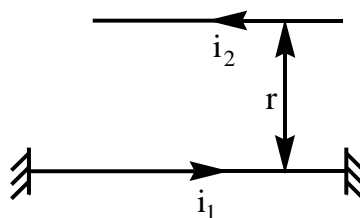
➤ **Force between two parallel current carrying long straight conductors :**

- (i) Force per unit length on each wire is given by $\frac{F}{\ell} = \frac{\mu_0 i_1 i_2}{2\pi r}$. If $i_1 = i_2 = 1 \text{ amp}$, $r = 1 \text{ m}$, then force per unit length of the conductor is $2 \times 10^{-7} \text{ N/m}$
- (ii) If currents in the two wires are in same direction, then the force of attraction takes place between them.
- (iii) If currents in the two wires are in opposite direction, then the force of repulsion takes place between them
- (iv) A straight and very long wire carries current i_1 and rectangular loop of wire carrying current i_2 is placed nearby it. The force on the loop is $F = \frac{\mu_0 i_1 i_2 \ell}{2\pi} \left[\frac{1}{a} - \frac{1}{b} \right]$



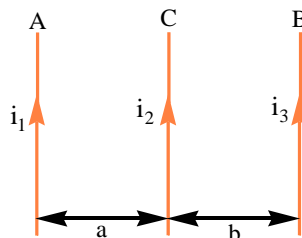
- (v) A very long horizontal wire carries a current i_1 is rigidly fixed. Another wire is placed directly above and parallel to it carries a current i_2 . r is the perpendicular distance of separation between the wires and currents are in opposite directions for the second wire remains stationary, the condition is $F = mg \Rightarrow \frac{\mu_0 i_1 i_2 \ell}{2\pi r} = mg$

$$\Rightarrow \frac{m}{\ell} = \frac{\mu_0 i_1 i_2}{2\pi r g}$$



- (vi) Three long parallel conductors carry currents as shown

(a) Resultant force per unit length on the wire 'C' is $F = \frac{\mu_0}{2\pi} \left[\frac{i_1 i_2}{a} \sim \frac{i_2 i_3}{b} \right]$

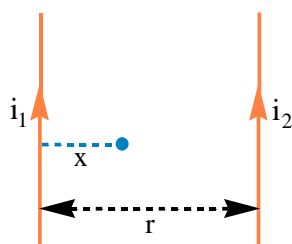


(b) If the resultant force on the wire 'C' is zero, the condition is $\frac{i_1 i_2}{a} = \frac{i_2 i_3}{b} \Rightarrow \frac{i_1}{a} = \frac{i_3}{b}$

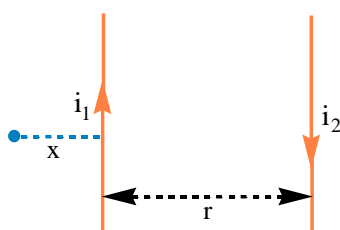
Note : Here the resultant force per unit length on the A and B wire can be also determined in the similar way. The currents can be along different directions.

➤ **Null points due to two current carrying parallel wires :**

- (i) Two straight parallel conductors are carrying currents i_1, i_2 ($i_1 < i_2$) in the same direction, and are separated by a distance r , the null point is formed in between them. The distance of the null point from the conductor carrying smaller current is $x = \frac{r}{\frac{i_2}{i_1} + 1}$



- (ii) Two straight parallel conductors are carrying current $i_1, i_2 (i_1 < i_2)$ in opposite directions, and are separated by a distance r , then the null point is formed outside the conductors, the distance of the null point from the conductor carrying smaller current is given by $x = \frac{r}{\frac{i_2}{i_1} - 1}$

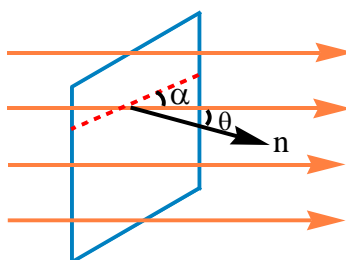


➤ **Force between two streams of electric charges :**

- (i) If two streams of electrons or protons are moving with velocity 'v' in parallel and same directions, there will be both electric repulsive force and magnetic attractive force. Since electric force predominates the magnetic force, there will be repulsion.
- (ii) If they move parallel and opposite directions, there will be electric repulsive force and magnetic repulsive force and hence there will be repulsion again.

➤ **Torque acting on a current loop kept in uniform magnetic field :**

- (i) When a coil carrying current is placed in uniform magnetic field, the net force on it is zero but it experiences a torque or couple.



- (ii) Torque acting on a current carrying coil placed in uniform magnetic field is $\vec{\tau} = \vec{M} \times \vec{B}$

- (iii) Torque acting on the coil is $\tau = BiNA \sin \theta$

$= BiNA \cos \alpha$. Here

A = area of coil carrying current i

N = number of turns of the coil

B = Magnetic induction of the field

α = Angle made by the plane of the coil with \vec{B}

θ = Angle made by the normal to the plane of the coil with \vec{B}

- (iv) If the plane of coil is parallel to the direction of magnetic field $\tau = \tau_{max}$
- (v) If the plane of coil is perpendicular to the direction of magnetic field, $\tau = 0$
- (vi) If current carrying coil is placed in a non-uniform magnetic field it experiences both force and torque.
- (vii) For a given area, torque is independent of shape of the coil
- (viii) Torque is directly proportional to area of the coil.

➤ **Special cases :**

- (i) When a current carrying coil is placed in uniform magnetic field, net force on it $F = 0$. But net torque may acts.
- (ii) When a current carrying coil is placed in non-uniform magnetic field, net force, net torque both acts.
 $\tau_{net} \neq 0$ $F_{net} \neq 0$.
- (iii) If the angle made by \vec{M} of the coil with \vec{B} in uniform magnetic field is ' θ ', then its potential energy $P.E = -\vec{M} \cdot \vec{B}$; $P.E = -MB \cos \theta$
- (iv) If a current carrying coil is rotated in a uniform field such that the angle made by \vec{M} with \vec{B} is changes from θ_1 to θ_2 .
 $W = MB(\cos \theta_1 - \cos \theta_2)$
- (v) If ext field is along, the direction of \vec{M} , then $\theta = 0^\circ$.
 $= 0$ $P.E = -MB(\min())$
- (vi) If external magnetic field is opposite to \vec{M} then, $\theta = 180^\circ$
 $= 0$. $P.E = +MB(\max())$
- (vii) The corresponds to unstable equilibrium.

➤ **Moving coil Galvanometer :**

- (i) Principle of moving coil galvanometer : When a current carrying coil suspended in a uniform magnetic field, it experiences a torque and hence it rotates.
- (ii) Poles of magnet are concave is shape, to make the magnetic field radial so that at all orientations the plane of the coil is parallel to the field, and hence torque acting on it is maximum. This makes the relation between current and deflection linear.
- (iii) Soft iron cylinder is kept at the center of magnetic field to increase the flux.
- (iv) Phosphor Bronze has
- (a) high Young's modulus so that the wire will not be stretched easily.

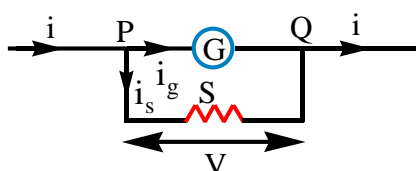
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- (b) low rigidity modulus so that the wire can be twisted easily.
- (c) small elastic after effects so that it comes back quickly to original position after withdrawing current.
- (v) Small mirror is attached on the phosphor Bronze wire, to measure the deflection using lamp and scale arrangement.
- (vi) If ' θ ' is the deflection for passage of current ' i ', then $C\theta = BiAN \Rightarrow i = \left(\frac{C\theta}{BAN}\right)$ where $k = \left(\frac{C}{BNA}\right)$ = Galvanometer constant or figure of merit. It is independent of B_H . Where ' C ' is couple per unit twist.
- (vii) a) Current sensitivity of a galvanometer is defined as the deflection produced in the galvanometer per unit current flowing through it, $S_I = \frac{d\theta}{di} = \frac{BAN}{C}$
- b) Voltage sensitivity of a galvanometer is defined as the deflection produced in the galvanometer per unit voltage applied to it.
- $$S_V = \frac{\theta}{V} = \frac{\theta}{i_G} \Rightarrow \frac{\theta}{V} = \frac{BAN}{CG}$$
- Where G is resistance of galvanometer
- (i) Increasing B (ii) Increasing A (iii) Increasing N (iv) Decreasing C
- (viii) It is used to measure current upto a minimum of 10^{-9}Amp .
- (a) Plane of coil need not be along the magnetic meridian
- (b) Galvanometer constant is independent of B_H . So it can be used to measure currents even at poles.
- (c) External magnetic fields have no effect on deflection. So, it can be used to measure current even in the environment of stray magnetic fields.

➤ **Shunt :**

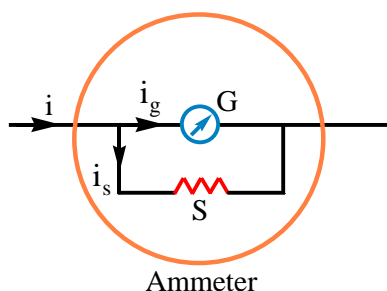
- (i) A low resistance connected in parallel to galvanometer to protect it from large current is known as shunt.
- (ii) When shunt is connected range increase but sensitivity decreases.



(iii) $R_{\text{equivalent}} = \frac{GS}{G+S}$ iv) $V = iR_{\text{eq}} = i \frac{GS}{G+S}$ v) $V_{PQ} = i_g G = i_g S$

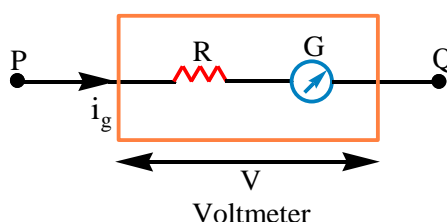
➤ **Ammeter :**

- (i) Galvanometer can be converted in to Ammeter by connecting low resistance parallel to it.



- (ii) To increase the range by 'n' times or to decrease the sensitivity by 'n' times, shunt to be connected across Galvanometer is $S = \frac{G}{\left(\frac{i}{i_g} - 1\right)} \Rightarrow S = \frac{G}{n-1}$
- Here $n = \frac{i}{i_g} = \frac{\text{newrange}}{\text{oldrange}} = \frac{\text{olddivision/amp}}{\text{newdivision/amp}}$
- (iii) Equivalent resistance of ammeter $= \frac{GS}{G+S}$
- (iv) The relation between currents is
- a) $i = i_g + i_s$ b) $i_g = \frac{iS}{G+S}$ c) $i_s = \frac{iG}{G+S}$
- d) $\frac{i_g}{i_s} = \frac{S}{G}; \frac{i_g}{i} = \frac{S}{G+S}; \frac{i_s}{i} = \frac{G}{G+S}$
- (v) It is a device used to measure current in electrical circuits.
- (vi) Resistance of an ammeter is very small and it is zero for an ideal ammeter. Potential drop across ideal ammeter is zero.
- (vii) Ammeter must always be connected in series to the circuit.
- (viii) Among low range and high range ammeters, low range ammeter has more resistance.

19. VOLTMETER



- (i) Galvanometer is converted into voltmeter by connecting high resistance in series to it.
- (ii) Voltmeter is always connected in parallel to the conductor [P.D. across which is to be measured] in the circuit.
- (iii) P.D. across the ends of voltmeter is, $V = i_g(G + R)$
- (iv) Voltmeter is used to measure P.D. across the conductor in electric circuits.
- (v) Resistance of a voltmeter is very high and that of an ideal voltmeter is infinity. Current drawn by an ideal voltmeter is zero.
- (vi) Among low range and high range voltmeters, high range voltmeter has more resistance.

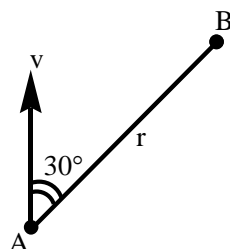
(Physics)

MEGNETICS

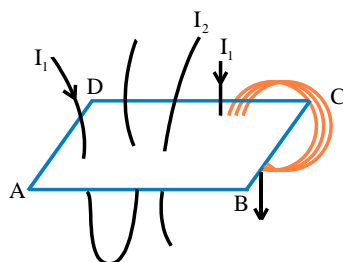
- (vii) Equivalent resistance of voltmeter = $G + R$
- (viii) Resistance to be connected in series to galvanometer to convert into voltmeter of range $0 - V$ volt is $R = \frac{V}{i_g} - G$
- (ix) To increase the range by n times, $n = \frac{\text{newrange}V_2}{\text{oldrange}V_1} = \frac{i_g(G+R)}{i_g(G)} = 1 + \frac{R}{G}$
- Here resistance to be connected in series to galvanometer is $R = G(n - 1)$

EXERCISE – 1

1. A charge particle A of charge $q = 2\text{C}$ has velocity $v = 100\text{ m/s}$. 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 ($r = 2\text{ m}$) : $n \times 10^{-7}\text{ T}$. Find n ?

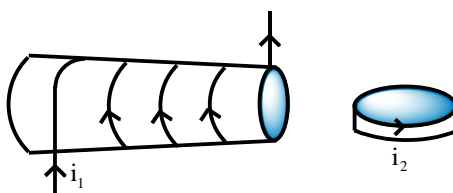


2. A point charge is moving in clockwise direction in a circle with constant speed. Consider the magnetic field produced by the charge at a point P (not centre of the circle) on the axis of the circle.
- (A) It is constant in magnitude only
 (B) It is constant in direction only
 (C) It is constant in direction and magnitude both
 (D) It is not constant in magnitude and direction both
3. Which of the following is correct for the points outside the wire or beam :
- (A) A current carrying wire produces magnetic field but not electric field
 (B) A current carrying wire produces both magnetic field and electric field
 (C) A proton beam moving with some velocity produces only electric field
 (D) A proton beam moving with some velocity produces only magnetic field
4. The magnetic lines of force due to a straight current carrying wire will be :
- (A) circular for finite length of wire (B) circular for semi-infinite wire
 (C) circular for infinite wire (D) all of the above
5. Consider a non conducting ring of a radius ' r ' and mass ' m ', which has a total charge ' q ' distributed uniformly on it. The ring is rotated about an axis passing through its centre and parallel to the plane of ring with an angular speed ω . Then the magnetic moment of the ring is $\frac{q\omega r^n}{\alpha}$. Find $\alpha + n$?
6. Three distinct current carrying wires intersect a finite rectangular plane ABCD. The current in left wire and the loop is I_1 . The direction of current in left most wire and right most loop is downwards as shown in figure. The current I_2 through middle wire is adjusted so that the path integral of the total magnetic field along the perimeter of the rectangle is zero, that is, $\oint_{ABCD} \vec{B} \cdot d\vec{\ell} = 0$. Then the current I_2 is :



- (A) $2I_1$ and upwards (B) $2I_1$ and downwards
(C) $4I_1$ and upwards (D) $3I_1$ and downwards

7. The diagram shows a solenoid and a loop such that the solenoid's axis lies in the plane of the loop. Both the solenoid and the loop carry constant currents in the directions as shown in the diagram. If the system is released from rest, the loop :



- (A) move towards the solenoid, rotates clockwise
(B) move towards the solenoid, rotates anticlockwise
(C) move away the solenoid, rotates clockwise
(D) move away the solenoid, rotates anticlockwise

8. A charged particle is projected in air horizontally near the earth's surface at a point where horizontal component of magnetic field is absent. Considering the effect of vertical component of the earth's magnetic field and the gravitational field due to the earth, the path of the particle will be :

- (A) circular (B) helical (C) straight line (D) parabolic

9. A charged particle enters a non-uniform uni-directional magnetic field such that its initial velocity is parallel to magnetic field, then the radius of curvature of its path is (in standard notation) :

- (A) $\frac{mv}{qB}$ (B) 0 (C) ∞ (D) $\frac{qB}{mv}$

10. A charged particle is released from rest in a region where there is a uniform and constant electric field; and a uniform and constant magnetic field. If the two fields are parallel to each other, the path of the particle is :

- (A) circle (B) helix (C) cycloid (D) straight line

11. An electron is at rest in a region having uniform and constant magnetic field. The magnitude of the magnetic field is suddenly doubled keeping its direction same. After the sudden change, the

magnetic field is again uniform and constant. After the magnetic field becomes double (Neglect the effect of gravity) :

- (A) The electron continues remains at rest
- (B) The electron starts to move along a straight line
- (C) The electron moves along a circular path
- (D) The electron moves along a helical path

12. A toroid of mean radius 'a', cross-section radius 'r' and total number of turns N. It carries a current 'i'. The torque experienced by the toroid if a uniform magnetic field of strength B is applied :

- (A) is zero
- (B) is $BiN\pi r^2$
- (C) is $BiN\pi a^2$
- (D) depends on the direction of magnetic field

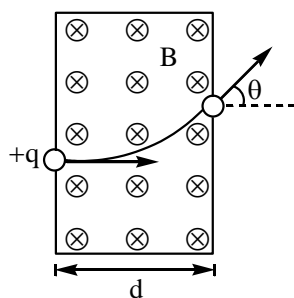
13. A charge of magnitude $1\mu\text{C}$ and mass 1 mg is attached to one end of a light string of length 2 m whose other end is fixed. The charge is given a velocity 1 m/s. There is a magnetic field of 1 T perpendicular to the plane of revolution of charge. The tension in string at that moment will be : (Neglect gravity)

- (A) $5 \times 10^{-7}\text{N}$
- (B) $15 \times 10^{-7}\text{N}$
- (C) 10^{-6}N
- (D) zero

14. If a charged particle goes unaccelerated in a region containing electric and magnetic fields :

- (A) \vec{E} must be parallel to \vec{B}
- (B) \vec{v} must be perpendicular to \vec{E}
- (C) \vec{v} must be perpendicular to \vec{B}
- (D) E must be equal to vB

15. A particle of mass m and charge q is projected into a region having a perpendicular uniform magnetic field B. Which of the following are correct



- (A) $\frac{mv}{2qB}$
- (B) $\frac{mv}{qB}$
- (C) $\frac{2mv}{qB}$

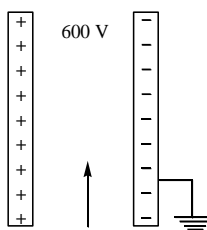
(A) If magnetic field width $d = \frac{mv}{2qB}$ the angle of deviation 30°

(B) If magnetic field width $d = \frac{mv}{qB}$ the angle of deviation $\frac{\pi}{2}$

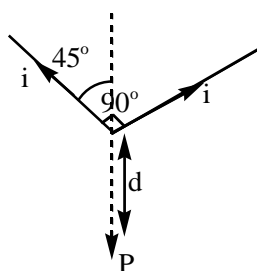
(C) If magnetic field with $d = \frac{2mv}{qB}$ the angle of deviation π

(D) If magnetic field with $d = \frac{mv}{2qB}$ the angle of deviation $\frac{\pi}{2}$

16. A potential difference of 600 V is applied across the plates of a parallel plate condenser. The separation between the plates is 3mm. an electron projected vertically, parallel to the plates, with a velocity of $2 \times 10^6 \text{ ms}^{-1}$ moves undeflected between the plates. Find the magnitude and direction of the magnetic field in the region between the condenser plates. (Neglect the edge effects). (Charge of the electron = $1.6 \times 10^{-19} \text{ C}$)



- (A) $B = 0.1 \text{ T}$ positive z-direction
(B) $B = 0.1 \text{ T}$ negative z-direction
(C) $B = 0.2 \text{ T}$ positive z-direction
(D) $B = 0.2 \text{ T}$ negative z-direction
17. Find the magnetic field at P due to the arrangement shown in figure.



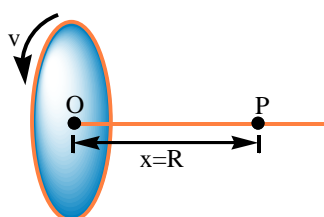
- (A) $\frac{\mu_0 i}{\sqrt{2}\pi d} \left(1 - \frac{1}{\sqrt{2}}\right) \otimes$
(B) $\frac{2\mu_0 i}{\sqrt{2}\pi d} \otimes$
(C) $\frac{\mu_0 i}{\sqrt{2}\pi d} \otimes$
(D) $\frac{\mu_0 i}{\sqrt{2}\pi d} \left(1 + \frac{1}{\sqrt{2}}\right) \otimes$

Key: A

Sol: $B = 2 \left[\frac{\mu_0}{4\pi} \cdot \frac{i}{d/\sqrt{2}} \right] (\sin 90^\circ - \sin 45^\circ)$

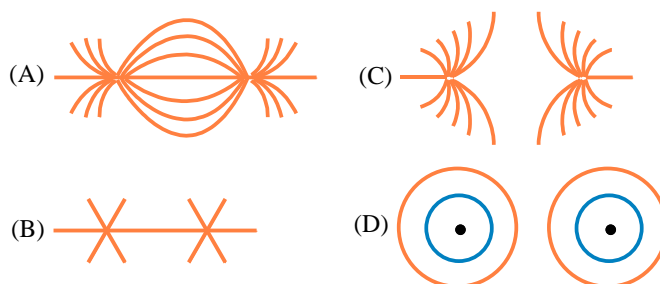
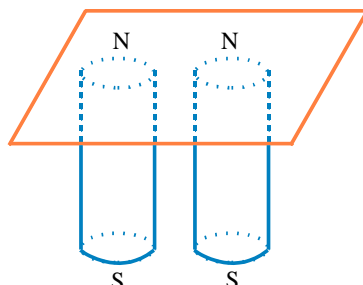
$$B = \frac{\mu_0 i}{\sqrt{2}\pi d} \left(1 - \frac{1}{\sqrt{2}}\right) \otimes$$

18. A uniformly charged ring of radius R is rotated about its axis with constant linear speed v of each of its particles. The ratio of electric field to magnetic field at a point P on the axis of the ring distant $x = R$ from centre of ring is : (c is speed of light)

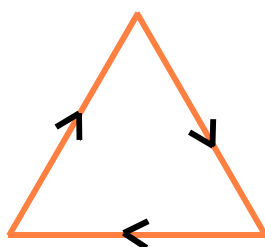


- (A) $\frac{c^2}{v}$
(B) $\frac{v^2}{c}$
(C) $\frac{c}{v}$
(D) $\frac{v}{c}$

19. Two long, identical bar magnets are placed under a horizontal piece of paper, as shown in figure. The paper is covered with iron filings. When the two north poles are a small distance apart and touching the paper, the iron filings move into a pattern that shows the magnetic lines of forces. Which of the following best illustrates the pattern that results ?

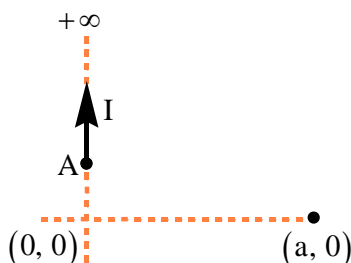


20. A current I flows along a triangular loop having sides of equal length a . The strength of magnetic field at the centre of the loop is $\frac{\alpha \mu_0 I}{\beta \pi a}$. Find $\alpha + \beta$?



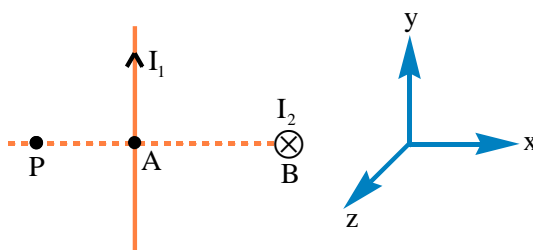
EXERCISE - 2

1. An infinitely long wire carrying current I is along Y axis such that its one end is at point $A(0, b)$ while the wire extends upto $+\infty$. The magnitude of magnetic field strength at point $(a, 0)$:



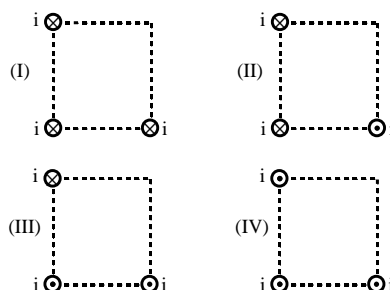
- (A) $\frac{\mu_0 I}{4\pi a} \left(1 + \frac{b}{\sqrt{a^2 + b^2}}\right)$ (B) $\frac{\mu_0 I}{4\pi a} \left(1 - \frac{b}{\sqrt{a^2 + b^2}}\right)$
 (C) $\frac{\mu_0 I}{4\pi a} \left(\frac{b}{\sqrt{a^2 + b^2}}\right)$ (D) None of these

2. Two infinitely long linear conductors are arranged perpendicular to each other and are in mutually perpendicular planes as shown in figure. If $I_1 = 2A$ along the y -axis and $I_2 = 3A$ along $-ve$ z -axis and $AP = AB = 1$ cm. The value of magnetic field strength \vec{B} at P is :



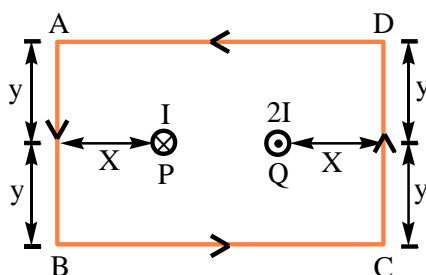
- (A) $(3 \times 10^{-5}T)\hat{j} + (-4 \times 10^{-5}T)\hat{k}$ (B) $(3 \times 10^{-5}T)\hat{j} + (4 \times 10^{-5}T)\hat{k}$
 (C) $(4 \times 10^{-5}T)\hat{j} + (3 \times 10^{-5}T)\hat{k}$ (D) $(-3 \times 10^{-5}T)\hat{j} + (4 \times 10^{-5}T)\hat{k}$

3. Three long wires, with identical currents, either directly into or directly out of the page, are placed at three corners of a square in four different arrangements as shown. Correct order of the magnitude of net magnetic field at the empty upper right corner of the square is :



- (A) $B_I = B_{IV} > B_{II} = B_{III}$ (B) $B_I > B_{IV} > B_{II} = B_{III}$
 (C) $B_{II} = B_{III} > B_I = B_{IV}$ (D) $B_I > B_{III} > B_{II} > B_{IV}$

4. Let B_P and B_Q be the magnetic field produced by the wire P and Q which are placed symmetrically in a rectangular loop ABCD as shown in figure. Current in wire P is I directed inward and in Q is $2I$ directed outwards.



If $\int_A^B \vec{B}_Q \cdot d\vec{\ell} = 2\mu_0$ tesla meter, $\int_D^A \vec{B}_P \cdot d\vec{\ell} = -2\mu_0$ tesla meter and $\int_A^B \vec{B}_P \cdot d\vec{\ell} = -\mu_0$ tesla meter, the value of I will be (in A)

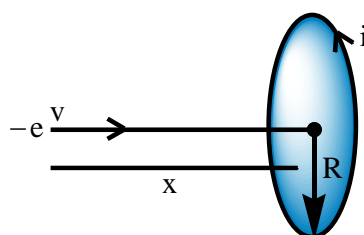
5. A current i in a circular loop of radius b produces a magnetic field. At a fixed point far from the loop (on its axis) the magnetic field is proportional to which of the following combinations of i and b ?

(A) ib (B) ib^2 (C) i^2b (D) $\frac{i}{b^2}$

6. Axis of a solid cylinder of infinite length and radius R lies along y -axis it carries a uniformly distributed current ' i ' along $+y$ direction. Magnetic field at a point $(\frac{R}{2}, y, \frac{R}{2})$ is :

(A) $\frac{\mu_0 i}{4\pi R}(\hat{i} - \hat{k})$ (B) $\frac{\mu_0 i}{2\pi R}(\hat{j} - \hat{k})$ (C) $\frac{\mu_0 i}{4\pi R}\hat{j}$ (D) $\frac{\mu_0 i}{4\pi R}(\hat{i} + \hat{k})$

7. An electron moving with velocity v along the axis approaches a circular current carrying loop as shown in the figure. The magnitude of magnetic force on electron at this instant is :

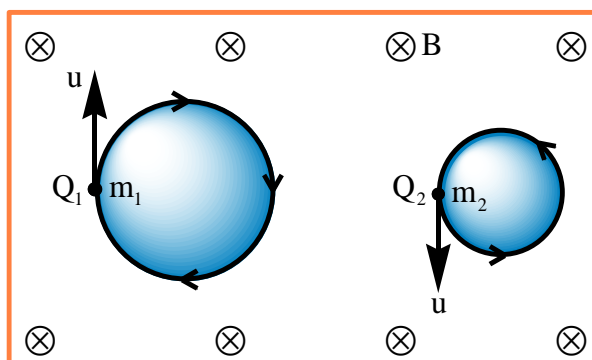


(A) $\frac{\mu_0}{2} \frac{eviR^2x}{(x^2+R^2)^{3/2}}$ (B) $\mu_0 \frac{eviR^2x}{(x^2+R^2)^{3/2}}$ (C) $\frac{\mu_0}{4\pi} \frac{eviR^2x}{(x^2+R^2)^{3/2}}$ (D) 0

8. A charge particle tied to an end of a string is performing circular motion around a wire on a frictionless horizontal table. The wire is in vertical direction passing through centre of the circle. If a current starts flowing in the wire then the tension in string $[B = f(t)]$:

(A) will increase (B) will decrease
(C) will remain same (D) may increase or may decrease

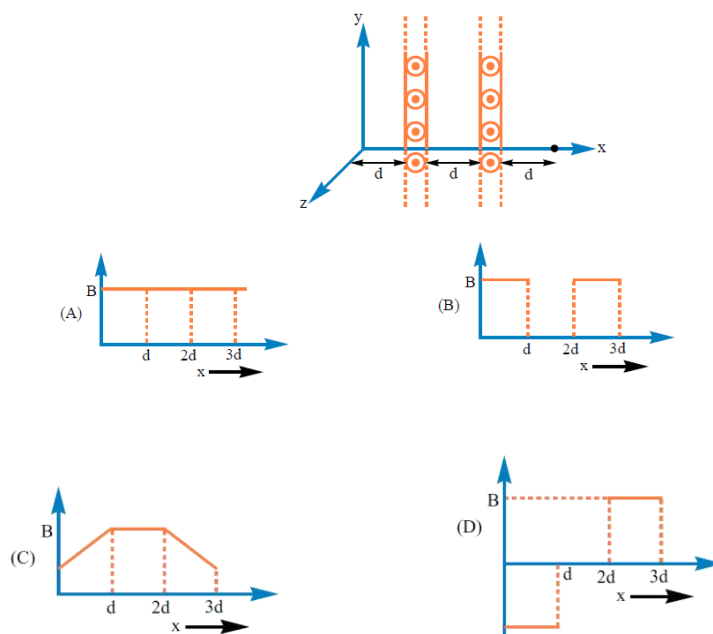
9. A neutral atom which is stationary at the origin in a gravity free space emits an α -particle A in the z-direction. The product atom is P. A uniform magnetic field exists in the z-direction. Disregarding the electromagnetic forces between A and P, which of the following is correct?
- (A) A and P will move along circular paths of equal radii
 (B) A has greater time period of rotation than P
 (C) A has greater kinetic energy than P
 (D) A and P will meet again somewhere in the yz-plane
10. A uniform magnetic field exists in region which forms an equilateral triangle of side a. The magnetic field is perpendicular to the plane of the triangle. A charge q enters into this magnetic field perpendicularly with speed v along perpendicular bisector of one side and comes out along perpendicular bisector of other side. The magnetic induction in the triangle is :
- (A) $\frac{mv}{qa}$ (B) $\frac{2mv}{qa}$ (C) $\frac{mv}{2qa}$ (D) $\frac{mv}{4qa}$
11. A proton moves in the positive z-direction after being accelerated from rest through a potential difference V. The proton then passes through a region with a uniform electric field E in the positive x-direction and a uniform magnetic field B in the positive y-direction, but the proton's trajectory is not affected. If the experiment were repeated using a potential difference of 2V, the proton would then be :
- (A) deflected in positive x-direction (B) deflected in negative x-direction
 (C) deflected in positive y-direction (D) deflected in negative y-direction
12. Two charged particles 1 and 2 (of masses m_1 and m_2 ; and charges Q_1 and Q_2 respectively) are travelling in circular orbit with the same speed in a region of uniform and constant magnetic field that is directed into the page, as shown. The magnitude of the charge on each particle is identical. Then which option below is correct (neglect the interaction between charged particles) :



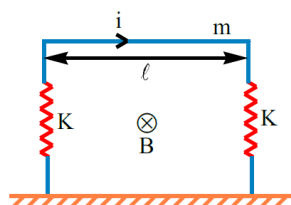
Uniform and constant magnetic field
 (Normal to plane of paper)

Option	Mass relationship	Sign of Charge Q_1	Sign of Charge Q_2
(A)	$m_1 = m_2$	+	-
(B)	$m_1 > m_2$	-	+
(C)	$m_1 < m_2$	-	+
(S)	$m_1 > m_2$	+	-

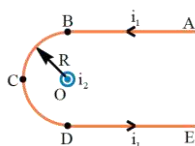
13. Two large conducting planes carrying current perpendicular to x-axis are placed at $(d, 0)$ and $(2d, 0)$ as shown in figure. Current per unit width in both the planes is same and current is flowing in the outward direction. The variation of magnetic induction (taken as positive if it is in positive y-direction) as function of 'x' ($0 \leq x \leq 3d$) is best represented by :



14. A horizontal metallic rod of mass 'm' and length ' ℓ ' is supported by two vertical identical springs of spring constant 'K' each and nature length ℓ_0 . A current 'i' is flowing in the rod in the direction shown. If the rod is in equilibrium, then the length of each spring in this state is:

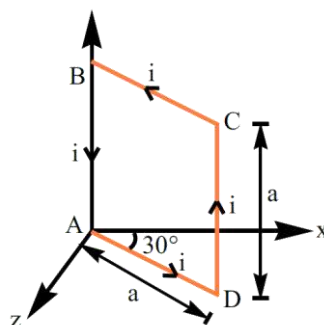


- (A) $\ell_0 + \frac{i\ell B - mg}{K}$ (B) $\ell_0 + \frac{i\ell B - mg}{2K}$ (C) $\ell_0 + \frac{mg - i\ell B}{2K}$ (D) $\ell_0 + \frac{mg - i\ell B}{K}$
15. ABCDE is a very long wire carrying current i_1 as shown. The portion BCD is a semi-circle with centre at O. Another very long wire passes through point O, perpendicular to the plane of ABCDE and it carries current i_2 outside the plane of paper. The two wires:



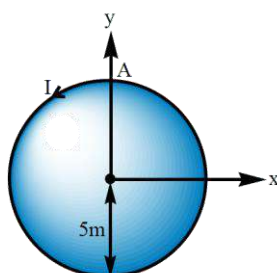
- (A) attract each other (B) repel each other
(C) do not exert any force on each other (D) nothing can be said

16. A square coil of side 'a' carrying current 'i' and is having one of its side AB parallel to y-axis and its plane is at angle $\theta = 30^\circ$ with x-axis (as shown). If a uniform magnetic field B exist in the region along \hat{k} direction, then torque due to magnetic force on the coil is :



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

17. A ring of radius 5 m is lying in the x-y plane and is carrying current of 1 A in anti-clockwise sense. If a uniform magnetic field $\vec{B} = 3\hat{i} + 4\hat{j}$ is switched on, then the co-ordinates of point about which the loop will lift up is :



- (A) (3, 4) (B) (4, 3) (C) (3, 0) (D) (0, 3)

18. A small current element of length 'dℓ' and carrying current is placed at (1, 1, 0) and is carrying current in '+ z' direction. If magnetic field at origin be \vec{B}_1 and at point (2, 2, 0) be \vec{B}_2 then:

- (A) $|\vec{B}_1| = |\vec{B}_2|$ (B) $\vec{B}_1 = \vec{B}_2$ (C) $|\vec{B}_1| = |2\vec{B}_2|$ (D) $\vec{B}_1 = -2\vec{B}_2$

19. A long thick conductor of radius 'R' carries a current uniformly distributed over its cross section.

- (A) The magnetic field strength is maximum on the surface
(B) The magnetic field strength is zero on the surface

(C) The strength of the magnetic field inside the cylinder will vary as inversely proportional to r , where r is the distance from the axis.

(D) The energy density of the magnetic field outside the conductor varies as inversely proportional to $\frac{1}{r^2}$, where ' r ' is the distance from the axis.

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

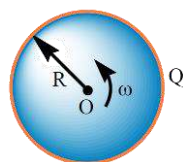
(A) The lines of force will be concentric circles with centres on the wire

(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

21. A nonconducting disc having uniform positive charge Q , is rotating about its axis with uniform angular velocity ω . The magnetic field at the center of the disc is:



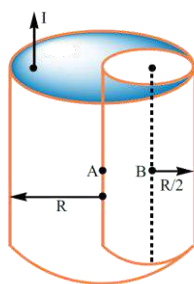
(A) directed outward

(B) having magnitude $\frac{\mu_0 Q \omega}{4\pi R}$

(C) directed inwards

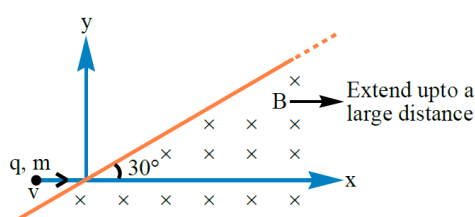
(D) having magnitude $\frac{\mu_0 Q \omega}{2\pi R}$

22. From a cylinder of radius R , a cylinder of radius $R/2$ is removed, as shown. Current flowing in the remaining cylinder is I . Magnetic field strength is:



(A) zero at point A (B) zero at point B (C) $\frac{\mu_0 I}{3\pi R}$ at point A (D) $\frac{\mu_0 I}{3\pi R}$ at point B

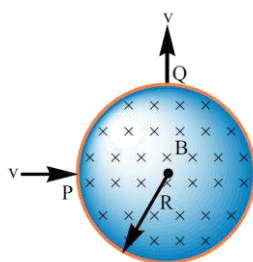
23. A charged particle of charge $+q$, mass m is moving with initial velocity ' v ' as shown in figure in a uniform magnetic field $B(-\hat{k})$. Select the correct alternative/alternatives:



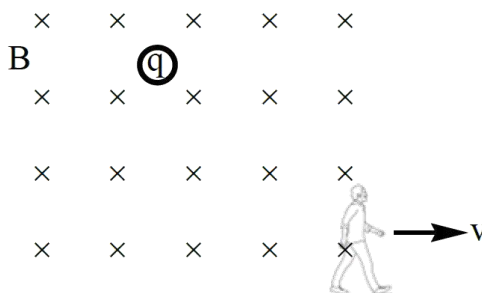
- (A) Velocity of particle when it comes out from magnetic field is $\vec{V} = v \cos 60^\circ \hat{i} - v \sin 60^\circ \hat{j}$
 (B) Time for which the particle was in magnetic field is $\frac{\pi m}{3qB}$
 (C) Distance travelled in magnetic field is $\frac{\pi mv}{3qB}$
 (D) The particle will never come out of magnetic field

24. A particle of charge 'q' and mass 'm' enters normally (at point P) in a region of magnetic field with speed v. It comes out normally from Q after time T as shown in figure. The magnetic field B is present only in the region of radius R and is uniform.

Initially and final velocities are along radial direction and they are perpendicular to each other. For this to happen, which of the following expression(s) is/are correct ?



- (A) $B = \frac{mv}{qR}$ (B) $T = \frac{\pi R}{2v}$ (C) $T = \frac{\pi m}{2qB}$ (D) None of these
25. A charged particle is kept at rest on a smooth horizontal surface in uniform magnetic field 'B' which is directed vertically downwards as shown in the figure.



An observer is moving with constant velocity v towards right. Then with respect to the observer which of the following statements is/are correct?

- (A) Path of the charged particle will be straight line
 (B) Path of charged particle will be circular
 (C) Magnetic force on the charged particle is zero
 (D) Magnitude of magnetic force on charged particle is qVB
26. A proton of charge 'e' and mass 'm' enters a uniform and constant magnetic field $\vec{B} = B\hat{i}$ with an initial velocity $\vec{V} = V_{ox}\hat{i} + V_{oy}\hat{j}$. Which of the following will be correct at any later time 't' ?
- (A) x-component of velocity will be $V_{ox} \cos\left(\frac{qBt}{m}\right)$

(B) y-component of velocity will be $V_{oy} \cos\left(\frac{qBt}{m}\right)$

(C) z-component of velocity will be $V_{oy} \sin\left(\frac{qBt}{m}\right)$ along $(+\hat{k})$ direction

(D) x-component of velocity will remains unchanged

27. Two straight infinitely long and thin parallel wires are spaced 0.1 m apart and carry a current of 10 ampere each. Find the magnetic field at a point which is at a distance of 0.1m from both wires in the two cases when the currents are in the (a) same and (b) opposite directions:

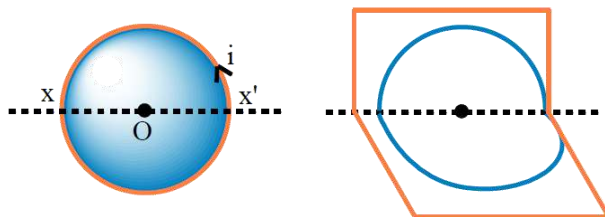
(A) When currents are in same direction, $B = 2\sqrt{3} \times 10^{-5}T$

(B) When currents are in opposite directions, $B = 2 \times 10^{-5}T$

(C) When currents are in same direction, $B = 2 \times 10^{-5}T$

(D) When currents are in opposite directions, $B = 2\sqrt{3} \times 10^{-5}T$

28. In the given figure magnetic field at the center of ring (O) is $8\sqrt{2}T$. Now it is turned through a 90° about xx' axis, so that two semi-circular parts are mutually perpendicular. Find the value of magnetic field at centre.



(A) 2T

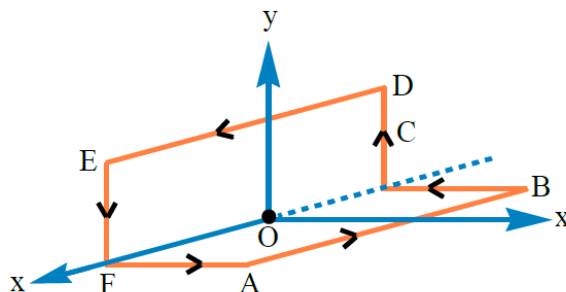
(B) 4T

(C) 6T

(D) 8T

EXERCISE - 3

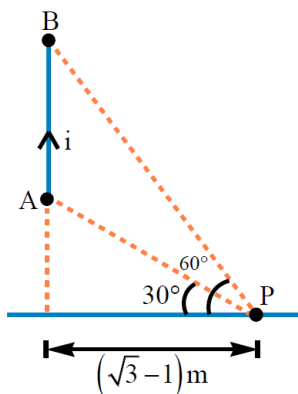
1. In the figures shown ABCDEFA is a square loop of side ℓ , but is folded in two equal parts so that half of it lies in x z plane and the other half lies in the y z plane. The origin 'O' is centre of the frame also. The loop carries current 'i'. The magnetic field at the centre is :



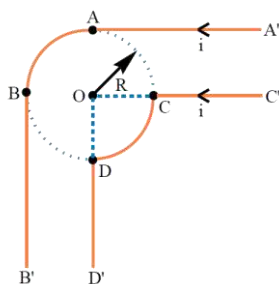
- (A) $\frac{\mu_0 i}{2\sqrt{2}\pi\ell} (\hat{i} - \hat{j})$ (B) $\frac{\mu_0 i}{4\pi\ell} (-\hat{i} + \hat{j})$ (C) $\frac{\sqrt{2}\mu_0 i}{\pi\ell} (\hat{i} + \hat{j})$ (D) $\frac{\mu_0 i}{\sqrt{2}\pi\ell} (\hat{i} + \hat{j})$
2. An infinite current carrying wire is placed along x-axis such that it lies between $x = 0$ to $x = +\infty$ (infinity). The current is in direction of positive x-axis. Let B_1, B_2 and B_3 be the magnitude of magnetic field at points $A(a, a), B(0, a)$ and $C(-a, a)$ respectively. Then pick the incorrect option.

- (A) $B_1 > B_2 > B_3$ (B) $B_2 = \frac{B_1 + B_3}{2}$
- (C) $B_1 : B_2 : B_3 = \sqrt{2} + 1 : 1 : \sqrt{2} - 1$ (D) $\frac{B_1 B_3}{B_2^2} = \frac{1}{2}$
3. A straight wire current element is carrying current 100 A, as shown in figure. The magnitude of magnetic field at point P which is at perpendicular distance $(\sqrt{3} - 1)$ m from the current element if end A and end B of the element subtend angle 30° and 60° at point P, as shown is $n \times 10^{-6}$ T.

Find n?

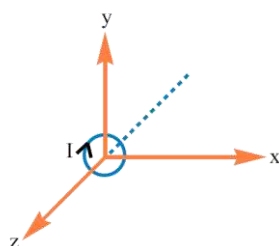


4. All straight wires are very long. Both AB and CD are arcs of the same circle, both subtending right angles at the centre O. Then the magnetic field at O is :



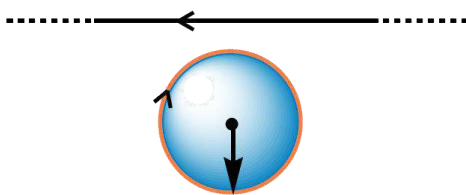
- (A) $\frac{\mu_0 i}{4\pi R}$ (B) $\frac{\mu_0 i}{4\pi R} \sqrt{2}$ (C) $\frac{\mu_0 i}{2\pi R}$ (D) $\frac{\mu_0 i}{2\pi R} (\pi + 1)$

5. A non-planar circular loop consists of two semi-circles one of which lies in yz-plane and the other is in xz-plane as shown. The magnetic force experienced by positive charge of value Q moving with velocity v along x direction when it is at the origin is :

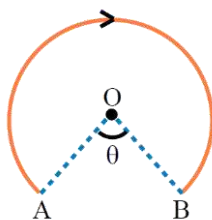


- (A) $\frac{Qv\mu_0 I}{4R}$ (B) $\frac{Qv\mu_0 I}{2R}$ (C) $\frac{Qv\mu_0 I}{2\sqrt{2}R}$ (D) 0

6. The radius of a coil of wire with N turns is 0.22 m, and 3.5 A current flows clockwise in the coil as shown. A long straight wire carrying a current 54 A toward the left is located 0.05 m from the edge of the coil. The magnetic field at the centre of the coil is zero tesla. The number of turns N in the coil are :

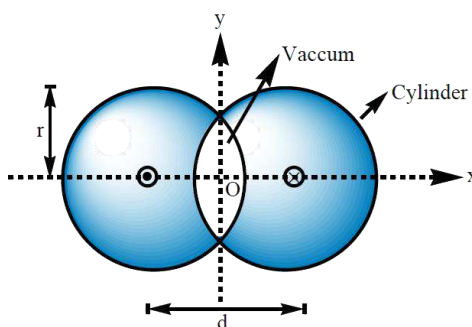


7. A current carrying wire AB of the length L is turned along a circle, as shown in figure. The magnetic field at the centre O.

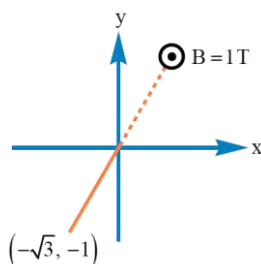


- (A) $\frac{\mu_0 \pi i}{L} \left(\frac{2\pi - \theta}{2\pi} \right)^2$ (B) $\frac{\mu_0 \pi i}{L} \left(\frac{2\pi - \theta}{2\pi} \right)$ (C) $\frac{\mu_0 \pi i}{L} (2\pi - \theta)$ (D) $\frac{\mu_0 \pi i}{L} (2\pi + \theta)^2$

8. Two long cylinders (with axis parallel) are arranged as shown to form overlapping cylinders, each of radius r , whose centers are separated by a distance d . Current of density J (Current per unit area) flows into the plane of page along the right shaded part of one cylinder and an equal current flows out of the plane of the page along the left shaded part of the other, as shown. The magnitude and direction of magnetic field at point O (O is the origin of shown x - y axes) are :



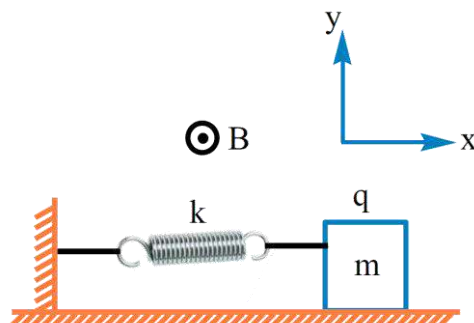
- (A) $\frac{\mu_0}{2\pi} \pi J d$, in the $+y$ -direction
 (B) $\frac{\mu_0}{2\pi} d^2 \frac{J}{r}$, in the $+y$ -direction
 (C) zero
 (D) None of the above
9. The ratio of the energy density of magnetic field in the middle region of a solenoid to that in end region is :
- (A) 4 : 1 (B) 1 : 4 (C) 1 : 1 (D) 2 : 1
10. A uniform magnetic field of magnitude 1 T exists in region $y \geq 0$ is along \hat{k} direction as shown. A particle of charge 1 C is projected from point $(-\sqrt{3}, -1)$ towards origin with speed 1 m/sec. If mass of particle is 1 kg, then co-ordinates of centre of circle in which particle moves are :



- (A) $(1, \sqrt{3})$ (B) $(1, -\sqrt{3})$ (C) $(\frac{1}{2}, -\frac{\sqrt{3}}{2})$ (D) $(\frac{\sqrt{3}}{2}, -\frac{1}{2})$
11. Electric charge q is uniformly distributed over a thin 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 . The force needed to move the rod along its length with a uniform velocity v is :
- (A) $\frac{\mu_0 i q v}{2\pi a}$ (B) $\frac{\mu_0 i q v}{4\pi a}$ (C) $\frac{\mu_0 i q v}{2\pi \ell}$ (D) $\frac{\mu_0 i q v}{4\pi \ell}$
12. A spring of spring constant 'K' is fixed at one end has a small block of mass m and charge q is attached at the other end. The block rests over a smooth horizontal surface. A uniform and

constant magnetic field B exists normal to the plane of paper as shown in figure. An electric field $\vec{E} = E_0 \hat{i}$

(E_0 is a positive constant) is switched on at $t = 0$ sec. The block moves on horizontal surface without ever lifting off the surface. Then the normal reaction acting on the block is :



- (A) maximum at extreme position and minimum at mean position
- (B) maximum at mean position and minimum at extreme position
- (C) is uniform throughout the motion
- (D) is both maximum and minimum at mean position

13. In region $x > 0$, a uniform and constant magnetic field $\vec{B}_1 = 2B_0 \hat{k}$ exists. Another uniform and constant magnetic field $\vec{B}_2 = B_0 \hat{k}$ exists in region $x < 0$. A positively charged particle of mass m and charge q is crossing origin at time $t = 0$ with a velocity $\vec{u} = u_0 \hat{i}$. The particle comes back to its initial position after a time : (B_0, u_0 are positive constants)

- (A) $\frac{3\pi m}{2qB_0}$
- (B) $\frac{2\pi m}{qB_0}$
- (C) $\frac{3\pi m}{qB_0}$

(D) Particle does not come back to its initial position

14. A uniform magnetic field of 1.5 T exists in a cylindrical region of radius 10.0 cm, its direction being parallel to the axis along east to west. A current carrying wire in north south direction passes through this region. The wire intersects the axis and experience a force of 1.2 N downward. If the wire is turned from North South to north east-south west direction, then magnitude and direction of the magnetic force is :

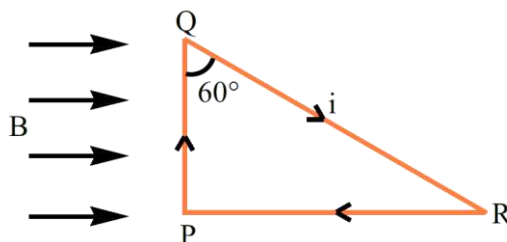
- (A) 1.2 N, upward
- (B) $1.2\sqrt{2}$ downward
- (C) 1.2 N, downward
- (D) $\frac{1.2}{\sqrt{2}}$ N, downward

15. A uniform magnetic field of 1.5 T exists in a cylindrical region of radius 10.0 cm, its direction being parallel to the axis along east to west. A current carrying wire in north south direction passes through this region. The wire intersects the axis and experience a force of 1.2 N downward. If wire in north-south direction is lowered from the axis by a distance of 6 cm, then magnitude and direction of force is :

- (A) 0.48 N, downward
- (B) 0.48 N, downward

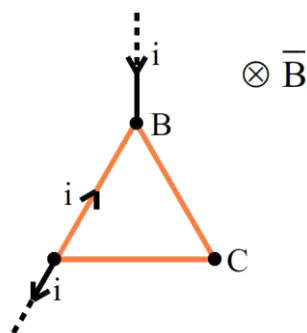
(C) 0.96 N, downward (D) 0.96 N, upward

16. For the circuit shown in figure, the direction and magnitude of the force on PQR is :



- (A) zero (B) $i\ell B$ out of the page
(C) $\frac{1}{2}i\ell B$ into the page (D) $i\ell B$ into the page

17. Figure shows an equilateral triangle ABC of side ℓ carrying currents, placed in uniform magnetic field B. The magnitude of magnetic force on triangle is :

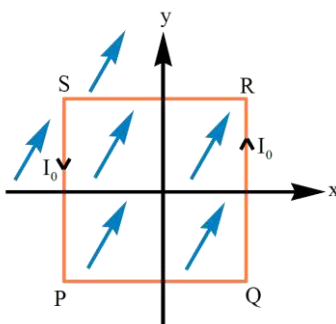


- (A) $i\ell B$ (B) $2i\ell B$ (C) $3i\ell B$ (D) zero

18. A circular coil of radius R and a current I, which can rotate about a fixed axis passing through its diameter is initially placed such that its plane lies along magnetic field B. Kinetic energy of loop when it rotates through an angle 90° is : (Assume that I remains constant)

- (A) $\pi R^2 BI$ (B) $\frac{\pi R^2 BI}{2}$ (C) $2\pi R^2 BI$ (D) $\frac{3}{2}\pi R^2 I$

19. A uniform, constant magnetic 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 centre at the origin O. At time $t = 0$, the frame is at rest in the position shown in the figure, with its sides parallel to the x and y axes. Each side of the frame is of mass M and length L. The torque $\vec{\tau}$ about O acting on the frame due to the magnetic field will be :



(A) $\vec{\tau} = \frac{BI_0L^2}{\sqrt{2}}(-\hat{i} + \hat{j})$

(B) $\vec{\tau} = \frac{BI_0L^2}{\sqrt{2}}(\hat{i} - \hat{j})$

(C) $\vec{\tau} = \frac{BI_0L^2}{\sqrt{2}}(\hat{i} + \hat{j})$

(D) $\vec{\tau} = \frac{BI_0L^2}{\sqrt{2}}(-\hat{i} - \hat{j})$

20. A circular coil of radius R and a current I, which can rotate about a fixed axis passing through its diameter is initially placed such that its plane lies along magnetic field B. Kinetic energy of loop when it rotates through an angle 90° is : (Assume that I remains constant)

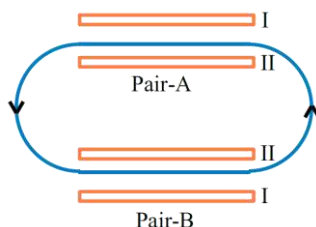
(A) $\pi R^2 BI$

(B) $\frac{\pi R^2 BI}{2}$

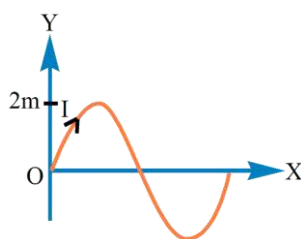
(C) $2\pi R^2 BI$

(D) $\frac{3}{2}\pi R^2 I$

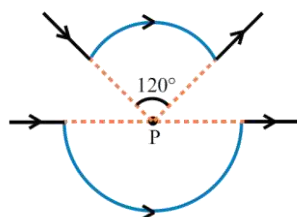
21. Figure shows the path of an electron in a region of uniform magnetic field. The path consists of two straight sections, each between a pair of uniformly charged plates, and two half circles. The electric field exists only between the plane.



- (A) Plate I of pair A is at higher potential than plane II of the same pair
 (B) Plate I of pair B is at higher potential than plate II of the same pair
 (C) Direction of the magnetic field is out of the page $[\odot]$
 (D) Direction of the magnetic field into the page $[\otimes]$
22. A current carrying conductor is in the form of a sine curve as shown, which carries current I. If the equation of this curve is $Y = 2 \sin\left(\frac{\pi x}{L}\right)$ and a uniform magnetic field B exists in space.

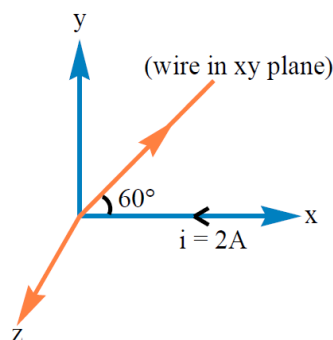


- (A) Force on wire is BIL if field is along Z-axis
 (B) Force on wire is 2BIL if field is along Y-axis
 (C) Force on wire is zero if field is along X-axis
 (D) Force on wire is BIL if field is in the XY plane making an angle 30° with X-axis
23. Figure shows two current segments. In the upper segment, an arc of radius 4 cm subtends an angle of 120° with centre P. The lower segment includes a large semicircle of radius 5 cm also with centre P. If $I = 0.4$ amp in both. Then find the net magnetic field at point P due to these current segments is



- (A) $\frac{4\pi}{30} \mu T$ (B) $\frac{3\pi}{30} \mu T$ (C) $\frac{2\pi}{30} \mu T$ (D) $\frac{\pi}{30} \mu T$

24. Find the magnetic field (in $10^{-7} T$) due to 2 long wires as shown at $(0,0,1)m$.

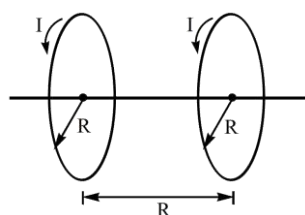


- (A) $2 \times 10^{-7} T$ (B) $3 \times 10^{-7} T$ (C) $4 \times 10^{-7} T$ (D) $5 \times 10^{-7} T$

25. Two coaxial long solenoids of equal lengths have currents i_1, i_2 , number of turns per unit length n_1, n_2 and radius 3m, 5m respectively. If $n_1 i_1 = n_2 i_2 = 250$ (in SI unit) and the two solenoids carry current in opposite sense, find the magnetic energy stored per unit length (in SI unit). (Take $\pi^2 = 10$)

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

26. Two circular coils of radius R, each with N turns, are perpendicular to a common axis. The centres of the coils are a distance R apart. Each coil carries a steady current I in the same direction, as shown in figure.



(A) The magnetic field on the axis at a distance x from the center of one coil is

$$B = \frac{N\mu_0 I R^2}{2} \left[\frac{1}{(R_2^2 + x^2)^{3/2}} + \frac{1}{(2R^2 + x^2 - 2Rx)^{3/2}} \right]$$

(B) The magnetic field on the axis at a distance x from the center of one coil is

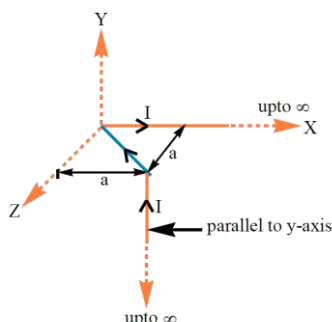
$$B = \frac{N\mu_0 I R^2}{2} \left[\frac{1}{(R_2^2 + x^2)^{3/2}} - \frac{1}{(2R^2 + x^2 - 2Rx)^{3/2}} \right]$$

(C) The value $\frac{dB}{dx}$ and $\frac{d^2B}{dx^2}$ both are zero at the point midway between the coils.

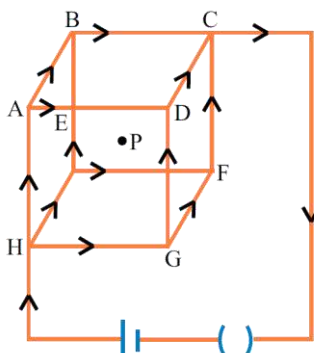
(D) The value $\frac{dB}{dx}$ and $\frac{d^2B}{dx^2}$ both are non zero at the point midway between the coils.

EXERCISE - 4

1. The magnetic field at the origin due to the current following in the wire is $\frac{\alpha\mu_0 I}{\beta\pi a} [-\hat{i} + \hat{k}]$. Find $\alpha + \beta$?

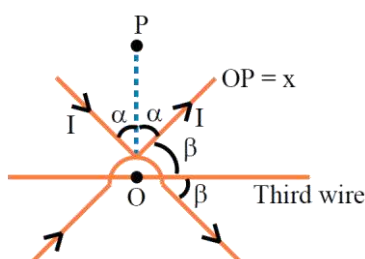


2. An insulating rod of length ℓ carries a charge q distributed uniformly on it. The rod is pivoted at its mid point and is rotated at a frequency f about a fixed axis perpendicular to rod and passing through the pivot. The magnetic moment of the rod system is $\frac{\pi q f \ell^\alpha}{\beta}$. Find $\alpha + \beta$?
3. A steady current is set up in a cubic network compsed of wires of equal resistance and length d as shown in figure. What is the magnetic field at the centre P due to the cubic network ?



- (A) $\frac{\mu_0 2I}{4\pi d}$ (B) $\frac{\mu_0 3I}{4\pi \sqrt{2}d}$ (C) 0 (D) $\frac{\mu_0 \theta\pi I}{4\pi d}$

4. Three infinite current carrying conductors are placed as shown in figure. Two wires carry same current while current in third wire is unknown. The three wires do not intersect with each other and all of them are in the plane of paper. Which of the following is correct about a point 'P' which is also in the same plane?



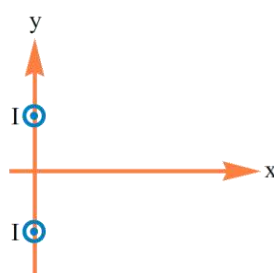
- (A) Magnetic field intensity at P is zero for all values of x

(B) If the current in the third wire is $\frac{2I}{\sin \alpha}$ (left to right) then magnetic field will be zero at P for all values of x

(C) If the current in the third wire is $\frac{2I}{\sin \alpha}$ (right to left) then magnetic field will be zero at P for all values of x

(D) None of the above

5. Two infinitely long parallel wires are at a distance d apart and carry equal parallel currents I in the same direction as shown in the figure. If the wires are located on y -axis (normal to x - y plane) at $y = \frac{d}{2}$ and $y = -\frac{d}{2}$, then the magnitude of x -coordinate of the point on x -axis where the magnitude of magnetic field is maximum is (Consider points on x -axis only) :



- (A) $\sqrt{2}d$ (B) $\frac{d}{\sqrt{2}}$ (C) $2d$ (D) $\frac{d}{2}$

6. Two coaxial long solenoids of equal lengths have current, i_1, i_2 , number of turns per unit length n_1, n_2 and radius r_1, r_2 respectively. If $n_1 i_1 = n_2 i_2$ and the two solenoids carry current in opposite sense, the magnetic energy stored per unit length is [$r_2 > r_1$] :

- (A) $\frac{\mu_0}{2} n_1^2 i_1^2 \pi (r_2^2 - r_1^2)$ (B) $\mu_0 n_1^2 i_1^2 \pi (r_2^2 - r_1^2)$
(C) $\frac{\mu_0}{2} n_1^2 i_1^2 \pi r_1^2$ (D) $\frac{\mu_0}{2} n_2^2 i_2^2 \pi r_2^2$

7. A wire of length ℓ and of cross section radii r is wound over a rod (length \gg radius of cross section) to make a solenoid. If connected across a battery of emf ϵ , the magnetic field in central region is found to be B . If another wire of same material but of length 2ℓ and radius of cross-section $r/2$ is wound over same rod and connected to same battery then the magnetic field in central region will be $\frac{B}{n}$. Find n ? [the turns are closely packed]

8. There exists a uniform magnetic and electric field of magnitude 1 T and 1 V/m respectively along positive y -axis. A charge particle of mass 1 kg and of charge 1 C is having velocity 1 m/sec along x -axis and is at origin at $t = 0$. Then the co-ordinates of particle at time π seconds will be :

- (A) $(0, 1, 2)$ (B) $(0, \frac{-\pi^2}{2}, -2)$ (C) $(2, \frac{\pi^2}{2}, 2)$ (D) $(0, \frac{\pi^2}{2}, 2)$

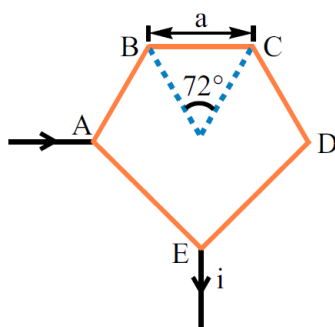
9. An electron makes a transition from $n = 2$ to $n = 1$ state in a hydrogen like atom.
(A) Magnetic field at the site of nucleus is decreased by 16 times

(B) Magnetic field at the site of nucleus is increased by 32 times

(C) Angular momentum of electron is changed

(D) None of the above

10. Magnetic field strength at the centre of regular pentagon made of a conducting wire of uniform cross – section area as shown in figure is:



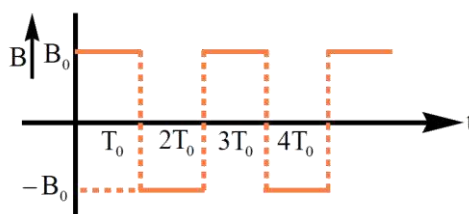
(A) $\frac{5\mu_0 i}{4\pi a} \left[2 \sin \frac{72^\circ}{2} \right]$

(B) 0

(C) not zero if current 'i' leaves D point instead of E

(D) zero even if the current 'i' leaves point D instead of point E

11. In a region magnetic field along x axis changes with time according to the given graph.



If time period, pitch and radius of helic path are T_0 , P_0 and R respectively then which of the following is incorrect is the particle is projected at an angle θ_0 with the positive x-axis in x-y plane :

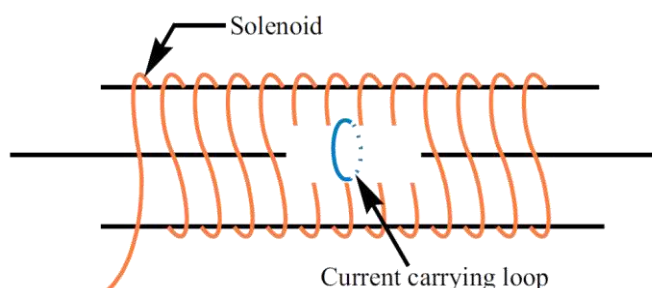
(A) At $t = \frac{T_0}{2}$, co-ordinates of charge are $\left(\frac{P_0}{2}, 0, -2R_0 \right)$

(B) At $t = \frac{3T_0}{2}$, co-ordinates of charge are $\left(\frac{3P_0}{2}, 0, 2R_0 \right)$

(C) Two extremes from x-axis are at a distance $2R_0$ from each other

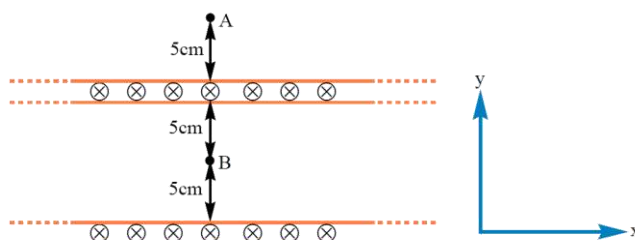
(D) Two extremes from x-axis are at a distance $4R_0$ from each other

12. A single circular loop of wire with radius 0.02 m carries a current of 8.0 A. It is placed at the centre of a solenoid that has length 0.65 m, radius 0.080 m and 1300 turns.



- (A) The value of the current in the solenoid so that the magnetic field at the centre of the loop becomes zero, is equal to 44 Ma
- (B) The value of the current in the solenoid so that the magnetic field at the centre of the loop becomes zero, is equal to 100 mA
- (C) The magnitude of the total magnetic field at the centre of the loop (due to both the loop and the solenoid) if the current in the loop is reversed in direction from that needed to make the total field equal to zero tesla, is $8\pi \times 10^{-5} \text{T}$
- (D) The magnitude of the total magnetic field at the centre of the loop (due to both the loop and the solenoid) if the current in the loop is reversed in direction from that needed to make the total field equal to zero tesla, is $16\pi \times 10^{-5} \text{T}$.

13. Figure shows cross section of two large parallel metal sheets carrying electric currents along their surfaces. The current in each sheet is $\frac{10}{\pi} \text{ A/m}$ along the width. Consider two points A and B, as shown in the figure with their positions.

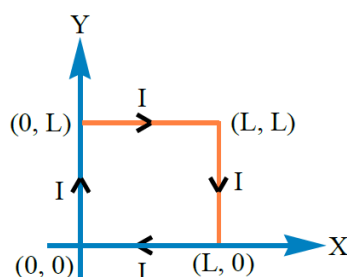


- (A) Magnetic field at A is $4 \mu\text{T}$ along x-direction
- (B) Magnetic field at A is $4 \mu\text{T}$ along negative x-direction
- (C) Magnetic field at B is zero
- (D) Magnetic field at B is $2 \mu\text{T}$ along x-direction

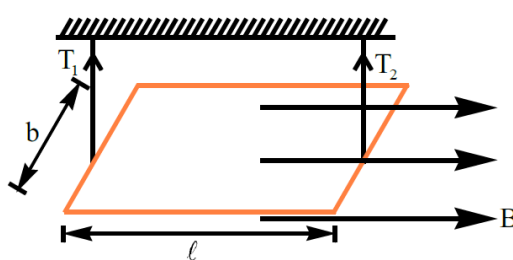
14. A ring of radius R has uniformly distributed charge. It spins about its axis with an angular velocity ω . P is a point on its axis at a distance x from its centre. The velocity of light in vacuum is c . The ratio of the magnetic field to the electric field at P is $\frac{\omega R^\alpha}{xc^\beta}$. Find $\alpha + \beta$?
15. A long cylindrical conductor whose axis is coincident with the z axis has an internal magnetic field given by $B = \frac{\mu_0 J_0 r}{6a} (3a - 2r)$ where a is the conductor's radius.

- (A) The total current flowing in the conductor is $\frac{J_0 \pi a^2}{3}$
- (B) The magnetic field outside the conductor is $\frac{\mu_0 J_0 \pi a^2}{6r}$
- (C) The current density is maximum at the axis of the conductor
- (D) The current density is minimum at the axis of the conductor

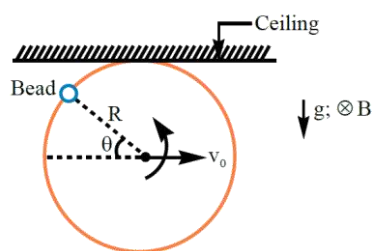
16. Figure shows a square loop in x-y plane carrying current I present in the magnetic field which is given by $\vec{B} = \frac{B_0 z}{L} \hat{j} + \frac{B_0 y}{L} \hat{k}$ where B_0 is positive constant, which of the following statement(s) is/are **correct**?



- (A) Force on side (0, 0) to (0, L) is $\left(\frac{B_0 IL}{2}\right) \hat{i}$
- (B) Force on side (0, L) to (L, L) is $-B_0 IL \hat{j}$
- (C) Net magnetic force on loop is zero
- (D) Force on side (L, 0) to (0, 0) is zero
17. A uniform conducting rectangular loop of sides ℓ , b and mass m carrying current I is hanging horizontally with the help of two vertical strings. There exists a uniform horizontal magnetic field B which is parallel to the longer side of loop. Choose the **correct** option(s).



- (A) The value of $T_1 = T_2 = \frac{mg}{2}$
- (B) The value of $T_1 = \frac{mg - 2ibB}{2}$
- (C) The value of $T_2 = \frac{mg + 2ibB}{2}$
- (D) The value of $T_1 < \text{value of } T_2$
18. An insulating ring of radius R , is rolled uniformly along the ceiling of a room with constant velocity v_0 . A charged bead of mass m , charge q is placed over the ring. Entire system is moving in an uniform magnetic field as shown in the figure. The bead moves along with ring without any contact force from ring. ($\theta = 90^\circ$)
- Choose the correct statements:



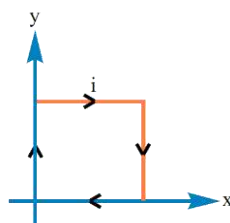
(A) The centripetal force on bead from the frame of reference of centre of mass of ring is qv_0B

(B) The magnetic field $B = \frac{mg}{qv_0}$

(C) The radius of the ring is $R = \frac{mv_0}{qB}$

(D) The tangential acceleration of bead is $\frac{qv_0B \cos \theta}{m}$

19. A square current carrying coil of edge length L . magnetic field on coil is given by $\vec{B} = \frac{B_0 y}{L} \hat{i} + \frac{B_0 x}{L} \hat{j}$ where B_0 is positive constant.



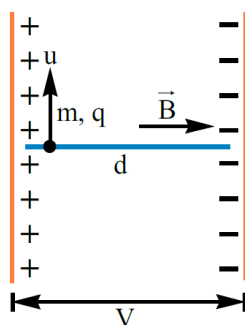
(A) Torque on coil is $\frac{1}{2} i L^2 B_0 \hat{i}$ if coil is free to rotate about x-axis

(B) Resultant force on coil is zero

(C) Equation of torque $\vec{M} \times \vec{B}$ is not valid on coil, where M is magnetic moment of coil

(D) Equation of torque $\vec{M} \times \vec{B}$ is valid on coil, where M is magnetic moment of coil

20. There is uniform magnetic field between large parallel plates of a capacitor having separation d and potential difference V . A charge particle is projected very near to +ve plate parallel to it with velocity u . Due to magnetic and electric field resultant motion of particle would be helical.



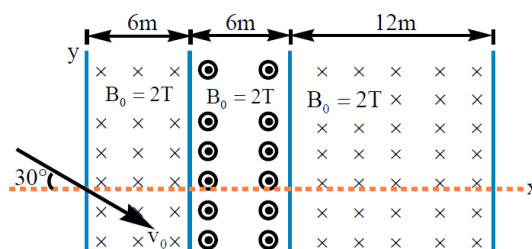
(A) Time taken by particle to reach at -ve plate is $\sqrt{\frac{2md^2}{qV}}$

(B) Time taken by particle to reach at -ve plate is $\sqrt{\frac{md^2}{qV}}$

(C) Number of revolutions completed by particle just before reaching at – ve plate $\sqrt{\frac{qB^2d^2}{\pi^2mV}}$

(D) Number of revolutions completed by particle just before reaching at – ve plate $\sqrt{\frac{qB^2d^2}{2\pi^2mV}}$

21. A particle having charge 1 C and mass 1 kg enters a region having uniform magnetic field of strength '2T' with a speed of 12 m/s, as shown in figure, then the correct statement(s) is/are :



(A) The time for which the charge particle remains in magnetic field is $\frac{4\pi}{3}s$

(B) The velocity of charge particle becomes parallel to x-axis 6 times during its motion

(C) The distance between the point where the charge particle enters the uniform magnetic field and the point where it emerges out is 6 m

(D) The deviation of the charge particle when it emerges out of the magnetic field is $\frac{2\pi}{3}$ rad

22. A circular disk of radius R with uniform charge density σ rotates with an angular speed ω . Find the magnetic field at the center of the disk is

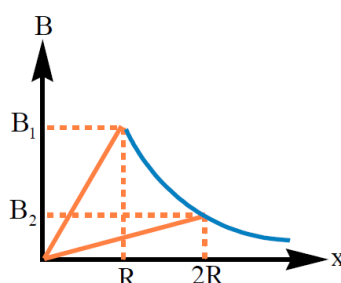
(A) $\frac{\mu_0\sigma R\omega}{2}$

(B) $\frac{\mu_0\sigma R\omega}{3}$

(C) $\frac{3}{2}\mu_0\sigma R\omega$

(D) $\frac{2}{3}\mu_0\sigma R\omega$

23. We have two separate long cylindrical wires both having different but uniform current densities. The radius of one of the wires is twice of the other. The figure shows the graph of magnetic field (B) with radial distance (r) from their axis. The curved parts of the two graphs are overlapping. Find the ratio $\left(\frac{B_1}{B_2}\right)$ is



(A) 2

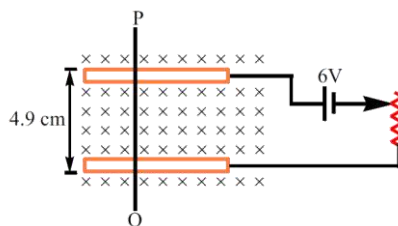
(B) 4

(C) 6

(D) 8

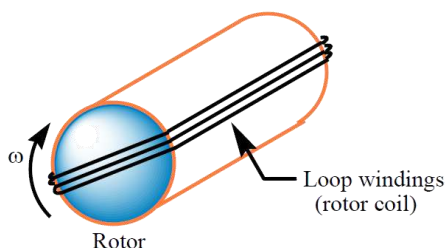
24. A wire PQ of mass 10 g is at rest on two parallel metal rails. The separation between the rails is 4.9 cm. A magnetic field of 0.80 tesla is applied perpendicular to the plane of the rails, directed downwards. The resistance of the circuit is slowly decreased. When the resistance decreases to

below 20 ohm, the wire PQ begins to slide on the rails. Find the coefficient of friction between the wire and the rails is



- (A) 0.12 (B) 0.52 (C) 0.72 (D) 0.92

25. In a motor, a rotor is fitted with the armature that has current of 10A. The rotor rotates with angular speed of 3 rad/s. magnetic field of magnitude 2T varies in direction in such a way that it is always perpendicular to the loop area. If the rotor coil has N number of turns and area of each loop is 0.45m^2 then find the value N. given that motor consumes 2106 W power and there are no losses.



- (A) 58 (B) 68 (C) 78 (D) 88

26. A long and thin metallic tube of radius $\frac{2}{\sqrt{\pi}}\text{cm}$ carries a current of 4000 A along its length. Calculate the magnetic pressure on the tube that tries to compress it.

- (A) 1000 Pa (B) 2000 Pa (C) 3000 Pa (D) 4000 Pa

27. A group of particles is travelling in a magnetic field of unknown magnitude and direction. It is observed that a proton moving at 1.5kms^{-1} in the +x-direction experiences a force of $2.25 \times 10^{-16}\text{N}$ in the +y-direction, and an electron moving at 4.75kms^{-1} in the -z-direction experiences a force of $8.5 \times 10^{-16}\text{N}$. Then

- (A) Magnitude of magnetic field 1.46 T
(B) Magnitude of magnetic field 2.46 T
(C) The magnetic field makes an angel $\theta = \pm 40$ with x-axis
(D) The magnetic field makes an angel $\theta = \pm 60$ with x-axis

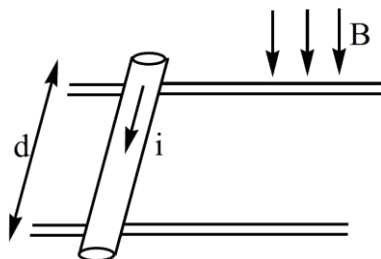
28. A spherical shell of radius R, having charge Q rotates with angular velocity ω about an axis passing through its centre.

- (A) Magnetic induction of the centre of the shell is $\frac{2}{3}\mu_0\sigma R\omega$
(B) The magnetic moment of the shell in terms of σ is $\frac{4}{3}(\pi\sigma R^4\omega)$

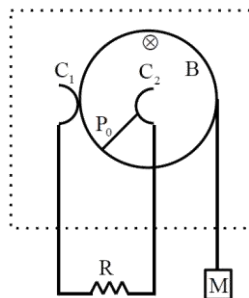
(C) Gyromagnetic ratio is $\frac{Q}{2m}$

(D) Gyromagnetic ratio is $\frac{2Q}{m}$

29. A cylindrical uniform rod of mass 0.72 kg and radius 6cm rest on two parallel rails, that are $d = 50\text{cm}$ apart. The rod carries a current $I = 48\text{A}$ (In the direction shown) and rolls along the rails without slipping. If it starts from rest, uniform magnetic field of magnitudes 0.25 T is directed perpendicular to the rod and the rail, then find the friction force (In N) between rod and rails



30. Consider a perfectly conducting disc of radius r_0 in a constant magnetic field B perpendicular to the plane of the disk sliding contacts are provided at the edge of the disc (C_1) and its axle (C_2). After long time angular velocity will become constant and becomes equal to ω & current in resistance is i , then



(A) $i = \frac{B\omega r_0^2}{R}$

(B) $i = \frac{B\omega r_0^2}{2R}$

(C) $\omega = \frac{4MgR}{B^2 r_0^3}$

(D) $\omega = \frac{2MgR}{B^2 r_0^3}$

EXERCISE – 5

1. A long, thick straight conductor of radius R carries current I uniformly distributed in its cross-section area. The ratio of energy density of the magnetic field at distance $R/2$ from surface inside the conductor and outside the conductor is $\frac{9}{4n}$. Find n ?
2. A particle of positive charge q and mass m enters with velocity $V \hat{j}$ at the origin in a magnetic field $B(-\hat{k})$ which is present in the whole space. The charge makes a perfectly inelastic collision with identical particle at rest but free to move at its maximum y -coordinate. After collision the combined charge will move on trajectory: (where $r = \frac{mv}{qB}$)

(A) $y = \frac{mv}{qB}(-\hat{i})$

(B) $(x + r)^2 + \left(y - \frac{r}{2}\right)^2 = \frac{r^2}{4}$

(C) $(x - r)^2 + (y - r)^2 = r^2$

(D) $(x - r)^2 + \left(y + \frac{r}{2}\right)^2 = \frac{r^2}{4}$
3. As shown in the figure, three sided frame is pivoted at P and Q and hangs vertically. Its sides are of same length and have a linear density of $\sqrt{3}kg/m$. A current of $10\sqrt{3}$ amp is sent through the frame, which is in a uniform magnetic field of $2T$ directed upwards as shown. Then angle through which the frame will be deflected in equilibrium is :
(Take $g = 10m/s^2$)

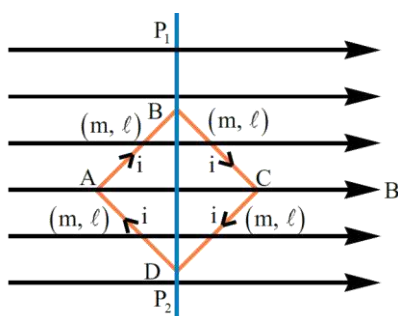
(A) 30°

(B) 45°

(C) 60°

(D) 90°
4. A circular beam of charge of radius a consists of electrons moving with a constant speed u along the $+z$ direction. The beam's axis is coincident with the z -axis and the electron charge density is given by $\rho = cr^2(C/m^3)$ where c is a constant and r is the radial distance from the axis of the beam:

(A) The current crossing the xy -plane is $\pi c u a^4$
 (B) The electric field at distance r ($r < a$) from z axis is proportional to r^3
 (C) The magnetic field at distance r ($r < a$) from z axis is proportional to r^3
 (D) The electric field at distance r ($r < a$) from z axis is inversely proportional to r .
5. Rod AB , BC , CD and DA form a square loop having current i , mass and length of each rod is m and ℓ respectively, is situated in a uniform magnetic field B as shown in the figure and it can rotate about axis P_1P_2 then:



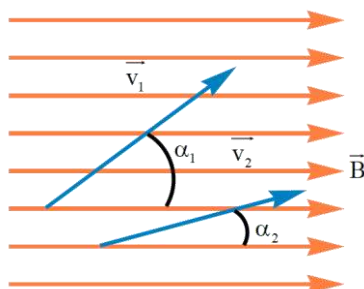
(A) Angular acceleration of the square loop at $t = 0$, is $\frac{3Bi}{2m}$

(B) Angular velocity when square loop rotated by 30° , is $\sqrt{\frac{3iB}{2m}}$

(C) Torque on the loop when it rotated by 60° , is $\frac{iB\ell^2}{2}$

(D) Angular acceleration of the square loop when it is rotated from starting to 90° , decreases

6. In a uniform magnetic field there are two charged particles 1 and 2 moving with velocities v_1 and v_2 respectively and carrying equal charges and equal mass with $|v_1| = |v_2| = v$. The velocity of one particle forms an angle α_1 with the direction of the field, while the other velocity forms an angle α_2 , ($\alpha_1 > \alpha_2$). Mark the **correct** statement(s).



- (A) Both the particles move along helical path
 (B) Time period of circulation is same for both the particles
 (C) Pitch of particle 1 is greater than that of particle 2
 (D) Radius of helix is greater for particle 1

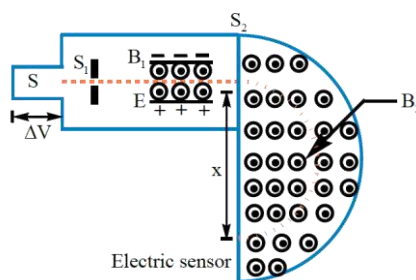
7. A charged particle is projected with initial velocity in x-y plane in a magnetic field $\vec{B} = 10\hat{k}T$ from the origin. The particle moves in a circle and just touches a straight line $y = 5(m)$ at $x = 5\sqrt{3}(m)$.

Then (mass of particle = $5 \times 10^{-5}kg$, charge = $1\mu C$):

- (A) The particle is projected at an angle 60° with x-axis
 (B) The radius of the circle is $10m$
 (C) The speed of the particle is $2m/s$
 (D) The speed of the particle is $5\sqrt{3}m/s$

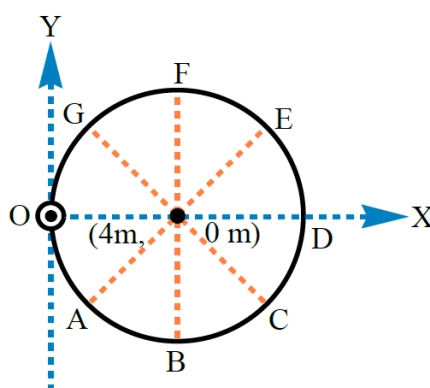
8. Shown below are essentials of a commercial mass spectrometer. This device is used to measure the composition of gas samples, by measuring the abundance of species of different masses. An

iron of mass m and charge $q = +e$ is produced in source S , a chamber in which a gas discharge is taking place. The initially stationary ion leaves S , accelerated by a potential difference $\Delta V > 0$, and then enters a selector chamber, S_1 , in which there is an adjustable magnetic field \vec{B}_1 , pointing out of the page and a deflecting electric field \vec{E} , pointing from positive to negative plate. Only particles of a uniform velocity \vec{v}_1 leave the selector. The emerging particles at S_2 , enter a second magnetic field \vec{B}_2 , also pointing out of the page. The particle then moves in a semicircle, striking an electronic sensor at a distance x from the entry slit:



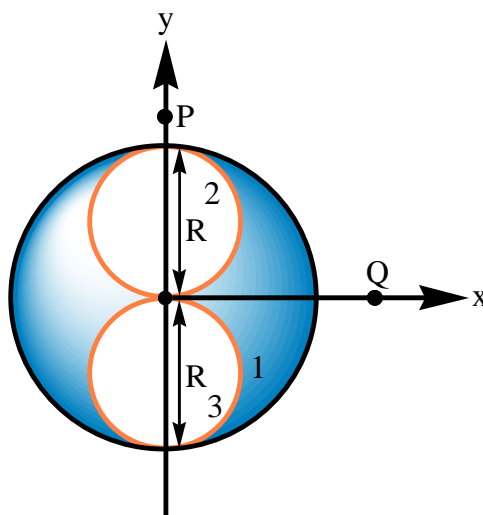
- (A) The mass of the particle is $\frac{eB_2^2 x^2}{8\Delta V}$
- (B) The mass of the particle is $\frac{eB_2^2 x^2}{4\Delta V}$
- (C) The magnetic field in the selector chamber that is needed to ensure that the particle travels straight through is $\frac{ExB_2}{2\Delta V}$
- (D) The magnetic field the selector chamber that is needed to ensure that the particle travels straight through is $\frac{ExB_2}{4\Delta V}$

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

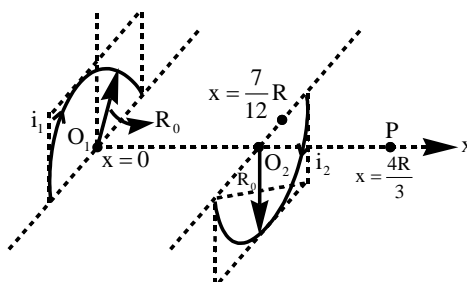


- (A) 2 (B) 4 (B) 6 (D) 8

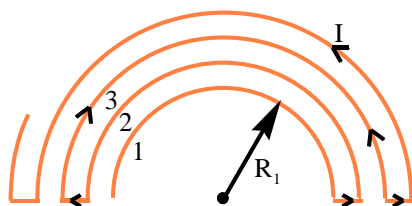
10. A long, cylindrical conductor of radius R has two cylindrical cavities of diameter R running parallel to its axis as shown in figure. The conductor carries a uniform current density J . The field strength B at position $Q(x = 2R)$ along the x -axis is $\frac{\alpha}{68}\mu_0JR$ then find α .



- (A) 3 (B) 6 (C) 9 (D) 12
11. The current density inside a long solid cylindrical wire of radius a is in the direction of the central axis and varies linearly with radial distance r from the axis according to $J = J_0 \frac{r}{a}$. Then find the magnetic field inside wire is
- (A) $\frac{\mu_0 J_0 r^2}{a}$ (B) $\frac{\mu_0 J_0 r^2}{2a}$ (C) $\frac{\mu_0 J_0 r^2}{3a}$ (D) $\frac{\mu_0 J_0 r^2}{4a}$
12. Two semicircular ring of same radius (R) having currents i_1 and i_2 are kept parallel to each other in y - z plane as shown in the figure. Centre of first ring is kept at $x = 0$ and that of second ring is kept at $x = \frac{7}{12}R$. Find the magnetic field at point $P(x = \frac{4R}{3})$ along the x -axis is

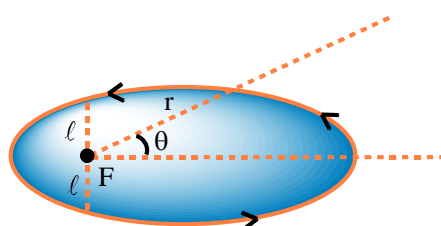


- (A) $\frac{\mu_0 i_1}{20R}$ (B) $\frac{3\mu_0 i_1}{20R}$ (C) $\frac{7\mu_0 i_1}{20R}$ (D) $\frac{9\mu_0 i_1}{20R}$
13. Infinite semi-circular wires are placed out from a single wire in a continuous fashion as shown in the figure. The radii of the semi-circles increases as $R_n = \alpha^{n-1}R_1$ where R_n is the radius of the n^{th} semicircle and α is constant greater than 1. The semicircle are concentric. Find the net magnetic field at the centre is



- (A) $\frac{\mu_0 i}{2R_1} \left[\frac{\alpha}{1-\alpha} \right]$ (B) $\frac{\mu_0 i}{2R_1} \left[\frac{\alpha}{1+\alpha} \right]$ (C) $\frac{\mu_0 i}{4R_1} \left[\frac{\alpha}{1+\alpha} \right]$ (D) $\frac{\mu_0 i}{4R_1} \left[\frac{\alpha}{1-\alpha} \right]$

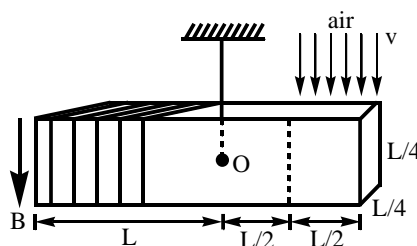
14. Find the magnetic field due to current i flowing in an elliptical loop at its focus. The equation of ellipse (in polar coordinates as shown) is $\frac{\ell}{r} = (1 + e \cos \theta)$. Here e is eccentricity which is a constant. Take $\ell = 50\text{cm}$, $e = 0.8$, $i = 2\text{A}$,



- (A) $2\pi \times 10^{-7}\text{T}$ (B) $8\pi \times 10^{-7}\text{T}$ (C) $4\pi \times 10^{-7}\text{T}$ (D) $6\pi \times 10^{-7}\text{T}$

15. A non-conducting non-magnetic rod having square cross-section of side $\frac{L}{4}$ is suspended from a rigid support as shown in the figure. A light and small coil of 600 turns is wrapped tightly at the left end of the rod where uniform magnetic field B exists in vertically downward direction. Air of density ρ hits the half of the right part of the rod with velocity v as shown in the figure. What should be the current in the coil so that rod remains horizontal?

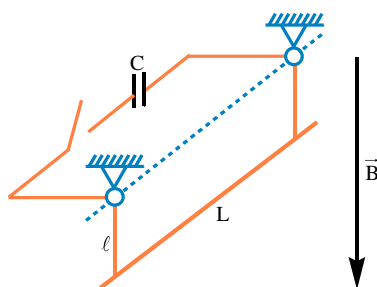
[Assume air particles come to rest after colliding with the rod]



[Take: $\rho = 1.05\text{kg/m}^3$, $v = 10\text{m/s}$, $B = 1\text{T}$, $L = 2\text{m}$]

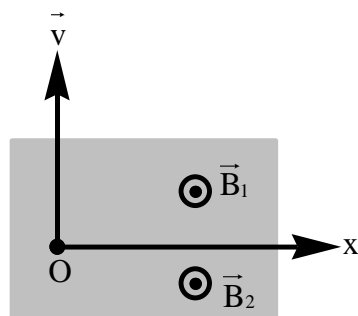
- (A) 105 mA (B) 225 mA (C) 345 mA (D) 525 mA

16. Metal rod with a mass $m = 10\text{g}$, and length $L = 0.2\text{m}$ is suspended by two light wires length $\ell = 1\text{cm}$ in a magnetic field induction $B = 1\text{T}$ which is directed vertically downwards (Figure). A capacitor of capacitance $C = 100\mu\text{F}$ charged to a voltage of 100V is connected as shown. Determine the maximum deflection of the rod from the initial position after the switch is closed. Resistance of wire and rod is not taken into account.



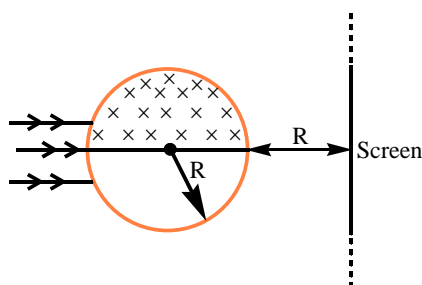
- (A) 37° (B) 45° (C) 53° (D) 60°

17. A charged particle is projected at a speed $v = 10^6 \text{ m/s}$ perpendicular to the boundary OX of two homogeneous magnetic fields (Figure). Magnetic fields are parallel to each other and perpendicular to the particle velocity. The average speed of particles along the interface between the fields $u = \frac{10^6}{\pi} \text{ m/s}$. If the average velocity of the particle is along positive x direction, what is the value of B_2 if B_1 is 1 T?



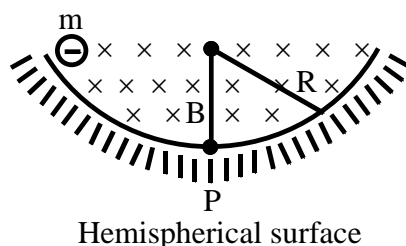
- (A) 3 T (B) 6 T (C) 9 T (D) 12 T

18. Figure shows circular region of radius $R = \sqrt{3} \text{ m}$ in which upper half has uniform magnetic field $\vec{B} = 0.2(-\hat{k}) \text{ T}$ and lower half has uniform magnetic field $\vec{B} = 0.2\hat{k} \text{ T}$. A very thin parallel beam of point charges each having mass $m = 2 \text{ gm}$, speed $v = 0.3 \text{ m/sec}$ and charge $q = +1 \text{ mC}$ are projected along the diameter as shown in figure. A screen is placed perpendicular to initial velocity of charges as shown. Find the distance between the points on screen where charges will strike after being deflected by the magnetic field is

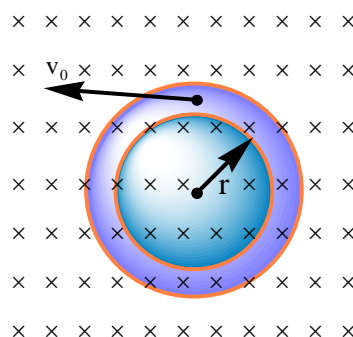


- (A) 4 m (B) 8 m (C) 12 m (D) 16 m

19. A charge particle of mass 'm' and charge -q is released from rest from the given position. In the presence and absence of uniform horizontal magnetic field normal reaction acting on the charge at point P are N_1 and N_2 respectively. Neglect friction. Find the value of $N_1 - N_2$ is

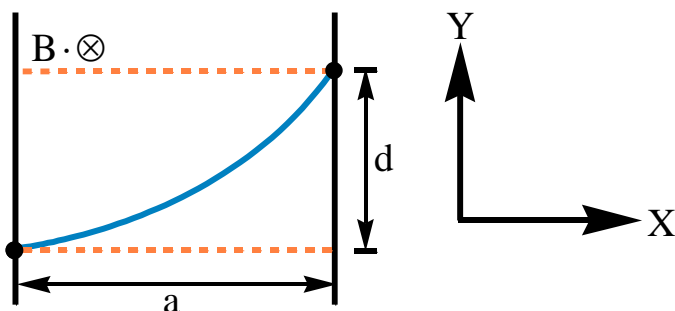


- (A) $Bq\sqrt{2gR}$ (B) $Bq\sqrt{3gR}$ (C) $2Bq\sqrt{gR}$ (D) $Bq\sqrt{gR}$
20. A small ball of mass m carrying positive charge +Q is dropped in uniform horizontal magnetic field B. The vertical depth of the deepest point of its path from initial position is $\frac{nm^2g}{Q^2B^2}$. Find n.
- (A) 1 (B) 2 (C) 3 (D) 4
21. A horizontal tube of small thickness having inner radius $r = \frac{R}{2}$ is placed in gravity free space. Magnetic field of strength B is present perpendicular to plane of circular tube. A charged particle (q, m) inside the tube is given tangential velocity $v_0 = \frac{qBR}{m}$. Find the work done by friction long after motion is [inner surface of tube is rough]

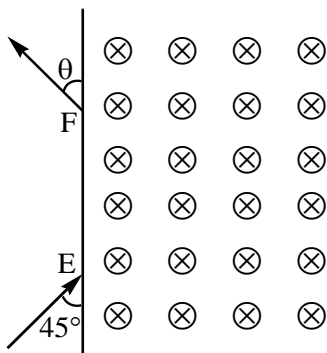


- (A) $-\frac{q^2B^2R^2}{8m}$ (B) $-\frac{2q^2B^2R^2}{8m}$ (C) $-\frac{3q^2B^2R^2}{8m}$ (D) $-\frac{4q^2B^2R^2}{8m}$
22. A neutral atom of atomic mass number 100 which is stationary at the origin in gravity free space emits an α -particle (a) in z-direction. The product ion is P. A uniform magnetic field exists in the x-direction. Disregard the electromagnetic interaction between A and P. If the angle of rotation of A after which A and P will meet for the first time is $\frac{n\pi}{25}$ radians, what is the value of n?
- (A) 12 (B) 24 (C) 36 (D) 48

23. A particle of charge $+q$ enters a region of uniform magnetic field B (directed into the plane of paper) as shown in the figure. Particle is deflected by distance d along Y axis after travelling a distance of along X -axis. Find magnitude of linear momentum of particle in newton-sec.
(Given: $a = 3\text{m}$, $d = 4\text{m}$, $Bq = 0.32\text{ C-tesla}$)



- (A) 1 (B) 2 (C) 3 (D) 4
24. A particle of mass $m = 1.6 \times 10^{-27}\text{kg}$ and charge $q = 1.6 \times 10^{-19}\text{C}$ enters a region of uniform magnetic field of strength 1T along the direction shown in figure. The speed of the particle is 10^7ms^{-1}

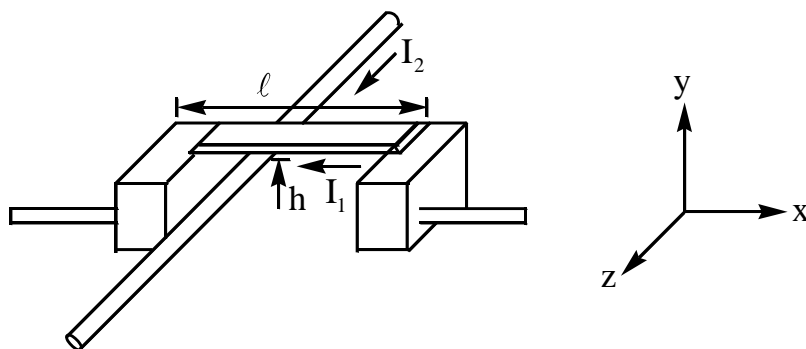


- (A) The magnetic field is directed along the inward normal to the plane of the paper. The particle leaves the region of the field at the point F. The distance EF and the angle θ are 0.28m and 60° respectively.
- (B) The magnetic field is directed along the inward normal to the plane of the paper. The particle leaves the region of the field at the point F. The distance EF and the angle θ are 0.14m and 45° respectively.
- (C) If the direction of the field is along the outward normal to the plane of the paper, the time spent by the particle in the region of the magnetic field after entering it at E is 27 ns
- (D) If the direction of the field is along the outward normal to the plane of the paper, the time spent by the particle in the region of the magnetic field after entering it at E is 47 ns
25. A disc of radius R rotates with angular velocity ω about an axis perpendicular to its surface passing through centre. Assuming the surface charge density σ varies with r as $\sigma = \alpha r^2$, where r is the

distance from its centre, find the magnetic induction on the axis of rotation at a point at distance x from the centre.

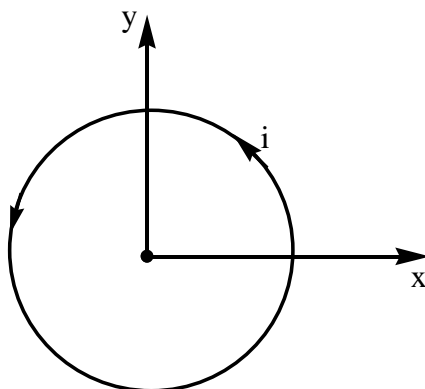
- (A) $\frac{\mu_0 \alpha \omega}{2} \left(\frac{(R^2 + x^2)^{3/2}}{3} - 2x^2(R^2 + x^2)^{1/2} + \frac{x^4}{(R^2 + x^2)^{1/2}} + \frac{8}{3}x^3 \right)$
- (B) $\frac{\mu_0 \alpha \omega}{2} \left(\frac{(R^2 + x^2)^{3/2}}{3} + 2x^2(R^2 + x^2)^{1/2} - \frac{x^4}{(R^2 + x^2)^{1/2}} + \frac{8}{3}x^3 \right)$
- (C) $\frac{\mu_0 \alpha \omega}{2} \left(\frac{(R^2 + x^2)^{3/2}}{3} - 2x^2(R^2 + x^2)^{1/2} - \frac{x^4}{(R^2 + x^2)^{1/2}} + \frac{8}{3}x^3 \right) s$
- (D) $\frac{\mu_0 \alpha \omega}{2} \left(\frac{(R^2 + x^2)^{3/2}}{3} - 2x^2(R^2 + x^2)^{1/2} - \frac{x^4}{(R^2 + x^2)^{1/2}} - \frac{8}{3}x^3 \right)$

26. A thin copper bar of length ℓ is supported horizontally by two (non-magnetic) contacts. The bar carries current I_1 in the $-x$ direction, as shown in figure. At a distance h below one end of the bar, a long straight wire carries a current I_2 in the z -direction. Determine the magnetic force exerted on the bar.



- (A) $\frac{\mu_0 I_1 I_2}{\pi} \log_e \left(\frac{h^2 + \ell^2}{h^2} \right) (-\hat{k})$
- (B) $\frac{\mu_0 I_1 I_2}{2\pi} \log_e \left(\frac{h^2 + \ell^2}{h^2} \right) (-\hat{k})$
- (C) $\frac{\mu_0 I_1 I_2}{3\pi} \log_e \left(\frac{h^2 + \ell^2}{h^2} \right) (-\hat{k})$
- (D) $\frac{\mu_0 I_1 I_2}{4\pi} \log_e \left(\frac{h^2 + \ell^2}{h^2} \right) (-\hat{k})$

27. Magnetic field in a space is given as $\vec{B} = -\frac{B_0 x}{R} \hat{k}$. A circular ring of radius R having current I lies in the space with centre at origin as shown in the figure. Find the magnitude of net magnetic force acting on the circular ring due to the magnetic field.



- (A) $2iB_0R$ (B) πiB_0R (C) $2\pi iB_0R$ (D) zero
28. A charge particle is moving with a velocity $3\hat{i} + 4\hat{j}$ m/sec and it has electric field $\vec{E} = 100\hat{k}$ N/C at a given point. Find the magnitude of magnetic field at the same point due to the motion of the charge particle.
- (A) $100\mu_0\epsilon_0$ (B) $25\mu_0\epsilon_0$ (C) $12.5\mu_0\epsilon_0$ (D) $50\mu_0\epsilon_0$
29. A particle having specific charge σ is projected in xy plane with a speed v . There exists a uniform magnetic field in z-direction having a fixed magnitude B_0 . The field is made to reverse its direction after every interval of $\frac{2\pi}{\sigma B_0}$. Calculate the maximum separation (in m) between two positions of the particle during its course of motion. (given $\frac{v}{\sigma B_0} = 2$ metre) (neglect any other force including gravity throughout the motion)

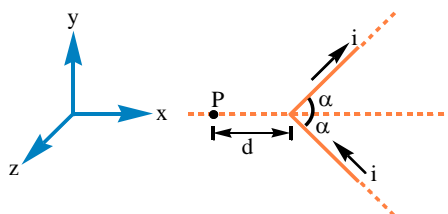
Proficiency Test-1

1. A particle is moving with velocity $\vec{v} = \hat{i} + 3\hat{j}$ and it produces an electric field at a point given by $\vec{E} = 2\hat{k}$. It will produce magnetic field at that point equal to:

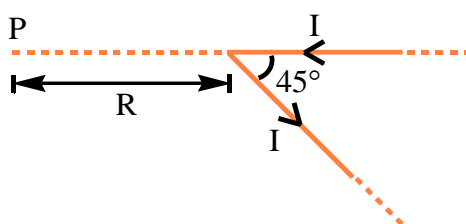
(all quantities are in S.I. units)

- (A) $\frac{2\hat{i}-6\hat{j}}{c^2}$ (B) $\frac{6\hat{i}+2\hat{j}}{c^2}$ (C) zero (D) $\mu\epsilon_0(6\hat{i} - 2\hat{j})$
2. Two observers moving with different velocities see that a point charge produces same magnetic field at the same point A. Their relative velocity must be parallel to \vec{r} , where \vec{r} is the position vector of point A with respect to point charge. This statement is :
- (A) True
(B) False
(C) nothing can be said
(D) true only if the charge is moving perpendicular to the \vec{r}

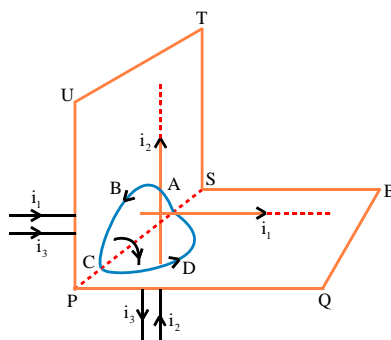
3. If the magnetic field at 'P' can be written as $K \tan\left(\frac{\alpha}{2}\right)$ then K is $\frac{\mu_0 I}{n\pi d}$. Find n?



4. A long straight wire, carrying current I, is bent at its midpoint to form an angle of 45° . Magnetic field at point P, distance R from point of bending is equal to $\frac{\mu_0 I}{4\pi}(\sqrt{n} - 1)$. Find n?

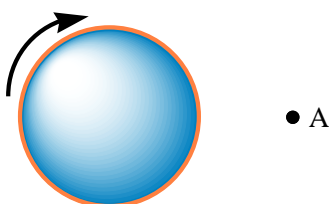


5. Figure shows an ampeian path ABCDA. Part ABC is in vertical plane PSTU while part CDA is in horizontal plane PQRS. Direction of circumlation along the path is shown by an arrow near point B and at D. $\oint \vec{B} \cdot d\vec{\ell}$ for this path according to Ampere's law will be :



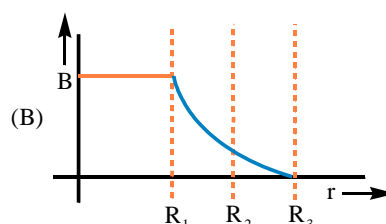
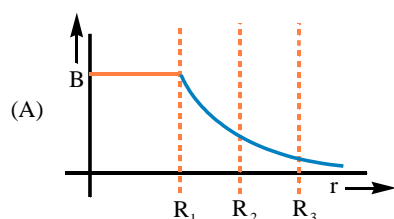
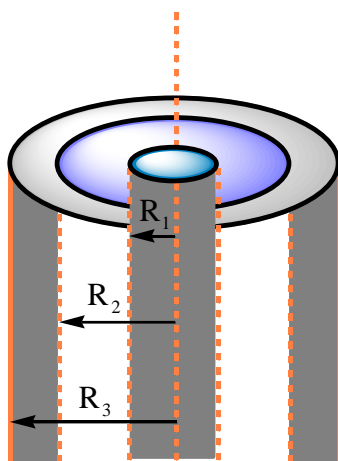
- (A) $(i_1 - i_2 + i_3)\mu_0$ (B) $(-i_1 + i_2)\mu_0$ (C) $i_3\mu_0$ (D) $(i_1 + i_2)\mu_0$

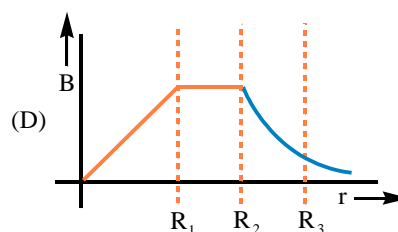
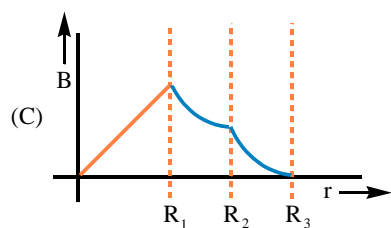
6. The negatively and uniformly charged nonconducting disc as shown, is rotated clockwise. The direction of the magnetic field at point A in the plane of the disc is :



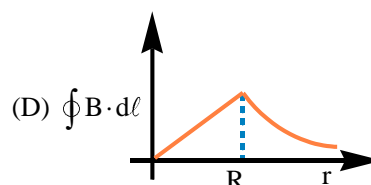
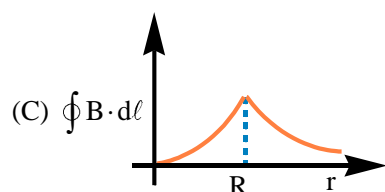
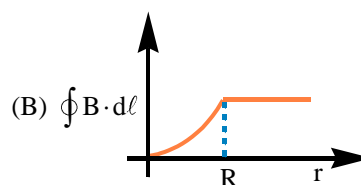
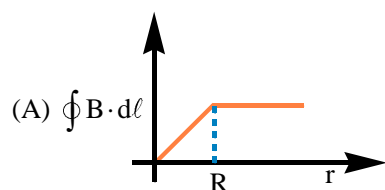
- (A) into the page (B) out of the page (C) up the page (D) down the page

7. A coaxial cable is made up of two conductors. The inner conductor is solid and is of radius R_1 and the outer conductor is hollow of inner radius R_2 and outer radius R_3 . The space between the conductors is filled with air. The inner and outer conductors are carrying currents of equal magnitudes and in opposite directions. Then the variation of magnetic field with distance from the axis is best plotted as :

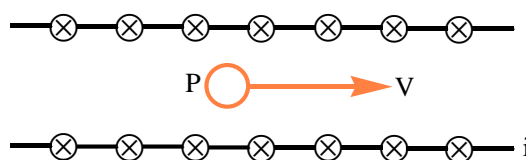




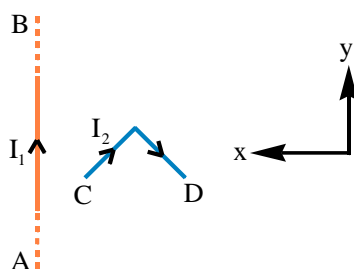
8. A cylindrical wire of radius R is carrying current i uniformly distributed over its cross-section. If a circular loop of radius ' r ' is taken as amperian loop, then the variation value of $\oint \vec{B} \cdot d\vec{\ell}$ over this loop with radius ' r ' of loop will be best represented by :



9. Two charges $+q$ and $-q$ are attached to the two ends of a light rod of length L , as shown in figure. The system is given a velocity \vec{V} perpendicular to magnetic field \vec{B} . The magnetic force on the system of charges and magnitude of force on one charge by the rod, are respectively :
- (A) zero, zero (B) zero, qvB (C) $2qvB$, 0 (D) $2qvB$, qvB
10. Two infinite sheets carrying current in same direction (of equal current per unit length K) are separated by a distance ' d '. A proton is released from a point between the plates with a velocity parallel to the sheets but perpendicular to the direction of current in the sheets. Then the path of the proton is :

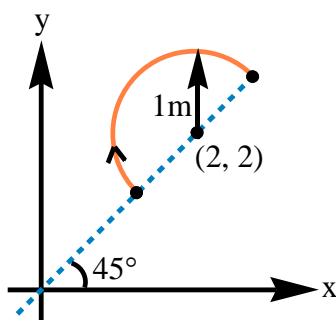


- (A) circle (B) helix (C) straight line
(D) straight line only if it is released from a point exactly midway between the two plates
11. In the figure shown a current I_1 is established in the long straight wire AB. Another wire CD carrying current I_2 is placed in the plane of the paper. The line joining the ends of this wire is perpendicular to the wire AB. The resultant force on the wire CD is :

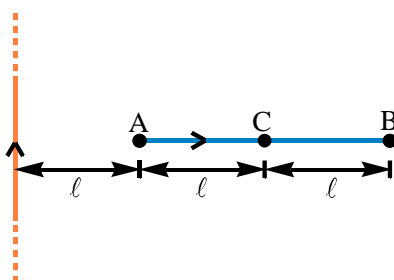


- (A) zero (B) towards negative x-axis
(C) towards positive y-axis (D) None of the above

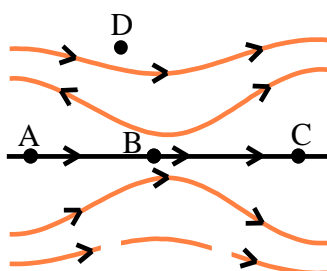
12. A uniform magnetic field $\vec{B} = 3\hat{i} + 4\hat{j} + \hat{k}$ exists in region of space. A semi-circular wire of radius 1 m carrying current 1 A having its centre at (2, 2, 0) is placed in x-y plane as shown in figure. The force on semi-circular wire will be:



- (A) $\sqrt{2}(\hat{i} + \hat{j} + \hat{k})$ (B) $\sqrt{2}(\hat{i} - \hat{j} + \hat{k})$ (C) $\sqrt{2}(\hat{i} + \hat{j} - \hat{k})$ (D) $\sqrt{2}(-\hat{i} + \hat{j} + \hat{k})$
13. A current carrying rod AB is placed perpendicular to an infinitely long current carrying wire as shown in the figure. The point at which the conductor should be hinged so that it will not rotate.

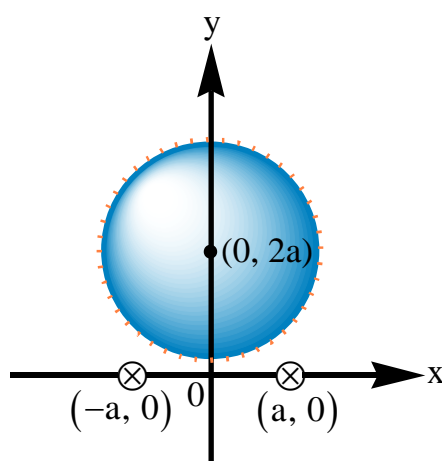


- (A) A (B) B (C) C (D) somewhere between A and C
14. A space has magnetic field in which the lines of induction are as shown in the figure:



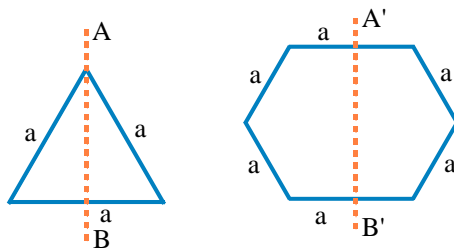
- (A) The magnetic induction at B is greater than the magnetic induction at C.
- (B) An electron placed at B experiences a larger force at B than that at C.
- (C) An electron shot with a velocity towards D, perpendicular to the lines of induction at B in the plane of the figure will emerge from its opposite corner.
- (D) An electron shot with a velocity along the line ABC will continue to be moving in the same direction.

15. Two long conducting wires carrying equal currents are placed parallel to the z-axis. A charged particle is made to move in a circular path of radius a with centre of the path at point $(0, 2a)$ in clockwise direction. During the course of motion, it passes through four points P, Q, R and S having coordinates $(0, a)$, $(-a, 2a)$, $(0, 3a)$ and $(a, 2a)$ respectively. The magnitude of force exerted on the particle by the magnetic field created by the wires is maximum when it passes through point.



- (A) P (B) Q (C) R (D) S

16. The magnetic dipole moment of a uniformly charged lamina in shape of equilateral triangle of side a is M , when rotated about axis AB with uniform ω (see figure). If a hexagonal lamina of side a and having same charge density is rotated about axis $A'B'$ (with same angular speed ω). Find the dipole moment generated is



(A) 10μ

(B) 20μ

(C) 30μ

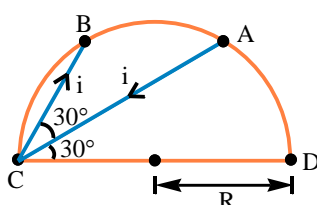
(D) 40μ

17. A particle having charge $q = 10\mu C$ moves in uniform magnetic field with velocity $v_1 = 10^6 ms^{-1}$ at angle 45° with x-axis in the x-y plane and experiences a force $F_1 = 5\sqrt{2}mN$ along the negative z-axis. When the same particle moves with velocity $v_2 = 10^6 ms^{-1}$ along the z-axis it experiences a force F_2 in y direction.
- (A) The magnetic field is $(10^{-3}T)\hat{i}$ (B) The magnetic field is $(10^{-3}T)(-\hat{i})$
 (C) The magnitude of the force F_2 is $10^2 N$ (D) The magnitude of the force F_2 is $10^{-2} N$

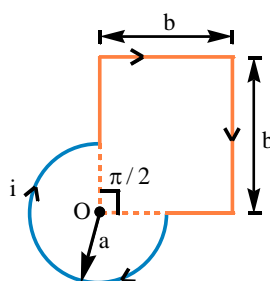
Proficiency Test-2

1. A current carrying wire is placed in the grooves of an insulating semi circular disc of radius 'R', as shown. The current enters at point A and leaves from point B. The magnetic field at point D is $\frac{\mu_0 i}{4\pi R \sqrt{n}}$

Find n?

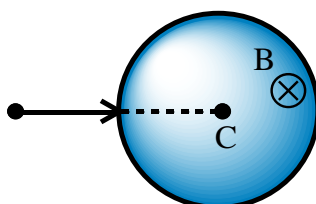


2. The magnitude of magnetic field at O (centre of the circular part) of the current carrying coil as shown is :

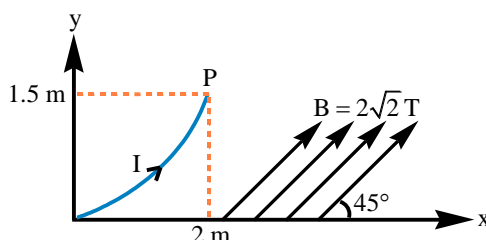


- (A) $\frac{\mu_0 i}{4\pi} \left(\frac{3\pi}{a} + \frac{\sqrt{2}}{b} \right)$ (B) $\frac{\mu_0 i}{2\pi} \left(\frac{3\pi}{2a} + \frac{\sqrt{2}}{b} \right)$ (C) $\frac{\mu_0 i}{2\pi} \left(\frac{\pi}{3a} + \frac{3}{\sqrt{2}b} \right)$ (D) $\frac{\mu_0 i}{4\pi} \left(\frac{3\pi}{2a} + \frac{\sqrt{2}}{b} \right)$

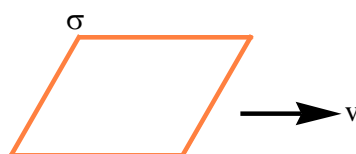
3. A charge particle moves in the magnetic field generated by a straight, long wire carrying constant current. It is projected with some velocity whose direction is radially away from the wire. Its radius of curvature :
- (A) will continuously increase
(B) will continuously decrease
(C) will first increase for some time and then decrease
(D) will first decrease for some time and then increase
4. In the figure shown, a charged particle of mass 2 g and charge $5\mu\text{C}$ enters a circular region of radius 10 cm, in which there is a uniform magnetic field of strength 4 T and directed perpendicular to the plane of circular region in the figure. If the particle velocity vector rotates through 90° angle in passing through this region, then its speed (in mm/s) is :



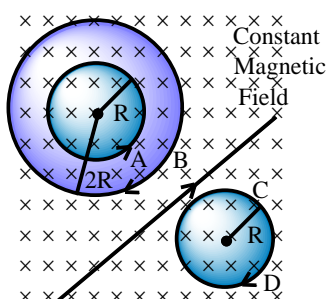
5. A long horizontal wire carries a current of 10 A. A charged particle of mass 1 mg moves parallel to the wire with a constant velocity of magnitude 10 m/s. The distance of the charge from the wire is 1 cm. The magnitude of the charge (in mC) is :
6. A parabolic wire as shown in the figure is located in x-y plane and carries a current $I = 10$ amp. A uniform magnetic field of intensity $2\sqrt{2}$ T, making an angle of 45° with x-axis exists throughout the plane. If the co-ordinates of end point 'P' of wire are (2 m, 1.5 m), then the total force acting on the wire is :



- (A) $40N\hat{k}$ (B) $10N\hat{k}$ (C) $-10N\hat{k}$ (D) $-40N\hat{k}$
7. A large plate with uniform surface charge density σ is moving with constant speed v as shown in the figure. The magnetic field at a small distance from plate is:

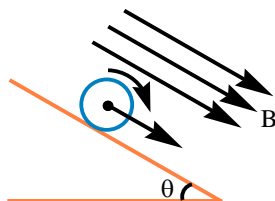


- (A) $\mu_0\sigma v$ in magnitude (B) $\frac{\mu_0\sigma v}{2}$ in magnitude
- (C) perpendicular to plate (D) parallel to plate
8. Four particle A, B, C and D of masses m_A, m_B, m_C and m_D respectively, follow the paths shown in the figure, in a uniform magnetic field. Each particle moving with same speed. Q_A, Q_B, Q_C and Q_D are the specific charge of particles A, B, C and D respectively:

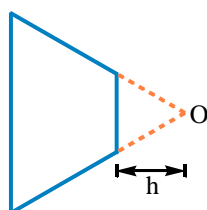


- (A) $Q_A < Q_B < Q_C < Q_D$
- (B) $Q_D < Q_B < Q_C < Q_A$
- (C) Charge on the particle B and particle D is of different nature
- (D) Work done by magnetic force on the particle C is minimum as compared to other particle

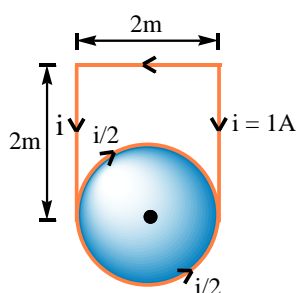
9. A cylindrical wire is rolling on rough inclined plane. There exist a magnetic field along the plane as shown. At a certain instant, when its angular velocity is ω , a current I is switched on across the length of cylinder is such a way that its angular velocity becomes constant. Find the **correct** statement(s).



- (A) Translational velocity will also become constant
 (B) Normal reaction will become zero
 (C) Friction force will become zero
 (D) Force on the cylinder due to magnetic field will be $mg \cos \theta$
10. A current of $I = \sqrt{2}A$ flows in a circuit having the shape of an isosceles trapezium. If magnetic field at point O in the plane of trapezium is $2 \times 10^{-6}T$ and if length of smaller base of trapezium is $\ell = 100mm$ and distance $h = 50mm$ as shown then find ratio of length of parallel sides of trapezium.



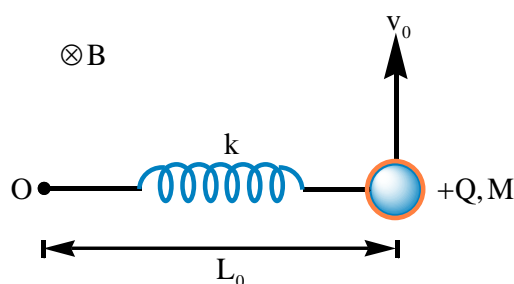
- (A) 1 (B) 2 (C) 3 (D) 4
11. A rod of length ℓ and total charge 'q' which is uniformly distributed is rotating with angular velocity ω about an axis passing through the centre of rod and perpendicular to rod. Find the magnitude of magnetic dipole moment of rod. (Take: $q = 4C$, $\omega = 6rad/s$ and $\ell = 2m$)
 (A) $2Am^2$ (B) $4Am^2$ (C) $6Am^2$ (D) $8Am^2$
12. Find the value of magnetic dipole moment of the following circuit the current distribution is shown in the diagram.



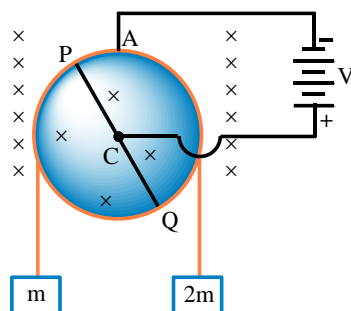
- (A) $1Am^2$ (B) $2Am^2$ (C) $3Am^2$ (D) $4Am^2$

Proficiency Test-3

1. A charged particle of unit mass and unit charge at some instant has velocity $\vec{v} = (8\hat{i} + 6\hat{j})ms^{-1}$ in magnetic field $\vec{B} = (2\hat{k})$ tesla. (Neglect all other forces). Choose the correct option(s).
 (A) The path of particle may be $x^2 + y^2 - 4x - 21 = 0$
 (B) The path of particle may be $x^2 + y^2 = 25$
 (C) The path of particle may be $y^2 + z^2 = 25$
 (D) Time period of particle will be 3.14 sec
2. In zero gravity region, a point charge $+Q$ of mass M is connected to a spring of natural length L_0 and spring constant k . A uniform magnetic field B is directed inside the plane of paper. The point charge is given an initial velocity v_0 perpendicular to the length of spring as shown. It is given that $B = \frac{Mv_0}{QL_0}$. Then which of the following quantities remain(s) conserved during the motion of particle?

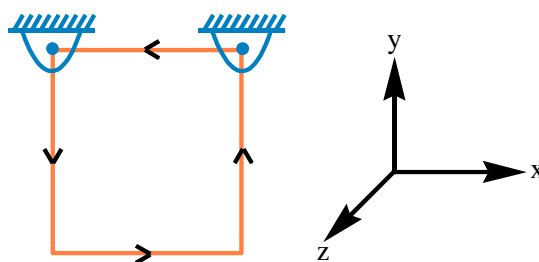


- (A) Kinetic energy
 - (B) Potential energy
 - (C) Total energy of system
 - (D) Angular momentum of particle about O
3. A long thick wire has an inner radius a , an outer radius b . The total current circulating inside the wire is I ; this current is uniformly distributed over the cross-section. Find the magnetic field at a distance r from the axis of wire,
 ($a = 1cm, b = 2cm, I = 5.5A, r = 1.1cm$)
 (A) $2\mu T$ (B) $4\mu T$ (C) $5\mu T$ (D) $7\mu T$
4. A conducting ring of mass m and radius r has a weightless conducting rod PQ of length $2r$ and resistance $2R$ attached to it along its diameter. It is pivoted at its centre C with its plane vertical, and two blocks of mass m and $2m$ are suspended by means of a light in-extensible string passing over it as shown in the figure. The ring is free to rotated about C and the system is placed in a magnetic field B (into the plane of the ring). A circuit is now completed by connecting the ring at A and C to a battery of emf V . Find the value of V so that the system remains static. Take $B = 0.1 T, m = 10 gm, r = 0.5 m, R = 1\Omega$.



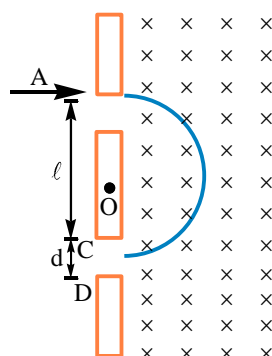
- (A) 1 V (B) 2 V (C) 3 V (D) 4 V

5. A current carrying uniform square frame is suspended from hinged supports as shown in the figure such that it can freely rotate about its upper side. The length and mass of each side of the frame is 2m and 4kg respectively. A uniform magnetic field $\vec{B} = (3\hat{i} + 4\hat{j})$ is applied. When the wire frame is rotated to 45° from vertical and released it remains in equilibrium. Find the magnitude of current in the wire frame is



- (A) 5 A (B) 10 A (C) 15 A (D) 20 A

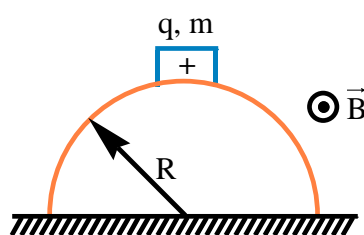
6. A beam of equally charged particles after being accelerated through a voltage V enters into a magnetic field 'B' as shown in the figure. It is found that all the particles hit the plane between C and D. Find $\frac{M_{max}}{M_{min}}$. Where M_{max} = the mass of the heaviest particle and M_{min} = the mass of lightest particles of the beam. (given $B = 4 \times 10^{-3}$ tesla, $V = 5$ volt, $\ell = 20$ cm and $d = 5$ cm)



- (A) $\frac{5}{4}$ (B) $\frac{4}{5}$ (C) $\frac{25}{16}$ (D)

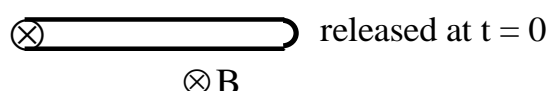
7. A small body of mass m , having a positive charge q begins to slide from the top of a smooth fixed half-cylinder of radius $R = 10$ m. At what height, measured from the base of the half-cylinder, the

body detaches itself from cylinder? Movement occurs in a uniform magnetic field B directed perpendicular to the plane of the drawing and the observer. Take $B = \frac{m}{2q} \sqrt{\frac{g}{R}}$.



- (A) 20 m (B) 15 m (C) 10 m (D) 5 m

8. A non-conducting rod of length 2m is hinged at one end and a charge of $\frac{1}{10} \text{ C}$ is distributed uniformly over it. At $t = 0$, it is released from the position shown. There exist a uniform magnetic field of $\sqrt{15} \text{ T}$ inside the plane of motion of rod. If mass of rod is 100g, then find the value of hinge force when rod is rotated by $\frac{\pi}{2}$ due to gravity.



- (A) 2 N (B) 4 N (C) 6 N (D) 8 N

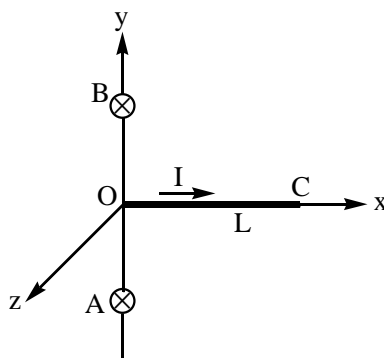
9. A particle of charge q and mass m is projected from origin with velocity $\vec{v} = v_0(\hat{i} - \hat{k})$ in a uniform magnetic field $\vec{B} = -B_0\hat{k}$.

- (A) The velocity of the particle as a function of time is $V(t) = V_0 \cos\left(\frac{qB_0t}{m}\right)\hat{i} + V_0 \sin\left(\frac{qB_0t}{m}\right)\hat{j} - V_0\hat{k}$
 (B) The velocity of the particle as a function of time is $V(t) = V_0 \cos\left(\frac{qB_0t}{m}\right)\hat{i} - V_0 \sin\left(\frac{qB_0t}{m}\right)\hat{j} + V_0\hat{k}$
 (C) The position of the particle as function of time is $r(t) = \frac{v_0}{B_0\alpha} \left[\sin\left(\frac{qB_0t}{m}\right)\hat{i} + \left\{1 - \cos\left(\frac{qB_0t}{m}\right)\right\}\hat{j} \right] - v_0t\hat{k}$
 (D) The position of the particle as function of time is $r(t) = \frac{v_0}{B_0\alpha} \left[\sin\left(\frac{qB_0t}{m}\right)\hat{i} + \left\{1 - \cos\left(\frac{qB_0t}{m}\right)\right\}\hat{j} \right] + v_0t\hat{k}$

10. A conducting wire of length ℓ is placed on a rough horizontal surface, where a uniform horizontal magnetic field B perpendicular to the length of the wire exists. Least values of the forces required to move the rod when a current I is established in the rod are observed to be F_1 and $F_2 (< F_1)$ for the two possible directions of the current through the rod respectively.

- (A) The weight of the rod is $BI\ell \left(\frac{F_1 + F_2}{F_1 - F_2} \right)$
 (B) The weight of the rod is $BI\ell \left(\frac{F_1 - F_2}{F_1 + F_2} \right)$
 (C) The coefficient of friction between the rod and the surface is $\frac{F_1 - F_2}{2BI\ell}$
 (D) The coefficient of friction between the rod and the surface is $\frac{F_1 + F_2}{2BI\ell}$

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



- (A) $F = \frac{\mu_0 I^2}{2\pi} \log_e \left(\frac{x^2 - a^2}{a^2} \right) (-\hat{k})$ (B) $F = \frac{\mu_0 I^2}{2\pi} \log_e \left(\frac{x^2 + a^2}{a^2} \right) (-\hat{k})$
 (C) $F = \frac{\mu_0 I^2}{\pi} \log_e \left(\frac{x^2 + a^2}{a^2} \right) (-\hat{k})$ (D) $F = \frac{\mu_0 I^2}{\pi} \log_e \left(\frac{x^2 - a^2}{a^2} \right) (-\hat{k})$
12. A particle of charge per unit mass α is released from origin with velocity $\vec{V} = v_0 \hat{i}$ in a magnetic field. $\vec{B} = -B_0 \hat{k}$ for $x \leq \frac{\sqrt{3}}{2} \frac{v_0}{B_0 \alpha}$ and $\vec{B} = 0$ for $x > \frac{\sqrt{3}}{2} \frac{v_0}{B_0 \alpha}$ and $\vec{B} = 0$ for $x > \frac{\sqrt{3}}{2} \frac{v_0}{B_0 \alpha}$. The x-coordinate of the particle at time $t > \left(\frac{\pi}{3B_0 \alpha} \right)$ would be
- (A) $\frac{\sqrt{3}}{2} \frac{v_0}{B_0 \alpha} + \frac{\sqrt{3}}{2} v_0 \left(t - \frac{\pi}{B_0 \alpha} \right)$ (B) $\frac{\sqrt{3}}{2} \frac{v_0}{B_0 \alpha} + v_0 \left(t - \frac{\pi}{3B_0 \alpha} \right)$
 (C) $\frac{\sqrt{3}}{2} \frac{v_0}{B_0 \alpha} + \frac{v_0}{2} \left(t - \frac{\pi}{3B_0 \alpha} \right)$ (D) $\frac{\sqrt{3}}{2} \frac{v_0}{B_0 \alpha} + \frac{v_0 t}{2}$

EXERCISE- 1

1	2	3	4	5	6	7	8	9	10
25	A	A	D	4	C	B	B	C	D
11	12	13	14	15	16	17	18	19	20
C	A	CD	B	ABC	B	A	A	B	11

EXERCISE- 2

1	2	3	4	5	6	7	8	9	10
B	B	A	6	B	A	D	C	C	B
11	12	13	14	15	16	17	18	19	20
B	B	D	B	C	A	A	A	AC	ABC
21	22	23	24	25	26	27	28		
AD	CD	ABC	ABC	AD	BD	AB	D		

EXERCISE- 3

1	2	3	4	5	6	7	8	9	10
C	C	5	C	A	4	A	A	A	C
11	12	13	14	15	16	17	18	19	20
A	D	B	C	C	A	A	A	A	A
21	22	23	24	25	26				
ABC	BCD	A	A	B	AC				

EXERCISE- 4

1	2	3	4	5	6	7	8	9	10
9	8	C	C	D	A	4	D	BC	BD
11	12	13	14	15	16	17	18	19	20
C	BD	AC	4	AC	ABD	BCD	ABC	ABC	AD
21	22	23	24	25	26	27	28	29	30
ABD	A	A	A	C	B	AC	ABC	00002.00	BC

EXERCISE- 5

1	2	3	4	5	6	7	8	9	10
4	B	B	BC	ABCD	ABD	ABC	AD	D	C
11	12	13	14	15	16	17	18	19	20
C	B	C	B	D	A	A	C	A	B
21	22	23	24	25	26	27	28	29	
C	D	A	BD	C	D	B	D	8	

(Physics)

MEGNETICS

Proficiency Test-1

1	2	3	4	5	6	7	8	9	10
D	A	2	2	D	A	C	B	B	C
11	12	13	14	15	16	17			
D	B	D	ACD	BD	C	AD			

Proficiency Test-2

1	2	3	4	5	6	7	8	9	10
3	D	C	1	5	B	BD	C	BCD	B
11	12								
B	D								

Proficiency Test-3

1	2	3	4	5	6	7	8	9	10
ABD	ABCD	D	B	B	C	D	B	AC	AC
11	12								
B	C								