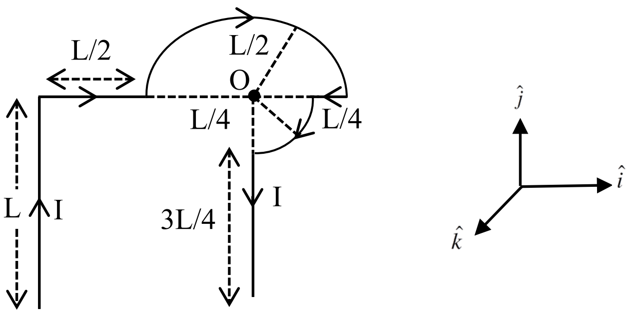
MAGNETISM

1. Which one of the following options represents the magnetic field $\vec{B}$ at O due to the current flowing in the given wire segments lying on the xy plane? **[JEE(Advanced) 2022]**



(A) $\vec{B} = \dfrac{-\mu_0 I}{L}\left(\dfrac{3}{2} + \dfrac{1}{4\sqrt{2}\pi}\right)\hat{k}$

(B) $\vec{B} = -\dfrac{\mu_0 I}{L}\left(\dfrac{3}{2} + \dfrac{1}{2\sqrt{2}\pi}\right)\hat{k}$

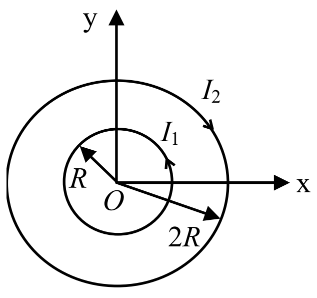
(C) $\vec{B} = \dfrac{-\mu_0 I}{L}\left(1 + \dfrac{1}{4\sqrt{2}\pi}\right)\hat{k}$

(D) $\vec{B} = \dfrac{-\mu_0 I}{L}\left(1 + \dfrac{1}{4\pi}\right)\hat{k}$

2. An α-particle (mass 4 amu) and a singly charged sulfur ion (mass 32 amu) are initially at rest. They are accelerated through a potential V and then allowed to pass into a region of uniform magnetic field which is normal to the velocities of the particles. Within this region, the α-particle and the sulfur ion move in circular orbits of radii r_α and r_s, respectively. The ratio (r_s/r_α) is______.

[JEE(Advanced) 2021]

3. Two concentric circular loops, one of radius R and the other of radius 2R, lie in the xy-plane with the origin as their common center, as shown in the figure. The smaller loop carries current I_1 in the anti-clockwise direction and the larger loop carries current I_2 in the clockwise direction, with $I_2 > 2I_1$. $\vec{B}$ (x, y) denotes the magnetic field at a point (x, y) in the xy-plane. Which of the following statement(s) is(are) current? **[JEE(Advanced) 2021]**



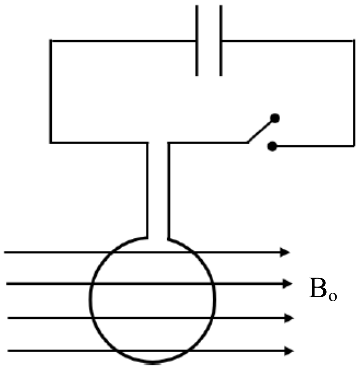
(A) $\vec{B}$ (x, y) is perpendicular to the xy-plane at any point in the plane

(B) $\left|\vec{B}(x,y)\right|$ depends on x and y only through the radial distance $r = \sqrt{x^2+y^2}$

(C) $\left|\vec{B}(x,y)\right|$ is non-zero at all points for r < R

(D) $\vec{B}$ (x, y) points normally outward from the xy-plane for all the points between the two loops

4. A circular coil of radius R and N turns has negligible resistance. As shown in the schematic figure, its two ends are connected to two wires and it is hanging by those wires with its plane being vertical. The wires are connected to a capacitor with charge Q through a switch. The coil is in a horizontal uniform magnetic field B_o parallel to the plane of the coil. When the switch is closed, the capacitor gets discharged through the coil in a very short time. By the time the capacitor is discharged fully, magnitude of the angular momentum gained by the coil will be (assume that the discharge time is so short that the coil has hardly rotated during this time)- **[JEE(Advanced) 2020]**



(A) $\frac{\pi}{2} NQB_oR^2$ (B) πNQB_oR^2 (C) $2\pi NQB_oR^2$ (D) $4\pi NQB_oR^2$

5. Two infinitely long straight wires lie in the xy-plane along the lines $x = \pm R$. The wire located at $x = +R$ carries a constant current I_1 and the wire located at $x = -R$ carries a constant current I_2. A circular loop of radius R is suspended with its centre at $(0, 0, \sqrt{3}R)$ and in a plane parallel to the xy-plane. This loop carries a constant current I in the clockwise direction as seen from above the loop. The current in the wire is taken to be positive if it is in the $+\hat{j}$ direction. Which of the following statements regarding the magnetic field $\vec{B}$ is (are) true ? **[JEE(Advanced) 2018]**

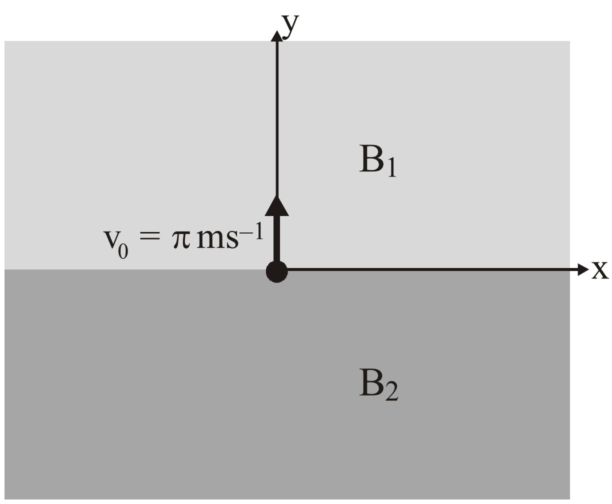
(A) If $I_1 = I_2$, then $\vec{B}$ cannot be equal to zero at the origin (0, 0, 0)

(B) If $I_1 > 0$ and $I_2 < 0$, then $\vec{B}$ can be equal to zero at the origin (0, 0, 0)

(C) If $I_1 < 0$ and $I_2 > 0$, then $\vec{B}$ can be equal to zero at the origin (0, 0, 0)

(D) If $I_1 = I_2$, then the z-component of the magnetic field at the centre of the loop is $\left(-\frac{\mu_0 I}{2R}\right)$

6. In the x-y-plane, the region $y > 0$ has a uniform magnetic field $B_1\hat{k}$ and the region $y < 0$ has a another uniform magnetic field $B_2\hat{k}$. A positively charged particle is projected from the origin along the positive y-axis with speed $v_0 = \pi ms^{-1}$ at $t = 0$, as shown in the figure. Neglect gravity in this problem. Let $t = T$ be the time when the particle crosses the x-axis from below for the first time. If $B_2 = 4B_1$, the average speed of the particle, in ms^{-1}, along the x-axis in the time interval T is _____.



[JEE(Advanced) 2018]

7. A moving coil galvanometer has 50 turns and each turn has an area $2 \times 10^{-4}\ m^2$. The magnetic field produced by the magnet inside the galvanometer is 0.02 T. The torsional constant of the suspension wire is 10^{-4} N m rad^{-1}. When a current flows through the galvanometer, a full scale deflection occurs if the coil rotates by 0.2 rad. The resistance of the coil of the galvanometer is 50 Ω. This galvanometer is to be converted into an ammeter capable of measuring current in the range 0 – 1.0 A. For this purpose, a shunt resistance is to be added in parallel to the galvanometer. The value of this shunt resistance, in ohms, is________. **[JEE(Advanced) 2018]**

Answer Q.8, Q.9 and Q.10 by appropriately matching the information given in the three columns of the following table.

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

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

8. In which case will the particle move in a straight line with constant velocity ? **[JEE(Advanced) 2017]**

(A) (II) (iii) (S) (B) (IV) (i) (S) (C) (III) (ii) (R) (D) (III) (iii) (P)

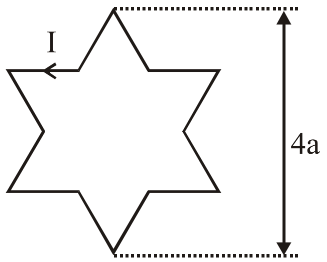
9. In which case will the particle describe a helical path with axis along the positive z-direction ? **[JEE(Advanced) 2017]**

(A) (II) (ii) (R) (B) (IV) (ii) (R) (C) (IV) (i) (S) (D) (III) (iii) (P)

10. In which case would the particle move in a straight line along the negative direction of y-axis (i.e., move along $-\hat{y}$) ? **[JEE(Advanced) 2017]**

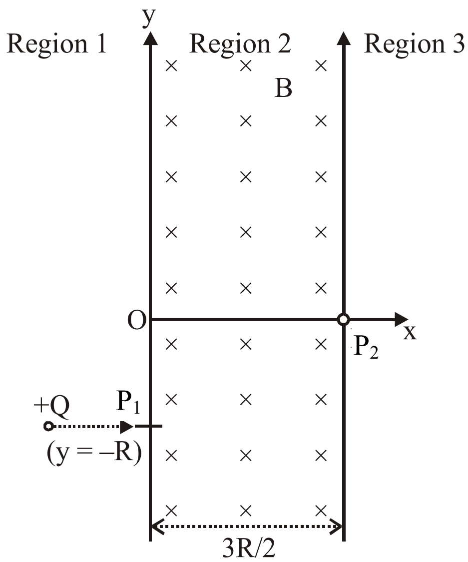
(A) (IV) (ii) (S) (B) (III) (ii) (P) (C) (II) (iii) (Q) (D) (III) (ii) (R)

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



(A) $\frac{\mu_0 I}{4\pi a}3\left[\sqrt{3}-1\right]$ (B) $\frac{\mu_0 I}{4\pi a}6\left[\sqrt{3}-1\right]$ (C) $\frac{\mu_0 I}{4\pi a}6\left[\sqrt{3}+1\right]$ (D) $\frac{\mu_0 I}{4\pi a}3\left[2-\sqrt{3}\right]$

12. A uniform magnetic field B exists in the region between x = 0 and x = $\frac{3R}{2}$ (region 2 in the figure) pointing normally into the plane of the paper. A particle with charge +Q and momentum p directed along x-axis enters region 2 from region 1 at point P_1(y = –R). Which of the following options(s) is/are correct ? **[JEE(Advanced) 2017]**



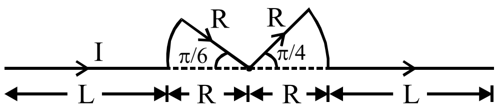
(A) For $B = \frac{8}{13}\frac{p}{QR}$, the particle will enter region 3 through the point P_2 on x-axis

(B) For $B > \frac{2}{3}\frac{p}{QR}$, the particle will re-enter region 1

(C) For a fixed B, particle of same charge Q and same velocity v, the distance between the point P_1 and the point of re-entry into region 1 is inversely proportional to the mass of the particle.

(D) When the particle re-enters region 1 through the longest possible path in region 2, the magnitude of the charge in its linear momentum between point P_1 and the farthest point from y-axis is $\frac{p}{\sqrt{2}}$.

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



(A) If $\vec{B}$ is along $\hat{z}$, $F \propto (L + R)$

(B) If $\vec{B}$ is along $\hat{x}$, $F = 0$

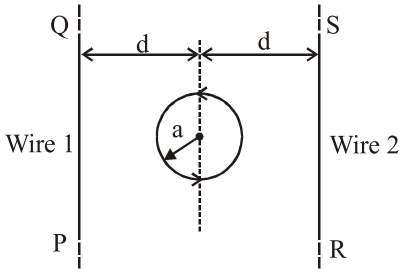
(C) If $\vec{B}$ is along $\hat{y}$, $F \propto (L + R)$

(D) If $\vec{B}$ is along $\hat{z}$, $F = 0$

14. Two parallel wires in the plane of the paper are distance X_0 apart. A point charge is moving with speed u between the wires in the same plane at a distance X_1 from one of the wires. When the wires carry current of magnitude I in the same direction, the radius of curvature of the path of the point charge is R_1. In contrast, if the currents I in the two wires have directions opposite to each other, the radius of curvature of the path is R_2. If $\frac{X_0}{X_1} = 3$, and $\frac{R_1}{R_2}$ value of is **[JEE(Advanced) 2014]**

Paragraph for Questions No. 15 & 16

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



15. When $d \approx a$ but wires are not touching the loop, it is found that the net magnetic field on the axis of the loop is zero at a height h above the loop. In that case **[JEE(Advanced) 2014]**

(A) current in wire 1 and wire 2 is the direction PQ and RS, respectively and $h \approx a$

(B) current in wire 1 and wire 2 is the direction PQ and SR, respectively and $h \approx a$

(C) current in wire 1 and wire 2 is the direction PQ and SR, respectively and $h \approx 1.2\ a$

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

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

[JEE(Advanced) 2014]

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

SOLUTIONS

1. Ans. (C)

Sol. $\vec{B}=\frac{\mu_0 I}{4\pi L}\sin 45°(-\hat{k})+\frac{\mu_0 I\pi}{4\pi\frac{L}{2}}(-\hat{k})+\frac{\mu_0 I}{4\pi\frac{L}{4}}\times\frac{\pi}{2}(-\hat{k})$

2. Ans. (4)

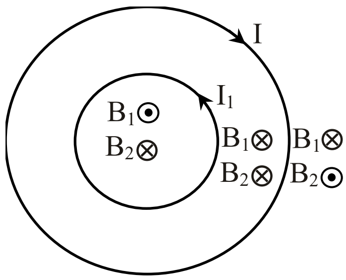
Sol. $r\frac{mv}{qB}=\frac{\sqrt{2mgV}}{qB}$

$\frac{P^2}{2m}=K.E=qV$

$\frac{r_S}{r_\alpha}=\sqrt{\frac{32}{1}\times\frac{2}{4}}=4$

3. Ans. (A, B)

Sol.



(A) $d\vec{B}=\frac{\mu_0 i\overrightarrow{d\ell}\times\vec{r}}{4\pi r^3}$

$\overrightarrow{d\ell}$ is in xy plane & $\vec{r}$ is also in xy plane

so $d\vec{B}$ is perpendicular to xy plane

(B) Due to symmetry it depends only on $r=\sqrt{x^2+y^2}$

(C) At centre $B_1=\frac{\mu_0 I_1}{2R}; B_2=\frac{\mu_0 I_2}{4R}\Rightarrow B_2>B_1$

bu as we approach towards first loop B_1 increases to infinity hence B_1 dominates.

So it would be zero at some point between inner loops and centre.

4. Ans. (B)

Sol. Torque experienced by circular loop = $\vec{M}\times\vec{B}$

where $\vec{M}$ is magnetic moment

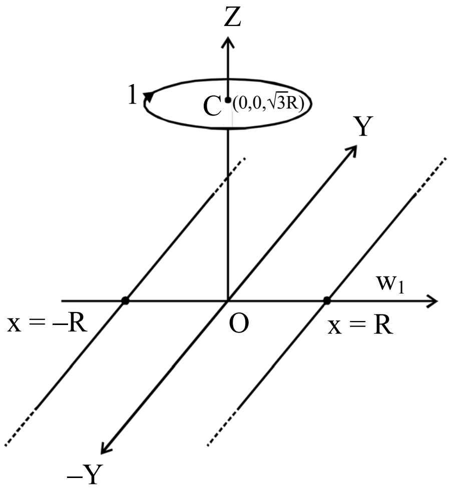
$\vec{B}$ is magnetic field

$\therefore\ \tau = i\pi R^2 N B_0$ [at the instant shown $\theta=\pi/2$]

$\therefore\ \vec{\tau}dt=d\vec{L}=i\pi R^2 NB_0\,dt=Q\pi R^2 N B_0[idt=Q]$

5. Ans. (A, B, D)

Sol.

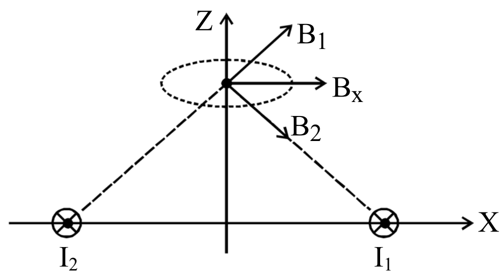


(A) At origin, $\vec{B}=0$ due to two wires if $I_1 = I_2$, hence $(\vec{B}_{net})$ at origin is equal to $\vec{B}$ due to ring, which is non-zero.

(B) If $I_1 > 0$ and $I_2 < 0$, $\vec{B}$ at origin due to wires will be along $+\hat{k}$ direction and $\vec{B}$ due to ring is along $-\hat{k}$ direction and hence $\vec{B}$ can be zero at origin.

(C) If $I_1 < 0$ and $I_2 > 0$, $\vec{B}$ at origin due to wires is along $-\hat{k}$ and also along $-\hat{k}$ due to ring, hence $\vec{B}$ cannot be zero.

(D)

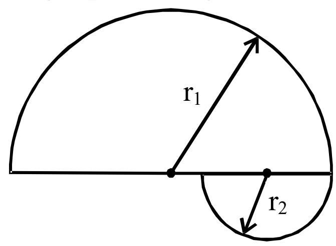


At centre of ring, $\vec{B}$ due to wires is along x-axis,

Hence z-component is only because of ring which $\vec{B}=\frac{\mu_0 i}{2R}(-\hat{k})$

6. Ans. (2.00)

Sol. (1) Average speed along x-axis



$\langle v_x\rangle=\frac{\int|\vec{v}_x|dt}{\int dt}=\frac{d_1+d_2}{t_1+t_2}$

(2) We have,

$$r_1 = \frac{mv}{qB_1}, r_2 = \frac{mv}{qB_2}$$

Since $B_1 = \frac{B_2}{4}$

$\therefore r_1 = 4r_2$

Time in $B_1 \Rightarrow \frac{\pi m}{qB_1} = t_1$

Time in $B_2 \Rightarrow \frac{\pi m}{qB_2} = t_2$

Total distance along x-axis $d_1 + d_2 = 2r_1 + 2r_2$

$= 2(r_1 + r_2) = 2(5r_2)$

Total time $T = t_1 + t_2 = 5t_2$

$\therefore$ Average speed $= \frac{10r_2}{5t_2} = 2\frac{mv}{qB_2} \times \frac{qB_2}{\pi m} = 2$

7. Ans. (5.55)

Sol. $n = 50$ turns $A = 2 \times 10^{-4}\ m^2$

$B = 0.02\ T \quad K = 10^{-4}$

$Q_m = 0.2$ rad $\qquad R_g = 50\ \Omega$

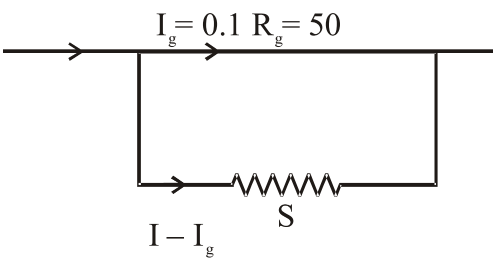
$I_A = 0 - 1.0\ A \qquad \tau = MB = C\theta$, $M = nIA$

$BINA = C\theta$

$0.02 \times 1 \times 50 \times 2 \times 10^{-4} = 10^{-4} \times 0.2\ 10$

$I_g = 0.1\ A$

For galvanometer, resistance is to be connected to ammeter in shunt.



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

$0.1 \times 50 = (1 - 0.1)\ S$

$S = \frac{50}{9} = 5.55$

8. Ans. (A)

Sol. $\vec{F}_{net} = \vec{F}_e + \vec{F}_B$

$= q\vec{E} + q\vec{v} \times \vec{B}$

For particle to move in straight line with constant velocity, $\vec{F}_{net} = 0$

$\therefore q\vec{E} + q\vec{v} \times \vec{B} = 0$

9. Ans. (C)

Sol. For path to be helix with axis along +ve z-direction, particle should experience a centripetal acceleration in x-y plane.

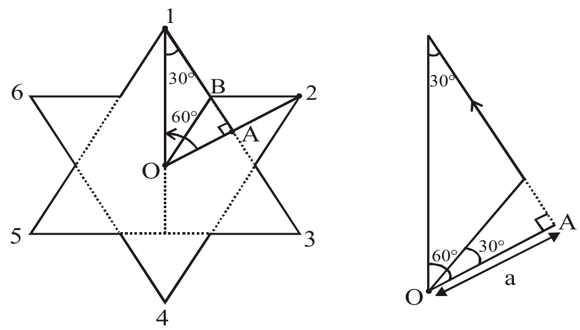
For the given set of options only option (C) satisfy the condition. Path is helical with increasing pitch.

10. Ans. (D)

Sol. For particle to move in –ve y-direction, either its velocity must be in –ve y-direction (if initial velocity $\neq 0$) & force should be parallel to velocity or it must experience a net force in –ve y-direction only (if initial velocity = 0)

11. Ans. (B)

Sol. The given points (1, 2, 3, 4, 5, 6) makes 360° angle at 'O'. Hence angle made by vertices 1 & 2 with 'O' is 60°.



Direction of magnetic field at 'O' due to each segment is same. Since it is symmetric star shape, magnitude will also be same.

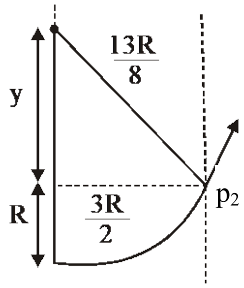
Magnetic field due to section BC.

$$(B_1) = \frac{ki}{a}(\sin(+60) - \sin 30) = \frac{ki}{2a}(\sqrt{3} - 1)$$

$$B_{net} = 12 \times B_1 = \frac{6ki}{a}(\sqrt{3} - 1) \& \left(k = \frac{\mu_0}{4\pi}\right)$$

12. Ans. (A, B)

Sol.



For $B = \frac{8}{13}\frac{p}{QR}$, radius of path

$R' = \frac{p}{Q.B} = \frac{p\times 13QR}{Q8p} = \frac{13}{8}R$

using pythagorous theorem, $y = \frac{5R}{8}$

$\therefore$ particle will enter region 3 through point P_2

for $B > \frac{2}{3}\frac{p}{QR}$

Radius of path $< \frac{3PQR}{Q2p} = \frac{3}{2}R$

$\therefore$ Particle will not enter in region 3 & will re-enter region 1

charge in momentum $=\sqrt{2}p$. When particle enters region 1 between entry point & farthest point from y-axis.

13. Ans. (A, B, C)

Sol. $\vec{F} = I\left(\overline{\text{Displacement}}\right)\times\vec{B}$

as magnetic field is uniform

$\vec{F} = I(2L+2R)\hat{i}\times\vec{B}$

When $\vec{B}$ is along y or z axis

$F \propto (L + R)$

When $\vec{B}$ is along x-axis

$F = 0$

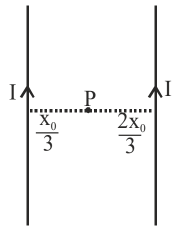
14. Ans. (3)

Sol. If current is in same direction, then magnetic field at point P will be

$$B_1 = \frac{\mu_0 I}{2\pi\left(\frac{x_0}{3}\right)} - \frac{\mu_0 I}{2\pi\left(\frac{2x_0}{3}\right)}$$

$$B_1 = \frac{3\mu_0 I}{4\pi x_0}$$

If current is in opposite direction, then magnetic field at point P will be



$$B_2 = \frac{\mu_0 I}{2\pi\left(\frac{x_0}{3}\right)} + \frac{\mu_0 I}{2\pi\left(\frac{2x_0}{3}\right)}$$

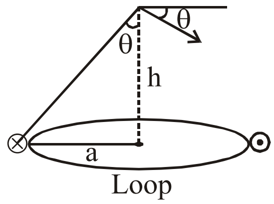
$$B_2 = \frac{9\mu_0 I}{4\pi x_0}$$

Radius of curvature, $R = \frac{mu}{qB}$

$$\frac{R_1}{R_2} = \frac{B_2}{B_1} = 3$$

15. Ans. (C)

Sol.



$$B_{wire} = \frac{\mu_0 i}{2\pi\sqrt{a^2+h^2}}2\sin\theta$$

$$= \frac{\mu_0 ia}{\pi(a^2+h^2)}$$

$$B_{loop} = \frac{\mu_0 ia^2}{2(a^2+h^2)^{3/2}}$$

$B_{wire} = B_{loop}$

$$\frac{\mu_0 ia}{\pi(a^2+h^2)} = \frac{\mu_0 ia^2}{2(a^2+h^2)^{3/2}}$$

$$\sqrt{a^2+h^2} = \frac{\pi a}{2}$$

$a^2 + h^2 = 2.5\,a^2$

$h^2 = 1.5a^2$

$h \approx 1.2\,a$

16. Ans. (B)

Sol. $|\vec{r}| = |\vec{M}\times\vec{B}| = MB\sin 30°$

where $M = (\pi a^2)I$ and $B = 2\times\frac{\mu_0 I}{2\pi d} = \frac{\mu_0 I}{\pi d}$

Therefore $\tau = \left(\frac{\mu_0 I}{\pi d}\right)(\pi a^2 I)\left(\frac{1}{2}\right) = \frac{\mu_0 I^2 a^2}{2d}$