GUIDED REVISION

Magnetic Effects of Current + Earth magnetic field, Type of magnetic materials

SECTION-I

Single Correct Answer Type **15 Q. [3 M (–1)]**

1. A copper wire of diameter 1.6 mm carries a current of 20 A. Find the maximum magnitude of the magnetic field $\vec{B}$ due to this current.

(A) 5.0 mT (B) 10 mT (C) 15 mT (D) 15.5 mT

2. An electron is moving along positive x-axis. A uniform electric field exists towards negative y-axis. What should be the direction of magnetic field of suitable magnitude so that net force of electron is zero

(A) positive z- axis (B) negative z-axis
(C) positive y-axis (D) negative y-axis

3. In a cyclotron, a charged particle

(A) undergoes acceleration all the time.
(B) speeds up between the dees because of the magnetic field.
(C) speeds up in a dee.
(D) slows down within a dee and speeds up between dees.

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

(A) zero (B) $\dfrac{\mu_0 \pi i I r^2}{4R}$

(C) $\dfrac{\mu_0 \pi i I r^2}{2R}$ (D) $\dfrac{\mu_0 \pi i I r^2}{R}$

5. The length of a magnet is large compared to its width and breadth. The time period of its oscillation in a vibration magnetometer is 2s. The magnet is cut along its length into three equal parts and three parts are then placed on each other with their like poles together. The time period of this combination will be- **[AIEEE - 2004]**

(A) 2s (B) 2/3 s (C) $2\sqrt{3}$ s (D) $2/\sqrt{3}$ s

6. A long straight wire along the z-axis carries a current I in the negative z direction. The magnetic vector field $\vec{B}$ at a point having coordinates (x, y) in the z = 0 plane is :- **[JEE 2002 (screening)]**

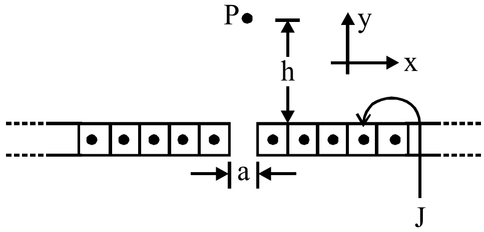
(A) $\dfrac{\mu_0 I}{2\pi}\dfrac{(y\hat{i} - x\hat{j})}{(x^2 + y^2)}$ (B) $\dfrac{\mu_0 I}{2\pi}\dfrac{(x\hat{i} + y\hat{j})}{(x^2 + y^2)}$

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

7. A charge particle is moving with a velocity $3\hat{i} + 4\hat{j}$ m/sec and it has electric field $\vec{E} = 10\hat{k}\,N/C$ at a given point. Find the magnitude of magnetic field at the same point due to the motion of the charge particle :-

(A) 100 $\mu_0\varepsilon_0$ (B) 25 $\mu_0\varepsilon_0$
(C) 12.5 $\mu_0\varepsilon_0$ (D) 50 $\mu_0\varepsilon_0$

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



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

(B) $\frac{\mu_0 Jh}{2a\pi}\hat{i}$

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

(D) $-\frac{\mu_0 j}{2}\left(\frac{h}{a\pi}-1\right)\hat{i}$

9. A long, straight wire carries a current along the Z-axis. One can not find two points in the X-Y plane such that

(A) the magnetic fields are equal

(B) the directions of the magnetic fields are the same

(C) the magnitudes of the magnetic fields are equal

(D) the field at one point is opposite to that at the other point.

10. A particle of specific charge (q/m) is projected from the origin of coordinates with initial velocity [u**i** – v**j**]. Uniform electric and magnetic fields exist in the region along the +y direction, of magnitude E and B. The particle will definitely return to the origin once if

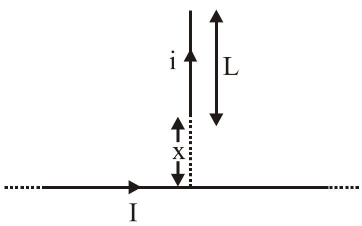
(A) $[vB/2\pi E]$ is an integer

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

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

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

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



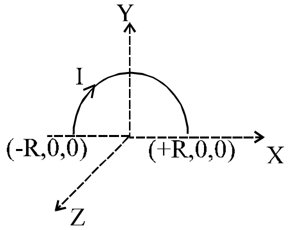
(A) $\frac{\mu_0 iI^2}{2\pi}\ell n\left(\frac{x+\ell}{2x}\right)$

(B) $\frac{\mu_0 iI^2}{2\pi}\ell n\left(\frac{2x+\ell}{2x}\right)$

(C) $\frac{\mu_0 iI}{2\pi}\ell n\left(\frac{x+\ell}{x}\right)$

(D) None of these

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



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

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

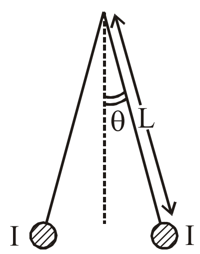
(A) $2\pi R^4\sigma\omega$ (B) $\pi R^4\sigma\omega$ (C) $\frac{\pi R^4}{2}\sigma\omega$ (D) $\frac{\pi R^4}{4}\sigma\omega$

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

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

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

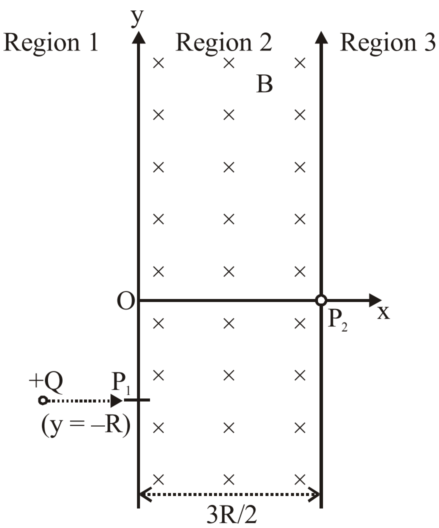
[JEE(Mains) - 2015]



(A) $2\sqrt{\frac{\pi g L}{\mu_0}\tan\theta}$ (B) $\sqrt{\frac{\pi\lambda g L}{\mu_0}\tan\theta}$ (C) $\sin\theta\sqrt{\frac{\pi\lambda g L}{\mu_0\cos\theta}}$ (D) $2\sin\theta\sqrt{\frac{\pi\lambda g L}{\mu_0\cos\theta}}$

Multiple Correct Answer Type 1 Q. [4 M (–1)]

16. 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 chage in its linear momentum between point P_1 and the farthest point from y-axis is $\frac{p}{\sqrt{2}}$.

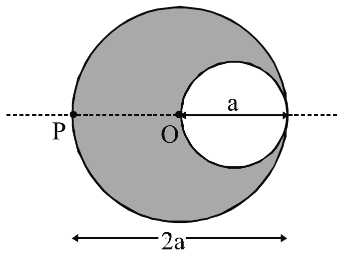
SECTION-III

Numerical Grid Type (Ranging from 0 to 9) 2 Q. [4 M (0)]

1. A wire of length L is shaped into a circle and then bent in such a way that the two semi-circles are perpendicular. The magnetic moment of the system when current I flows through the system is $\left(\frac{\sqrt{2}\,iL^2}{8\pi}\right)n$, than value of n is :

2. A cylindrical cavity of diameter a exists inside a cylinder of diameter 2a as shown in the figure. Both the cylinder and the cavity are infinitely long. A uniform current density J flows along the length. If the magnitude of the magnetic field at the point P is given by $\frac{N}{12}\mu_0 aJ$, then the value of N is :

[IIT-JEE 2012]



SECTION-IV

Matrix Match Type (4 × 5) **2 Q. [8 M (for each entry +2(0)]**

1. A charged particle with some initial velocity is projected in a region where uniform electric and/or magnetic fields are present. In Column-I information about the existence of electric and/or magnetic field and direction of initial velocity of charged particle are given, while in column-II the possible paths of charged particle is mentioned. Match the entries of Column I with the entries of Column-II.

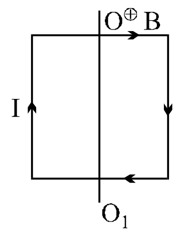
Column–I	**Column–II**
(A) $\vec{E} = 0, \vec{B} \neq 0$ and initial velocity is at an unknown angle with $\vec{B}$	(P) Straight line
(B) $\vec{E} \neq 0, \vec{B} = 0$ and initial velocity is at an unknown angle with $\vec{E}$	(Q) Parabola
(C) $\vec{E} \neq 0, \vec{B} \neq 0, \vec{E} \parallel \vec{B}$ and initial velocity is perpendicular to $\vec{E}$	(R) Circular
(D) $\vec{E} \neq 0, B \neq 0, \vec{E}$ is perpendicular to $\vec{B}$ and initial velocity is perpendicular to both $\vec{E}$ and $\vec{B}$	(S) Helical path with nonuniform pitch
	(T) Helical path with uniform pitch

2. Match the column I with column II -

Column–I	**Column–II**
(A) Paramagnetic substance	(P) $\chi_m = -1$
(B) Diamagnetic substance	(Q) $\chi_m < 0$
(C) Super conductor	(R) $\chi_m >> 1$
(D) Ferromagnetic substance	(S) $\mu_r > 1$

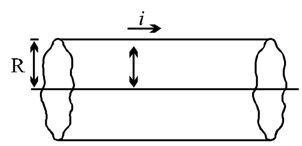
Subjective Type 9 Q. [4 M (0)]

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

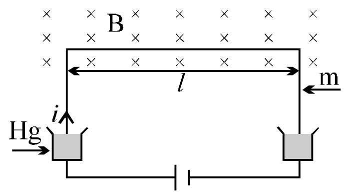


2. Two moving coil meters. M_1 and M_2 have the following particulars : ***(NCERT)***
$R_1 = 10\ \Omega$, $N_1 = 30$,
$A_1 = 3.6 \times 10^{-3}\ m^2$. $B_1 = 0.25$ T
$R_2 = 14\ \Omega$, $N_2 = 42$ $A_2 = 1.8 \times 10^{-3}\ m^2$, $B_2 = 0.50$ T
(The spring constants are identical for the two meters). Determine the ratio of (a) current sensitivity and (b) voltage sensitivity of M_2 and M_1.

3. A cylindrical conductor of radius R carries a current along its length. The current density J, however, it is not uniform over the cross section of the conductor but is a function of the radius according to J = br, where b is a constant. Find an expression for the magnetic field B.
(a) at $r_1 < R$ & (b) at distance $r_2 > R$, measured from the axis



4. A U-shaped wire of mass m and length *l* is immersed with its two ends in mercury (see figure). The wire is in a homogeneous field of magnetic induction **B**. If a charge, that is, a current pulse $q = \int i dt$, is sent through the wire, the wire will jump up.
Calculate, the height h that the wire reaches, the size of the charge or current pulse, assuming that the time of the current pulse is very small in comparision with the time of flight. Make use of the fact that impulse of force equals $\int F dt$,which equals mv. Evaluate q for B = 0.1 Wb/m^2, m = 10gm, ℓ = 20cm & h = 3 meters. [g = 10 m/s^2]



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

6. 3 infinitely long thin wires each carrying current *i* in the same direction, are in the x-y plane of a gravity free space . The central wire is along the y-axis while the other two are along $x = \pm d$.

(i) Find the locus of the points for which the magnetic field B is zero .

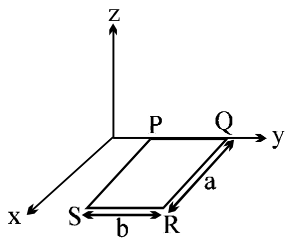
(ii) If the central wire is displaced along the z-direction by a small amount & released, show that it will execute simple harmonic motion. If the linear density of the wires is λ, find the frequency of oscillation.

7. A rectangular loop PQRS made from a uniform wire has length a, width b and mass m. It is free to rotate about the arm PQ, which remains hinged along a horizontal line taken as the y-axis (see figure). Take the vertically upward direction as the z-axis. A uniform magnetic field $\vec{B} = (3\hat{i} + 4\hat{k})B_0$ exists in the region. The loop is held in the x-y plane and a current I is passed through it. The loop is now released and is found to stay in the horizontal position in equilibrium. **[JEE 2002]**

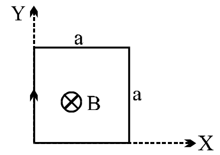
(a) What is the direction of the current I in PQ?

(b) Find the magnetic force on the arm RS.

(c) Find the expression for I in terms of B_0, a, b and m.

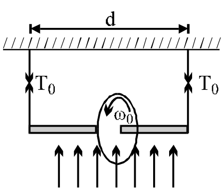


8. A rectangular loop of wire is oriented with the left corner at the origin, one edge along X-axis and the other edge along Y-axis as shown in the figure. A magnetic field is into the page and has a magnitude that is given by $\beta = \alpha y$ where α is constant. Find the total magnetic force on the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



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

[JEE 2003]



Magnetic Effects of Current + Earth magnetic field, Type of magnetic materials

SECTION-I

Single Correct Answer Type 15 Q. [3 M (–1)]

1. Ans. (A) **2. Ans. (B)** 3. Ans. (A) 4. **Ans. (C)**
5. Ans. (A) **6. Ans. (A)** **7. Ans. (D)** **8. Ans. (C)**
9. Ans. (A) **10. Ans. (C)** **11. Ans. (C)** **12. Ans. (A)**
13. Ans. (D) **14. Ans. (A)** **15. Ans. (D)**

Multiple Correct Answer Type 1 Q. [4 M (–1)]

16. Ans. (A,B)

SECTION-III

Numerical Grid Type (Ranging from 0 to 9) 2 Q. [4 M (0)]

1. Ans. 1 **2. Ans. 5**

SECTION-IV

Matrix Match Type (4 × 5) 2 Q. [8 M (for each entry +2(0)]

1. Ans. (A) → (P,R, T) ; (B) → (P,Q) ; (C) → (S) ; (D) → (P)
2. Ans. (A) → (S); (B) → (Q); (C) → (P); (D) → (R)

Subjective Type 9 Q. [4 M (0)]

1. Ans. $T_0 = 2\pi\sqrt{\frac{m}{6IB}} = 0.57$ s **2. Ans.** (a) 1.4, (b) 1

3. Ans. $B_1 = \frac{\mu_0 b r_1^2}{3}$, $B_2 = \frac{\mu_0 b R^3}{3r_2}$ **4. Ans.** $\sqrt{15}$ C

5. Ans. $i_1 = 0.1110$ A, $i_2 = 0.096$ A **6. Ans.** $z = 0$, $x = \pm\frac{d}{\sqrt{3}}$, (ii) $\frac{I}{2\pi d}\sqrt{\frac{\mu_0}{\pi\lambda}}$

7. Ans. (a) current in loop PQRS is clockwise from P to QRS., (b) $\vec{F} = BI_0 b\,(3\hat{k}-4\hat{i})$, (c) $I = \frac{mg}{6bB_0}$

8. Ans. $F = \alpha a^2 i\ \hat{j}$ **9. Ans.** $\omega = \frac{dT_0}{QR^2B}$

Magnetic Effects of Current + Earth magnetic field, Type of magnetic materials
SOLUTIONS
SECTION-I

Single Correct Answer Type **15 Q. [3 M (–1)]**

1. Ans. (A)

Sol. Maximum magnetic field is at surface of conductor.

$$= \frac{\mu_0 i}{2\pi R}$$

2. Ans. (B)

3. Ans. (A)

Sol. Circular motion is accelerated motion.

4. Ans. (C)

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

$M = iA = i\pi r^2$

$$\tau = \frac{\mu_0 I i \pi r^2}{2R}$$

5. Ans. (A)

Sol.

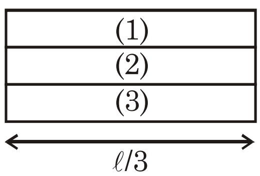
Mass = m

$$I_1 = \frac{m\ell^2}{12}$$

$M_1 = m'\ell$

m' = pole strength

mass = $\frac{m}{3}$



$$I_2 = 3\left(\frac{\frac{m}{3}\left(\frac{\ell}{3}\right)^2}{12}\right)$$

$$I_2 = \frac{m\ell^2}{108}$$

$$M_2 = 3\left(\frac{m'\ell}{3}\right) = m'\ell$$

$$\frac{T_1}{T_2} = \frac{2\pi\sqrt{\frac{I_1}{M_1 B}}}{2\pi\sqrt{\frac{I_2}{M_2 B}}}$$

$$= \sqrt{\frac{I_1}{I_2} \times \frac{M_2}{M_1}}$$

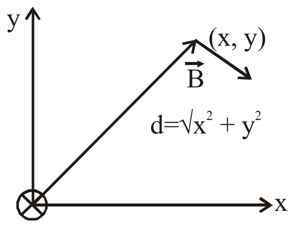
$$= \sqrt{9 \times 1}$$

$$T_2 = \frac{T_1}{3} = \frac{2}{3} \sec$$

6. Ans. (A)

Sol. $B = \dfrac{\mu_0 I}{2\pi\sqrt{x^2 + y^2}}$

unit vector in the direction of magnetic field is



$$\hat{B} = \frac{y\hat{i} - x\hat{j}}{\sqrt{x^2 + y^2}}$$

$$\vec{B} = B \cdot \hat{B} = \frac{\mu_0 I\left(y\hat{i} - x\hat{j}\right)}{2\pi\left(x^2 + y^2\right)}$$

7. Ans. (D)

Sol. $\vec{E} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r^2}\hat{r} = 10\hat{k}$

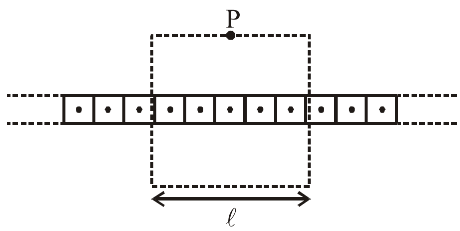
$$\hat{r} = \hat{k}$$

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v} \times \hat{r}}{r^2} = \mu_0\varepsilon_0\left\{\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\right\}\left(\vec{v} \times \hat{r}\right)$$

$$\left|\vec{B}\right| = \left|\left(10\mu_0\varepsilon_0\right)\left(\vec{v} \times \hat{r}\right)\right| = \left|\left(10\mu\varepsilon_0\right)\left(4\hat{i} - 3\hat{j}\right)\right| = 50\mu_0\varepsilon_0$$

8. Ans. (C)

Sol. Magnetic field due to whole plate



$$\oint B \cdot d\ell = \mu_0 J \times \ell$$

$$B \cdot 2\ell = \mu_0 J\ell$$

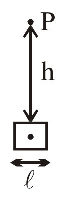
$$B = \frac{\mu_0 J}{2}\left(-\hat{i}\right)$$

magnetic field due to small sagment of width a.

Since small segment will behave like a long infinite wire carring current $I = J \cdot a$

$$\text{So } B = \frac{\mu_0 (Ja)}{2\pi h}\left(-\hat{i}\right)$$

So magnetic field due to plate after removing small segment



$$B = \frac{\mu_0 J}{2} - \frac{\mu_0 Ja}{2\pi h}$$

$$= \frac{\mu_0 J}{2}\left(1 - \frac{a}{\pi h}\right)\left(-\hat{i}\right)$$

9. Ans. (A)

Sol. Magnetic field is a vector quantity

10. Ans. (C)

Sol. Path of particle will be helicle.

$x = R\sin(\omega t)$

$$y = v\cdot t + \frac{1}{2}\left(\frac{QE}{m}\right)t^2$$

$$\left\{\omega = \frac{QB}{m}\right\}$$

$$R = \frac{mv}{qB}$$

$x = 0 \Rightarrow \omega t = n\cdot 2\pi$, n is positive integer

$y = 0$

$$t = \frac{2n\pi m}{QB}$$

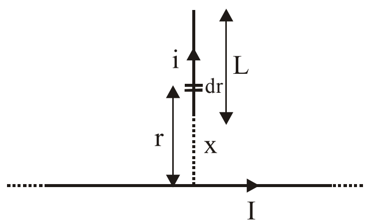
$$y = 0 \Rightarrow t = \frac{2mv}{Q.E}$$

$$\frac{2n\pi m}{QB} = \frac{2mv}{QE}$$

$$n = \frac{vB}{\pi E}$$

11. Ans. (C)

Sol. Magnetic field at dr, $B = \dfrac{\mu_0 I}{2\pi r}$



Force on small element at a distance r of wire

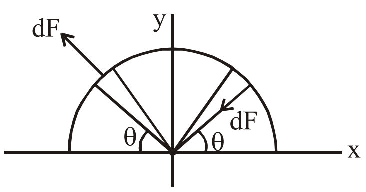
of length L is $dF = i(dr)\left(\dfrac{\mu_0 I}{2\pi r}\right)$

$$F = \frac{\mu_0 i I}{2\pi}\int_x^{x+L}\frac{dr}{r} = \frac{\mu_0 i I}{2\pi}\ell n\left(\frac{x+L}{x}\right)$$

12. Ans. (A)

Sol. If we take two small sagments on ring as shown in figure. Net force on both segments is in –x direction.

$$F_x = \int_0^{\pi} I\cdot\frac{B_0\left(R\cos\theta\right)\cdot Rd\theta\cdot\cos\theta}{2R}$$



$$= -\frac{IB_0R}{2}\int_0^{\pi}\cos^2\theta\, d\theta = -\frac{\pi IB_0R}{4}$$

$$F_y = \frac{IB_0R}{2}\int_0^{\pi}\sin\theta\cos\theta\, d\theta = 0$$

Net force will be

$$\vec{F} = \frac{\pi I B_0 R}{4}\left(-\hat{i}\right)$$

13. Ans. (D)

Sol. $\frac{M}{L} = \frac{Q}{2m}$

$$M = \frac{Q}{2m}(I\omega)$$

$$M = \frac{Q}{2m}\left(\frac{mR^2}{2}\omega\right)$$

$$M = \frac{(\sigma A)R^2\omega}{4}$$

$$\left[M = \sigma\omega\frac{\pi R^4}{4}\right]$$

14. Ans. (A)

Sol. Coercivity $= \frac{B}{\mu_0} = 3 \times 10^3 = nI$

$3 \times 10^3 = 1000\ I$

$I = 3A$

15. Ans. (D)

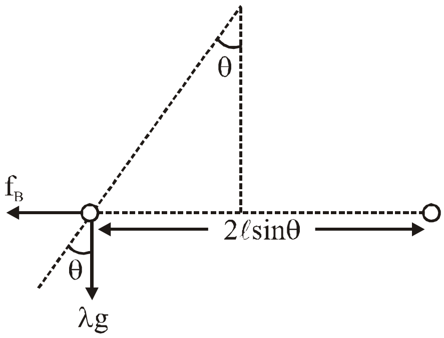
Sol. $B = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{2\pi(2\ell\sin\theta)}$

$\tan\theta = \frac{f_B}{\lambda g}$ where f_B is force per unit length(Bi)

$\lambda g \tan\theta = \frac{\mu_0 I}{2\pi(2\ell\sin\theta)} \times I$

on solving

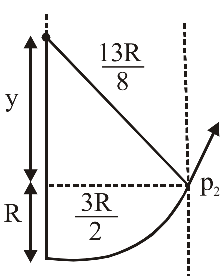
$I = 2\sin\theta\sqrt{\frac{\pi\lambda g\ell}{\mu_0\cos\theta}}$



Multiple Correct Answer Type 1 Q. [4 M (–1)]

16. Ans. (A,B)

Sol.



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

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

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 < $\frac{3PQR}{2PQ} = \frac{3}{2}R$

$\therefore$ 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.

SECTION-III

Numerical Grid Type (Ranging from 0 to 9) 2 Q. [4 M (0)]

1. Ans. 1

Sol. $M = I\frac{\pi R^2}{2}\sqrt{2}$ and $2\pi R = L$

Hence $M = \frac{IL^2\sqrt{2}}{8\pi}$

2. Ans. 5

Sol. $B_P = B_{Whole} - B_{Cavity}$

$$B_P = \frac{\mu_0 Ja}{2} - \frac{\mu_0 J\left(\frac{a}{2}\right)^2}{2\times\left(a+\frac{a}{2}\right)}$$

$$B_P = \mu_0 Ja\left(\frac{1}{2} - \frac{\frac{1}{4}}{3}\right)$$

$$= \mu_0 Ja\left(\frac{1}{2} - \frac{1}{12}\right)$$

$$= \mu_0 Ja\left(\frac{6-1}{12}\right)$$

$$B_P = \frac{5}{12}\mu_0 Ja$$

N = 5

SECTION-IV

Matrix Match Type (4 × 5) **2 Q. [8 M (for each entry +2(0)]**

1. Ans. (A) $\rightarrow$ **(P,R, T) ; (B) $\rightarrow$ (P,Q) ; (C) $\rightarrow$ (S) ; (D) $\rightarrow$ (P)**

Sol. $E = 0$ & $B \neq 0$

$F = qvB \sin\theta$

$F = 0$ if $\theta = 0°$

Path straight line

Path helical if $\theta \neq 90°$ & $0° < 0° < 180°$

Path circular if $\theta = 90°$

$E \neq 0, B = 0$

then a constant force $\vec{F} = q\vec{E}$ will act on charged particle

So path will be straight line if $\vec{F} \parallel \vec{v}$

& path will be parabola if angle between $\vec{F}$ & $\vec{v}$ is not 0° or 180°.

2. **Ans. (A) $\rightarrow$ (S); (B) $\rightarrow$ (Q); (C) $\rightarrow$ (P); (D) $\rightarrow$ (R)**

Subjective Type **9 Q. [4 M (0)]**

1. **Ans.** $T_0 = 2\pi\sqrt{\dfrac{m}{6IB}} = 0.57$ s

Sol. $$I = 2\left(\frac{m}{4}\frac{a^2}{12}\right) + 2\left(\frac{m}{4}\left(\frac{a}{2}\right)^2\right)$$

$$I = \frac{ma^2}{24} + \frac{ma^2}{8}$$

$$I = \frac{ma^2}{6}$$

$$T = 2\pi\sqrt{\frac{I}{MB}} = 2\pi\sqrt{\frac{\frac{ma^2}{6}}{Ia^2B}}$$

$$= 2\pi\sqrt{\frac{m}{6IB}} = 0.57\,\text{sec}$$

2. **Ans.** (a) 1.4, (b) 1

Sol. (a) $$\frac{(C.S.)_1}{(C.S.)_2} = \frac{N_1A_1B_1}{k_1} \times \frac{k_2}{N_2A_2B_2}$$

$$= \frac{30 \times 3.6 \times 10^{-3} \times 0.25}{42 \times 1.8 \times 10^{-3} \times 0.5}$$

$$= \frac{5}{7}$$

$$\frac{(C.S.)_2}{(C.S.)_1} = \frac{7}{5} = 1.4$$

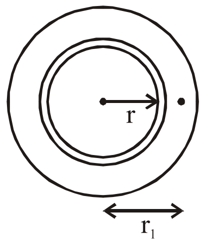
(b) $\dfrac{(\text{V.S.})_1}{(\text{V.S.})_2} = \dfrac{(\text{C.S.})_1}{(\text{C.S.})_2} \times \dfrac{R_2}{R_1} = \dfrac{5}{7} \times \dfrac{14}{10} = 1$

3. **Ans.** $B_1 = \dfrac{\mu_0 b r_1^2}{3}, \; B_2 = \dfrac{\mu_0 b R^3}{3r_2}$

Sol. (a) $di = J \cdot dA$

$\int (i\ell B) dt = mv$

$= br \times 2\pi r \times dr$



$$d_B = \frac{\mu_0 di}{2\pi r_1} = \frac{\mu_0 br \times 2\pi r dr}{2\pi r_1}$$

$$B = \int_0^{r_1} \frac{\mu_0 br^2 dr}{r_1} = \frac{\mu_0 b r_1^2}{3}$$

(b) $B = \int \dfrac{\mu_0 br^2 dr}{r_2} = \dfrac{\mu_0 b R^3}{3r_2}$

4. **Ans.** $\sqrt{15}$ C

Sol. $\int F dt = mv$

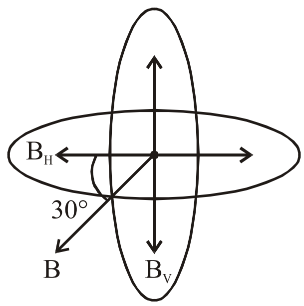
$\int (i\ell B) dt = mv$

$$\int i dt = \frac{mv}{\ell B} = \frac{m\sqrt{2gh}}{\ell B} = \frac{10^{-2}\sqrt{2 \times 10 \times 3}}{0.2 \times 0.1} = \sqrt{15}\text{C}$$

5. **Ans.** $i_1 = 0.1110$ A, $i_2 = 0.096$ A

Sol. B_1 (vertical coil) $= B_H$

$$B_H = \frac{N\mu_0 I_1}{2R_1} = \frac{4\pi \times 10^{-2} \times I_1 \times 100}{2 \times 20 \times 10^{-2}}$$



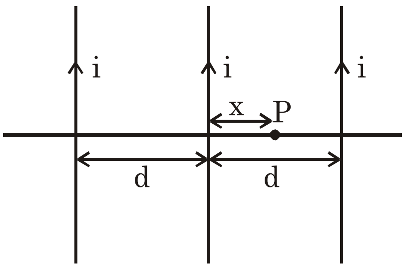
$$B_V = \frac{B_H}{\sqrt{3}}$$

B_2 (Horizontal coil) $= B_V = \dfrac{B_H}{\sqrt{3}}$

$$\frac{N_2 \mu_0 I_2}{2R_2} = \frac{B_H}{\sqrt{3}}$$

6. **Ans.** $z = 0$, $x = \pm \frac{d}{\sqrt{3}}$, (ii) $\frac{I}{2\pi d}\sqrt{\frac{\mu_0}{\pi\lambda}}$

Sol. (i)



$$B_P = \frac{\mu_0 i}{2\pi(d+x)} + \frac{\mu_0 i}{2\pi x} - \frac{\mu_0 i}{2\pi(d-x)}$$

$B_P = 0$

$$\frac{1}{d+x} - \frac{1}{d-x} + \frac{1}{x} = 0$$

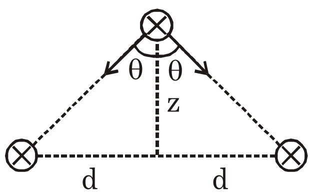
$$\frac{d-x-d-x}{d^2-x^2} + \frac{1}{x} = 0$$

$$\frac{1}{x} = \frac{2x}{d^2-x^2}$$

$3x^2 = d^2$

$$x = \pm\frac{d}{\sqrt{3}}, \; z = 0$$

(ii)



$F = I\ell B$

$$= i\ell\left(\frac{\mu_0 i}{2\pi\sqrt{z^2+d^2}}\right)$$

$F_{net} = -2F\cos\theta$

$$F_{net} = -2\frac{\mu_0 i^2 \ell}{2\pi\sqrt{z^2+d^2}}\left(\frac{z}{\sqrt{z^2+d^2}}\right)$$

$$F_{net} = -\frac{\mu_0 i^2 \ell}{\pi d^2} z \quad (z <<< d)$$

$F = -kz$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{\mu_0 i^2}{\lambda\pi d^2}} = \frac{i}{2\pi d}\sqrt{\frac{\mu_0}{\pi\lambda}}$$

7. **Ans.** (a) current in loop PQRS is clockwise from P to QRS., (b) $\vec{F} = BI_0b\ (3\hat{k}-4\hat{i})$, (c) $I = \dfrac{mg}{6bB_0}$

Sol. (a) $(T_{mg})_{PQ} \to$ (+y)-direction

So, torque of magnetic force should have component along (–y)-direction

So, current will be clockwise.

(b) $\vec{F} = I\left(d\vec{\ell} \times \vec{B}\right)$

$$= I\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & -b & 0 \\ 3B_0 & 0 & 4B_0 \end{vmatrix}$$

$$= IB_0b\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & -1 & 0 \\ 3 & 0 & 4 \end{vmatrix}$$

$$= IB_0b\left(3\hat{k} - 4\hat{i}\right)$$

(c) $\tau_{net} = 0$

$$mg \times \frac{a}{2} = \vec{M} \times \vec{B}$$

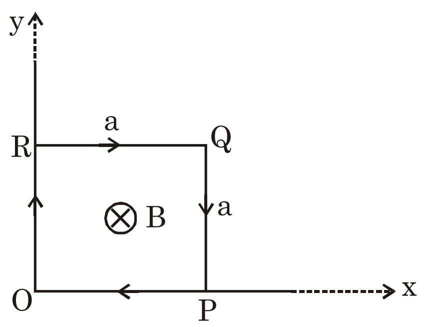
$$mg\frac{a}{2}\hat{j} = iab\left(-\hat{k}\right) \times B_0\left(3\hat{i} + 4\hat{k}\right)$$

$$mg\frac{a}{2} = 3iabB_0$$

$$i = \frac{mg}{6bB_0}$$

8. Ans. $F = \alpha a^2 i\ \hat{j}$

Sol.



For OR,

$$\vec{F} = idyB\left(-\hat{i}\right)$$

$$\vec{F} = i\alpha\int_0^a y\,dy\left(-\hat{i}\right)$$

$$\vec{F} = \frac{i\alpha a^2}{2}\left(-\hat{i}\right)$$

For RQ,

$y = a$

$B = \alpha a$

$$\vec{F} = i\left(a\right)\left(\alpha a\right)\left(+\hat{j}\right)$$

$$\vec{F} = i\,\alpha\,a^2\left(+\hat{j}\right)$$

For QP,

$$\vec{F} = i\,dy\left(B\right)\left(+\hat{i}\right)$$

$$\vec{F} = i\alpha\int_0^a y\,dy\left(+\hat{i}\right)$$

$$\vec{F} = \frac{i\alpha a^2}{2}\left(+\hat{i}\right)$$

For PO,

$y = 0$

$\vec{F} = 0$

$$\vec{F}_{net} = i\alpha a^2\left(+\hat{j}\right)$$

9. **Ans.** $\omega = \dfrac{d\,T_0}{QR^2B}$

Sol. Initially, $2T_0 = Mg$

$$T_0 = \frac{Mg}{2}$$

Finally, $T_1 + T_2 = Mg$

$$T_{net} = T_1\frac{d}{2} - T_2\frac{d}{2} + \mu B = I\alpha$$

for maximum ω_0

$\alpha = 0$

$$T_1 - T_2 = \frac{2\mu B}{d}$$

$$T_1 = \frac{3Mg}{4}, T_2 = \frac{Mg}{4}$$

$$\frac{Mg}{2} = 2\frac{\mu B}{d}$$

$$\mu = \frac{Mgd}{4B}$$

$$\frac{\mu}{L} = \frac{Q}{2M}$$

$$\mu = \frac{Q}{2M}\left(MR^2\omega_0\right)$$

$$\mu = \frac{QR^2\omega_0}{2}$$

$$\frac{Mgd}{4B} = \frac{QR^2\omega_0}{2}$$

$$\omega_0 = \frac{Mgd}{2QR^2B}$$

$$\omega_0 = \frac{dT_0}{QR^2B}$$