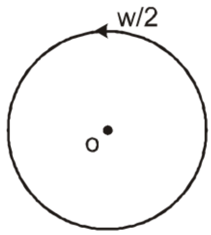
TOPIC : MAGNETIC EFFECT OF CURRENT & MAGNETIC FORCE ON CHARGE OR CURRENT (EMF)

EXERCISE # 1

SECTION (A)

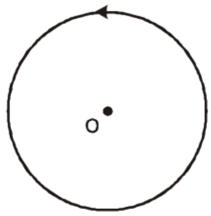
1. $B = \frac{\mu_0 i}{2R} = \frac{\mu_0 qf}{2R} = \frac{\mu_0\ qw}{2R\ 2\pi}\left(f = \frac{w}{2\pi}\right)$



or $B = \frac{\mu_0 100 \times 1.6 \times 10^{-19} \times 10^{11} \times 2\pi}{4\pi \times 0.8}$

$B = 10^{-6}\ \mu_0$

3. $B = \frac{\mu_0 i}{2R}$



$B_0 = \frac{\mu_0 qf}{2R} = \frac{\mu_0\ q\omega}{2R.\ 2\pi}$

$B_0 = 20^{-7} \times \frac{q\omega}{R}$

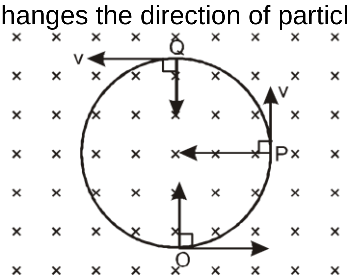
4. $r = 0.5 \times 10^{-10}$ m

$f = 5 \times 10^{15}$

$i = qf$

$= 1.6 \times 10^{-19} \times 5 \times 10^{15} = 8.0 \times 10^{-4}$ A = 0.8 mA

5. When a charged particle moves through a perpendicular magnetic field, then a magnetic force acts on it which changes the direction of particle but does not alter the magnitude of tis velocity(i.e. speed)



Note: If a charged particle moves at 45° to magnetic field then path of the particle will be a helix whose circular part has radius according to relation

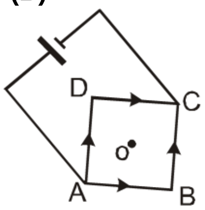
$r = \frac{mv\sin\theta}{qB}$

6. After passing through a magnetic field, the magnitude of its mass and velocity of the particle remain same, so its energy does not change, ie., kinetic energy will remain T.

7. Due to flow of current in same direction in two adjacent sides, an attractive magnetic force will be produced due to which spring will get compressed. '

8. Electrons, protons, and helium atoms are deflected in magnetic field so, the compound can emit electrons, protons and He^{2+} .

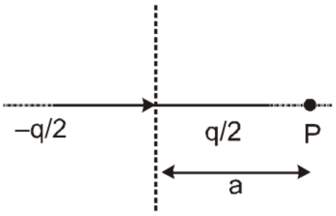
SECTION (B)



1.

$B_0 = B_{AB} + B_{BR} + B_{AD} + B_{DC}$

Now $B_{AB} = -B_{DC}$ and $B_{AD} = -B_{BC}$ then $B_0 =$ zero

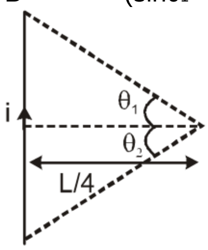


2.

Point P on the extended part of line they

B_P = zero = 0

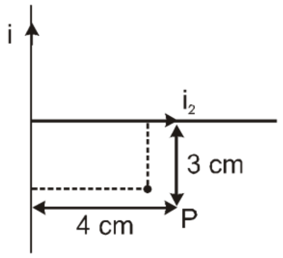
3. $B = \frac{\mu_0 i}{4\pi R}(\sin\theta_1 + \sin\theta_2)$



$\sin\theta_2 = \frac{L/2}{\sqrt{(L/2)^2 + (L/4)^2}} = \frac{1}{2(\sqrt{1/4 + 1/16})} = \frac{4}{2\sqrt{5}}$ $\Rightarrow$ $B = \frac{\mu_0 i}{4\pi R}\left(\frac{2\times 4}{2\sqrt{5}}\right)$

$B = \frac{4\mu_0 i}{\sqrt{5}\pi L}$

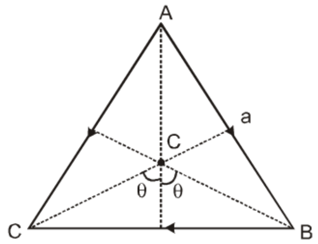
4.



$B_P = B_1 \odot + B_2 \odot$

$= \frac{\mu_0 i_1}{2\pi r_1} + \frac{\mu_0 i_2}{4\pi r_2} = \frac{2\times10^{-7}\times2}{4\times10^{-2}} + \frac{10^{-7}\times1.5}{3\times10^{-2}}$ = 1.5 ×10$_{-5}$ tesla

5.



$\theta = 60^o$

Perpendicular distance of C from any side

$B = 3B_1$ as $B_{AB} = B_{BC} = B_{CA} = B_1$

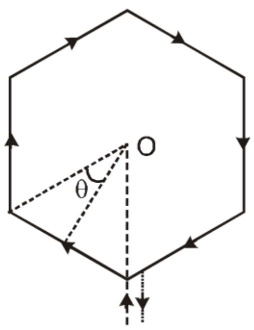
$= \frac{3\times\mu_0 i}{4\pi r}$ $(\sin\theta_1 + \sin\theta_2)$

$r = \frac{a}{2\sqrt{3}}$ and $\theta_1 = 60^o = \theta_2$

$B_C = \frac{3\times\mu_0 i\, 2\sqrt{3}}{4\pi\, a} \times \frac{2\times\sqrt{3}}{2}$

$B_C = \frac{9\mu_0 i}{2\pi\, a}$

6.



Perpencicular distance from side of "O" is a cos 30º

$r = \frac{\sqrt{3}a}{2}$

$B_{net} = 6.B,$

$= 6 \times \frac{\mu_0 i}{4\pi r}$ (sin 30º + sin 30º) = $\frac{6\times\mu_0 i\times2}{4\pi.\sqrt{3}a} \times \frac{2\times1}{2} = \frac{\sqrt{3}\mu_0 i}{\pi a}$

7. For external points the current carrying wire behaves as if thewhole current were concentrated at theaxis, so malgnetic field at far points from axis B = $\frac{\mu_0 i}{2\pi r}$ remains unaffected if diameter of wire is changed.

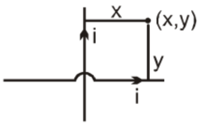
8. B = $\frac{\mu_0}{2\pi}\cdot\frac{1}{r}[5-2.5]$ = $2\times10^{-7}\times\frac{1}{2.5}\times2.5$ = $\frac{\mu_0}{2\pi}$

10. $\because$ $B \propto \frac{1}{r}$ $\quad\therefore$ $\frac{B}{f}=2B$

11. B = $\frac{\mu_0}{2\pi}\cdot\frac{i}{r}(\sin45)\times4$ = $2\sqrt{2}\cdot\frac{\mu_0}{\pi a}\cdot i$

12. Biot–Savart's law, dB = $\frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$. In vector form, $\vec{dB}=\frac{\mu_0}{4\pi}\frac{I\vec{dl}\times\hat{r}}{r^2}$

14. $\frac{\mu_0 i}{2\pi x}=\frac{\mu_0 i}{2\pi y}$

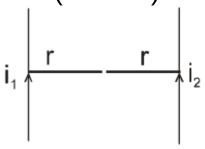


y = x

15. $i_1 > i_2$

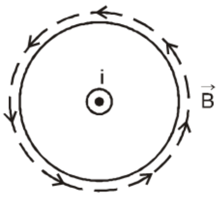
$\frac{\mu_0}{2r}(i_1 - i_2) = 10$

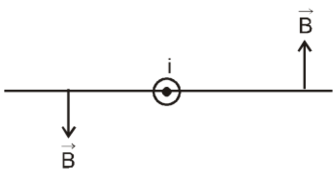
$\frac{\mu_0}{2r}(i_1 + i_2) = 30$



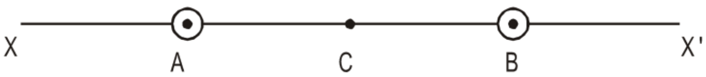
$\Rightarrow \frac{i_1+i_2}{i_1-i_2}=\frac{3}{1} \quad \Rightarrow \frac{i_1}{i_2}=\frac{2}{1}$ **Ans.(3)**

16. If the current flows out of the paper, the magnetic field at points to the right of the wire will be upwards & to the left will be downwards as shown in figure.





Now let us come to the problem.
Magnetic field at C = 0
Magnetic field in region BX' will be upwards (+ve) because all points lying in this region are to the right of both the wires.

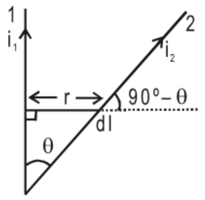


Similary
Magnetic field in region AX will be downwards (-ve)

Magnetic field in region AC will be upwards (+ve) , because points are closer to A, compared to B. Similarly Magnetic field in region BC will be downwards (-ve).
Graph (2) satisfies all these conditions. Therefore correct answer is (2).

17. Magnetic field on dl element due ot current i_1 is

$$B = \frac{\mu_0}{2\pi}\frac{i_1}{r} \qquad \text{...... (i)}$$



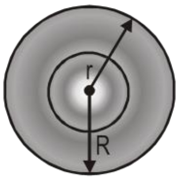
Unit force acting on dl element

$$\frac{F}{dl} = i_2 B \sin(90^o - \theta) \qquad \text{......(ii)}$$

Thus, $$\frac{F}{dl} = \frac{\mu_0}{2\pi}\frac{i_1 i_2}{r}\cos\theta$$

$$F = \frac{\mu_0 i_1 i_2 \, dl \cos\theta}{2\pi r}$$

18. Let R be radius of a long thin cylindrical shell.
To calculate the magnetic induction at a distance r (r < R) from the axis of cylinder, a circular loop of radius r is shown :



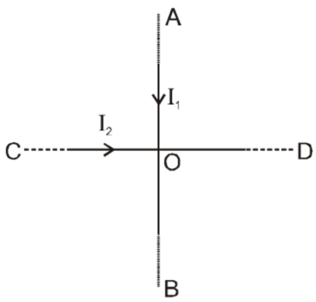
Since, no current is enclosed in the circle so, from Ampere's circuital law, magnetic induction is zero at every point of circle. Hence, the magnetic induction at any point inside the infinitely long straight thin walled tube (cylindrical) is zero.

19. $B_1 = \frac{\mu_0 i}{2\pi a^2} r$ where $0 \le r \le a$, $B_1 = \frac{\mu_0 i}{2\pi a^2} . \frac{a}{2}$

$B_1 = \frac{\mu_0 i}{4\pi a^2}$, $B_2 = \frac{\mu_0 i}{2\pi (2a)}$ (at r = 2a), $\frac{B_1}{B_2} = 1$.

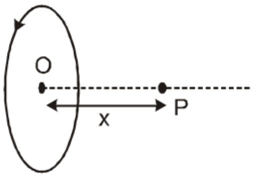
20. Magnetic field inside the infinitely long pipe is zero at all points.

21. Magnetic field due to AB and CD are $\frac{\mu_0 I_1}{2\pi d}$ and $\frac{\mu_0 I_2}{2\pi d}$ respectively



$B_{net} = \dfrac{\mu_0}{2\pi d}\sqrt{I_1^2 + I_2^2}$

SECTION (C)

1. 

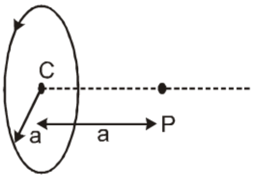
$B_P = \dfrac{B_0}{8} \Rightarrow \dfrac{\mu_0 i R^2}{2(R^2 + x^2)^{3/2}} = \dfrac{\mu_0 i}{2R \times 8}$, R = a (given)

$8R_3 = (R_2 + x_2)_{3/2}$

$2R = (R_2 + x_2)_{1/2}$

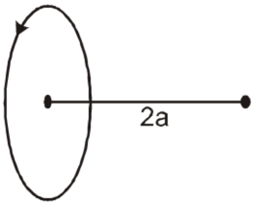
$x_2 = 3R_2$

$x = \sqrt{3}\ R = \sqrt{3}\ a$

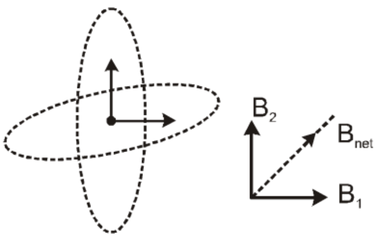
2. 

$\dfrac{B_C}{B_P} = \dfrac{\mu_0 i / 2a}{\mu_0 i a^2 / 2(a^2 + a^2)^{3/2}} = \dfrac{2\sqrt{2}}{1}$

3. $B_0 = B_1\odot + B_2\otimes$ as B zero due to θ_2 P and RS a + "O" = $\dfrac{\mu_0 i}{4\pi}\left(\dfrac{1}{r_1}\right) - \dfrac{\mu_0 i}{4\pi}\left(\dfrac{1}{r_2}\right) = \dfrac{\mu_0 i}{4\pi}\left(\dfrac{1}{r_1} - \dfrac{1}{r_2}\right)$

4. 

$B = \dfrac{\mu_0 i a^2}{2(a^2 + (2a)^2)^{3/2}} = \dfrac{\mu_0 i}{10\sqrt{5}a} \Rightarrow B = \dfrac{\mu_0 i}{10\sqrt{5}a}$

6. 

$B_1 = \dfrac{\mu_0 i N}{2R}$

$B_2 = \dfrac{\mu_0 \sqrt{3}\, i N}{2R} \Rightarrow B_{net} = \sqrt{B_1^2 + B_2^2} = \dfrac{\mu_0\, iN}{2R}(1+3)^{1/2} = \dfrac{\mu_0\, iN}{2R}.2 \Rightarrow B_{net} = \dfrac{\mu_0\, iN}{R}$

7. Suppose the magnetic field produced due to each coil is B.

The two coils are kept perpendicular hence, the angle between these is 90° therefore, the resultant magnetic field is given by = $\sqrt{B^2+B^2+2B.B.\cos 90°}$ = $\sqrt{2B^2+2B^2\times 0}=\sqrt{2B^2}=B\sqrt{2}$
Hence, the ratio of magnetic field due to one coil and the resultant magnetic field is given by = $\frac{B}{\sqrt{2}B}=1:\sqrt{2}$

8. Magnetic induction at the centre of current carrying coil

$B = \frac{\mu_0 ni}{2r}$ … (i)

Suppose the length of the wire be L. Ist case : For coil of one turn, let radius be r_1.

$\therefore$ $L = 2\pi r_1 \times n$ or $r_1 = \frac{L}{2\pi\times n} = \frac{L}{2\pi}$ ($\because n = 1$)

2nd case : For coil of two turns, let radius be r_2. $\therefore$ $L = 2\pi r_2 \times n$

or $r_2 = \frac{L}{2\pi\times n} = \frac{L}{2\pi\times 2}$ (n = 2) or $r_2 = \frac{r_1}{2}$ From Eq. (i), we have

$\frac{B_1}{B_2} = \frac{n_1}{r_1}\times\frac{r_2}{n_2}$ or $\frac{B_1}{B_2} = \frac{1\times\frac{r_1}{2}}{r_1\times 2}$ $\therefore$ $\frac{B_1}{B_2} = \frac{1}{4}$

9. At the centre of circular coil carrying current, the magnetic field is,

$B = \frac{\mu_0 Ni}{2r}$

where N = number of turns in the coil
i = current flowing
r = radius of the coil

Given, N = 1000, i = 0.1A, r = 0.1m
Substituting the values, we have

$B = \frac{4\pi\times 10^{-7}\times 1000\times 0.1}{2\times 0.1}$ = $2\pi \times 10^{-4} = 6.28 \times 10^{-4}$ tesla

11. Use $B = \frac{\mu_0}{4\pi}.\frac{\theta.i}{r}$

12. Magnetic field at the centre of circular coil

$B = \frac{\mu_0 Ni}{2r}$

Ist case : $N = 1$, $L = 2\pi r \Rightarrow r = \frac{L}{2\pi}$

$\therefore$ $B = \frac{\mu_0\times 1\times i}{2r} = \frac{\mu_0 i}{2r}$

IInd case : $N = 2$, $L = 2 \times 2\pi r'$

$\Rightarrow$ $r' = \frac{L}{4\pi} = \frac{r}{2}$ $\therefore$ $B' = \frac{\mu_0\times 2\times i}{2r'} = \frac{\mu_0\times 2i}{2\times(r/2)} = \frac{4\mu_0 i}{2r} = 4B$

Note : Magnetic field at the centre of circular coil is maximum and decreases as we move away from the centre (on the axis of coil)

13. Magnetic field at centre of circular coil A is

$B_A = \frac{u_0 Ni}{2R}$

R is radius and i is current flowing in coil.

Similarly $B_B = \frac{\mu_0 N(2i)}{2.(2R)} = \frac{\mu_0 Ni}{2R} = \frac{B_A}{B_B} = 1$

14. The magnetic field at the centre of circular coil is

$B = \frac{\mu_0 i}{2r}$

where r = radius of circle = $\frac{l}{2\pi}$ $(\because l = 2\pi r)$

$\therefore \quad B = \frac{\mu_0 i}{2} \times \frac{2\mu}{l} = \frac{\mu_0 i\pi}{l}$ ....(i)

when wire of length l bents into a circular loops of n turns, then

$l = n \times 2\pi r' \quad \Rightarrow \quad r' = \frac{1}{n \times 2\pi}$

Thus, new magnetic field

$B' = \frac{\mu_0 ni}{2r'} = \frac{\mu_0 ni}{2} \times \frac{n \times 2\pi}{l} = \frac{\mu_0 i\pi}{l} \times n_2$

$= n_2 B$ [from eq (i)]

15. The magnetic field at a point on the axis of a circular loop at distance x from the centre is

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

Given : B = 54 μT, x = 4 cm, R = 3cm

Putting the given values we get

$\therefore \quad 54 = \frac{\mu_0 i \times (3)^2}{2\left(3^2 + 4^2\right)^{3/2}} \quad \Rightarrow \quad 54 = \frac{9\mu_0 i}{2(25)^{3/2}} = \frac{9\mu_0 i}{2 \times (5)^3}$

$\therefore \quad \mu_0 i = \frac{54 \times 2 \times 125}{9}$

$\mu_0 i = 1500$

Now, putting x = 0 in equation (i), magnetic field at the centre of loop is

$B = \frac{\mu_0 i R^2}{2 \times 3} = \frac{\mu_0 i}{2R} = \frac{1500}{2 \times 3} = 250\ \mu T$

SECTION (D)

1. $\frac{\mu_0}{4\pi}.\frac{\pi.i}{R} + \frac{\mu_0}{4\pi}.\frac{i}{R} \quad \Rightarrow \quad \frac{\mu_0}{4\pi}.\frac{i}{R}(\pi + 1)$

2. Use $B = \frac{\mu_0}{4\pi}.\frac{\left(\frac{3\pi}{2}\right).i}{R}$

3. $B = \frac{\mu_0}{4\pi}.\theta.i\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

4. Magnetic field at the centre of a circular coil is

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

where i is current flowing in the coil and r is radius of coil

At the centre of coil - 1,

$B_1 = \frac{\mu_0}{4\pi} \times \frac{2\pi i_1}{r_1}$ ...(i)

At the centre of coil -2

$B_2 = \frac{\mu_0}{4\pi} \times \frac{2\pi i_2}{r_2}$ ...(ii)

but $B_1 = B_2$

∴ $\frac{\mu_0}{4\pi}\frac{2\pi i_1}{r_1} = \frac{\mu_0}{4\pi}\frac{2\pi i_2}{r_2}$ or $\frac{i_1}{r_1} = \frac{i_2}{r_2}$

As $r_1 = 2r_2$

∴ $\frac{i_1}{2r_2} = \frac{i_2}{r_2}$ or $i_1 = 2i_2$

Now, ratio of potential differences

$\frac{V_2}{V_1} = \frac{i_2 \times r_2}{i_1 \times r_1} = \frac{i_2 \times r_2}{2i_2 \times 2r_2} = \frac{1}{4}$ ∴

SECTION (E)

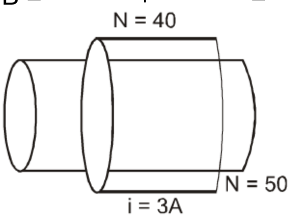
1. B = $\frac{\mu_0 \, . \, i}{2\pi R} . N$

$B \propto N$

So the magnetic field will be double

2. l = 0.1 m, i = 3A

B = $\frac{\mu_0 N_i i_1}{\ell_1} + \frac{\mu_0 N_2 i_2}{\ell_2} = \mu_0 \times \frac{i}{\ell}[N_1 + N_2]$

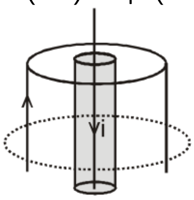


$= \frac{4\pi \times 10^{-7} \times 3 \times 900}{1}$ $= 4 \times 3.14 \times 10^{-7} \times 3 \times 900 = 33912 \times 10^{-2} = 3.4 \times 10^{-3}$

5. N = 200/cm, i = 2.5

$B = \mu_0 \, . \, ni = 4\pi \times 10^{-7} \times \dfrac{\frac{200}{1} \times 2.5}{\frac{1}{100}} = 6.28 \times 10^{-2}\ Wb/m^2$

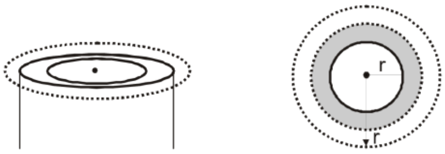
6. $B\,(2\pi r) = \mu_0\,(i - i) = 0$



$B = 0$

7. $B = \mu_0\mu_r ni = 10^{-7} \times 4\pi \times 4000 \times 1000 \times 5 = 8\pi\ T = 25.12\ T$

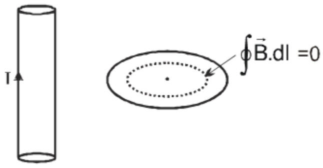
8. $\oint \vec{B}.\vec{dl} = \mu_0 \dfrac{i}{\pi R^2} \times \pi r^2$



$= \dfrac{\mu_0 i r^2}{R^2}$

$\oint \vec{B}.\vec{dl} = \mu_0 i$

9.



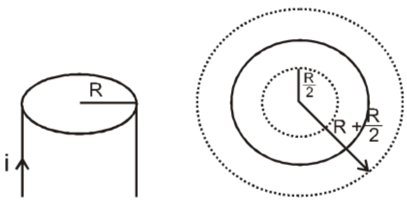
$\oint \vec{B}.\vec{dl} = 0$

B = 0 Ans. (2)

10. $B = \mu_0 ni$ or $B \propto ni$ $\therefore$ $\dfrac{B_1}{B_2} = \dfrac{n_1 i_1}{n_2 i_2}$

Here, $n_1 = n_1$, $n_2 = \dfrac{n}{2}$, $i_1 = i$, $i_2 = 2i$, $B_1 = B$ Hence, $\dfrac{B}{B_2} = \dfrac{n}{n/2} \times \dfrac{i}{2i} = 1$ or $B_2 = B$

11. $B_{inside} = \dfrac{\mu_0 \frac{i}{\pi R^2} \times \frac{\pi R^2}{4}}{2\pi \frac{R}{2}} = \dfrac{\mu_0 i}{4\pi R}$



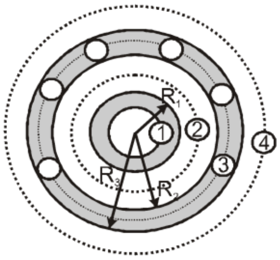
$B_{Outside} = \dfrac{\dfrac{\mu_0 i}{2\pi \frac{3R}{2}}}{} = \dfrac{\mu_0 i}{3\pi R}$

Energy density $\propto B^2$

$\dfrac{\varepsilon_1}{\varepsilon_2} = \left[\dfrac{B_1}{B_2}\right]^2 = \dfrac{9}{16}$

12. Loop (1)

$B = \dfrac{\mu_0 \dfrac{i}{\pi R_1^2} \times \pi r^2}{2\pi r} = \dfrac{\mu_0 i}{2\pi R_1^2} r \quad B \propto r$



loop (2)

$B = \dfrac{\mu_0 i}{2\pi r} \quad B \propto \dfrac{1}{r}$

loop (3)

$B = \dfrac{\mu_0 \left(i - \dfrac{i}{R_3^2 - R_2^2}\left[r^2 - R_2^2\right]\right)}{2\pi r} = \dfrac{\mu_0 (R_3^2 - r^2)}{2\pi r (R_3^2 - R_2^2)}$

loop (4) $\quad B = \dfrac{\mu_0 (i - i)}{2\pi r} = 0$ Ans. (C)

SECTION (F)

2. $R_P = \dfrac{mV}{qB} = \dfrac{\sqrt{2mK}}{qB}$ or $K = \dfrac{1}{2} mV^2$ and $K = q$ Volt

or qe or $K = q V_0 = \dfrac{\sqrt{2m_P eV_0}}{eB} = 8$ cm

$R_D = \dfrac{\sqrt{2m_D eV_0}}{eB}$ $5 = \sqrt{2}$ R_P and $m_P = \dfrac{m_D}{2} = \sqrt{2} \times 8 = 11.31$ cm

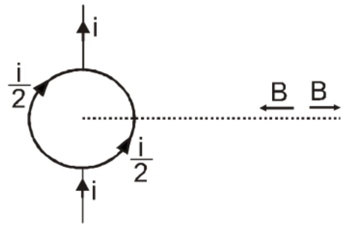
3. $T = \dfrac{2\pi m}{qB}$

$\dfrac{T_\alpha}{T_P} = \dfrac{2\pi 4m_P / 2eB}{2\pi m_P / eB} = 2$

6. $F = qVB$

$F_{Max} = q_{Max}VB$

7.



= 0

8.

$V \parallel B$

$F = 0$

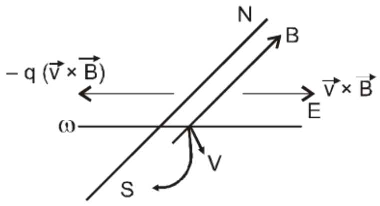
9. $qV = \frac{1}{2} mv^2$

$$R = \frac{mv}{qB} = \frac{m\sqrt{\frac{2qV}{m}}}{qB} = \sqrt{\frac{2mv}{qB^2}}$$

$$\frac{R_1}{R_2} = \sqrt{\frac{m_1}{m_2}}$$

$$\frac{m_1}{m_2} = \left(\frac{R_1}{R_2}\right)^2$$

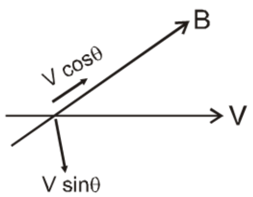
10.



F towards west

So particle will be deflected towards west **Ans. (2)**

11.



$$\frac{mv^2}{R} = q\,v\,(B \sin\theta)$$

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

12. (2) Radius of the circle = $\frac{mv}{Bq}$

or Radius $\propto$ mV if B and q are same.

(Radius)$_A$ > (Radius)$_B$ $\therefore$ $m_A v_A > m_B v_B$

13. The charged particle will be accelerated parallel (if it is a positive charge) or antiparallel (if it is a negative charge) to the electric field, i.e., the charged particle will move parallel or antiparallel to electric and magnetic field. Therefore net magnetic force on it will be zero and its path will be a straight line.

14. When particle describes circular path in a magnetic field, its velocity is always perpendicular to the magnetic force.

Power $P = \vec{F}.\vec{v} = Fv\cos\theta$

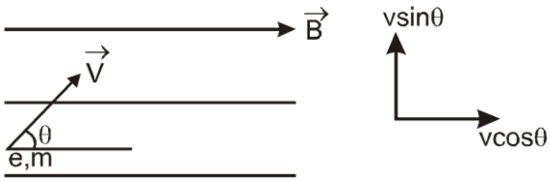
Here, $\theta = 90°$

$P = 0$

But $P = \frac{W}{t} \Rightarrow W = P.t$

Hence, work done W = 0 (everywhere)

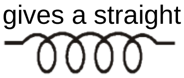
15. If electron moves in a magnetic field at an angle θ (other than 0°, 180° or 90°), its velocity can be resolved in two components one along $\vec{B}$ and another perpendicular to $\vec{B}$. Let thetwo components be $V_{||}$ and $v_{\perp}$. Then



$V_{||} = v\cos\theta$

and $v_{\perp} = v\sin\theta$

The component perpendicular to field ($v_{\perp}$)gives a circular path and the component parallel to field ($V_{||}$) gives a straight line path. The resultant path is, helix as shown in figure.



The radius of this helical path is

$r = \frac{mv_{\perp}}{eB} = \frac{mv\sin\theta}{eB}$ or $r = \frac{v\sin\theta}{\left(\frac{e}{m}\right)B}$

Given, $v = 1 \times 10^3$ m/s, B = 0.3T, θ = 30°

$\frac{e}{m} = 1.76 \times 10^{11}$ C/kg

$r = \frac{1\times10^3\sin30°}{1.76\times10^{11}\times0.3} = \frac{1\times10^3\times\frac{1}{2}}{1.76\times10^{11}\times0.3} = 10^{-8}\text{m}$

16. **Key Idea:** For a charged particle to move in a circular path in a magnetic field, the magnetic force on charge particle provides the necessary centripetal force.

hence, magnetic force = centripetal force

i.e., $qvB = \frac{mv^2}{r}$ or $qvB = mr\omega^2$ $(v = r\omega)$ or $\omega^2 = \frac{qvB}{mr} = \frac{q(r\omega)B}{mr}$ or $\omega = \frac{qB}{m}$

If n is the frequency of rotation, then

$\omega = 2\pi n \Rightarrow n = \frac{\omega}{2\pi} = \frac{qB}{2\pi m}$

Note : In the resultant expression $\frac{q}{m}$ is known as specific charge. It is sometimes denoted by α. So, in terms of α , the above formula can be written as

$\omega = B\alpha$ and $n = \frac{B\alpha}{2\pi}$

17. $\frac{q}{m} = 10^8$ C/Kj
$v = 3 \times 10^5$ m/s
$\theta = 30°$, $B = 0.3$ T
$R = \frac{mv}{B.q\sin\theta} = \frac{10^{-8} \times 3 \times 10^5}{0.3 \times 1/2} = 2$ cm

19. q = 1C, B = 0.5 T, v = 10 m/s
F = qBv
= 1 × 0.5 × 10 = 5N

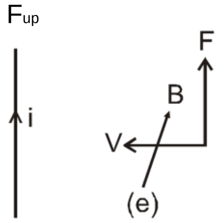
20. $v = 8.4 \times 10^6$ m/s
$\because \quad \frac{1}{2}mv^2 = eV$
$\Rightarrow \quad \frac{e}{m} = \frac{1.v^2}{2V} = \frac{1}{2} \times \frac{(8.4 \times 10^6)^2}{200} = 1.75 \times 10^{11}$

24. $m = 9.0 \times 10^{-31}$ kg
$e = 1.6 \times 10^{-19}$
$B = 1.0 \times 10^{-4}$ Wb/m^2
$T = \frac{2\pi m}{Bq} = \frac{2 \times 3.14}{1.0 \times 10^{-4}} \times \frac{9.0 \times 10^{-31}}{1.6 \times 10^{-19}} = 3.5 \times 10^{-7}$

25. m = 0.6 gm, q = 25 nC, $v = 1.2 \times 10^4$ ms^{-1}
$\because \quad mg = B.\,qv$
$B = \frac{mg}{qv} = \frac{0.6 \times 10^{-3} \times 10}{25 \times 10^{-9} \times 1.2 \times 10^4} = 20$

26. Force on a moving charge
$F = qvB \sin\theta$
$\therefore$ $\theta = 0$ then $\sin\theta = 0$
$\therefore$ F = 0

27. F_{up}



28. Since, electron and proton have same momenta so, the same force will act on them by the magnetic field.
$F = qvB \sin \theta$
$= qvB$ ($\because \theta = 90^o$)
Hence, both will move on same trajectory (curved path)

29. Magnetic needle is placed in non-uniform magnetic field. It experiences force and torque both due to unequal forces acting on poles.

30. The force per unit length between the two wires is

$$\frac{F}{1} = \frac{\mu_0}{4\pi}, \frac{2i_2}{d} = \frac{\mu_0 i^2}{2\pi d}$$

The force will be attractive as current directions in both are same.

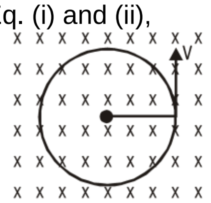
31. When electron is projected in an electric field, then velocity of electron will decrease.

32. Magnetic force $F = q\upsilon B$ .... (i)

Centripetal force

$$F = \frac{m\upsilon^2}{r} \quad \text{.......... (ii)}$$

From Eq. (i) and (ii),



$$\frac{m\upsilon^2}{r} = q\upsilon B \quad \Rightarrow \quad r = \frac{m\upsilon}{qB}$$

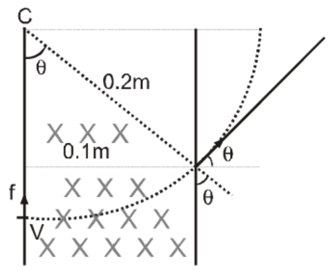
The time taken by the particle to complete one revolution,

$$T = \frac{2\pi r}{\upsilon} = \frac{2\pi m\upsilon}{qB} = \frac{2\pi m}{qB}$$

33. Straight line

35. Magnetic force can not do any work, so kinetic energy remains constant. Since initial velocity is perpendicular to magnetic field, hence momentum will change.

36.



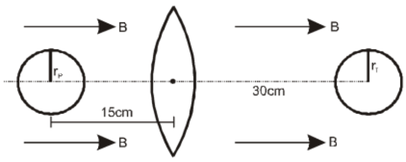
$$r = \frac{mv}{qB} \quad \& \quad \frac{1}{2} mv_2 = qV$$

$$= \frac{m}{qB}\sqrt{\frac{2qV}{m}}$$

$$r = \sqrt{\frac{2mV}{q}} \frac{1}{B} = 0.2$$

$$\sin\theta = \frac{d}{r} = \frac{1}{2} \quad \Rightarrow \quad \theta = 30_0$$

$$= 0.2m$$

37. 

$$\frac{1}{V} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{V} + \frac{1}{15} = \frac{1}{10}$$

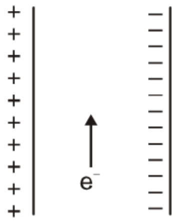
$V = 30\text{cm}$

$$r_{particle} = \frac{mv}{qB} = \frac{2\times10^{-5}\times4.8}{2\times10^{-3}\times1.2} = 4\text{cm}$$

$$\frac{r_I}{r_P} = \frac{V}{u} = 2$$

$r_{Image} = 8\text{cm}$

SECTION (G)

3. 

$\Rightarrow$ $F_e = F_m$

$E \, . \, e = B \, . \, e \, . \, v$

$$B = \frac{E}{v} = \frac{200}{4\times10^{-3}\times10^{6}} = 0.05\ T$$

5. $R = \dfrac{mv\sin\theta}{Bq}$

6. $p = (v\cos\theta) \times \dfrac{2\pi m}{B.q}$

7. For electron to pass undeflected,
electric force on electron = magnetic force on electron
i.e. $eE = evB$

or $v = \dfrac{E}{B}$ or $v = \dfrac{|\vec{E}|}{|\vec{B}|}$

8. $v = 2 \times 10_3$ m/s, $B = 1.5$ T
$E \, . \, q = B \, . \, q \, v$

$E = Bv = 3 \times 10_3 \times \dfrac{v}{m}$

10. **Key Idea** Centripetal force is provided by the magnetic force qvB.
The radius of the orbit in which ions moving is determined by the relation as given below

$$\frac{mv^2}{R} = qvB$$

where m is the mass, v is velocity, q is charge of ion and B is the flux density ofthe magnetic field, so that qvB is the magnetic force acting on the ion, and $\frac{mv^2}{R}$ is the centripetal force on the ion moving in a curved path of radius R.

The angular frequency of rotation of the ions about the vertical field B is given by

$$\omega = \frac{v}{R} = \frac{qB}{m} = 2\pi\upsilon$$

where υ is frequency.

Energy of ion is given by

$$E = \frac{1}{2}mv^2 = \frac{1}{2}m(R\omega)^2 = \frac{1}{2}mR^2B^2\frac{q^2}{m^2} \quad \text{or} \quad E = \frac{1}{2}\frac{R^2B^2q^2}{m} \quad ...(i)$$

If ions are accelerated by electric potential V, then energy attained by ions

$E = qV$ ...(ii)

From Eqs. (i) and (ii), we get

$$qV = \frac{1}{2}\frac{R^2B^2q^2}{m} \quad \text{or} \quad \frac{q}{m} = \frac{2V}{R^2B^2}$$

If V and B are kept constant, then $\frac{q}{m} \propto \frac{1}{R^2}$

11. If $\vec{E}$ is the electric field strength and $\vec{B}$ the magnetic field strength and q the charge on a particle, then electric force on the charge

$\vec{F}_e = q\vec{E}$

and magnetic force on the charge $\vec{F}_m = q\vec{v} \times \vec{B}$

The net force on the charge $\vec{F} = \vec{F}_e + \vec{F}_m = q\vec{E} + q\vec{v} \times \vec{B}$

12. At point P, Maxwell cork skew rule defines the direction of magnetic field and Fleming's left hand rule reveal the concept of force on the charge in this field.

According to Maxwell's cork screw rule the direction of magnetic field at point P in plane of paper is perpendicular to the plane of paper inwards i.e., along z-direction.

Now since charge is moving along x-direction therefore, from Fleming's left hand rule stretching the fore finger in direction of paper inwards the thumb will indicate the direction of force F acting on the charged particle along oy.

Alternative : As discussed above, B acts inwards into plane of the paper and v is along ox hence,

$$F = Q(\vec{v} \times \vec{B}) = Q\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v & 0 & 0 \\ 0 & 0 & -B \end{vmatrix} = Q[\hat{i}\,(0) - \hat{j}\,(-vB) + \hat{k}\,(0) = +\hat{j}\,QvB$$ i.e., force is along oy direction.

13. The time period of electron moving in a circular orbit

$$T = \frac{\text{circumference of circular path}}{\text{speed}} = \frac{2\pi r}{v}$$ and equivalent current due to electron flow

$$I = \frac{e}{T} = \frac{e}{(2\pi r / v)} = \frac{ev}{2\pi r}$$

Magnetic field at centre of circle $B = \frac{\mu_0 I}{2r} = \frac{\mu_0 ev}{4\pi r^2} \Rightarrow B = r \propto \sqrt{\frac{v}{B}}$

14. When a charged particle q is moving in a uniform magnetic field $\vec{B}$ with velocity $\vec{v}$ such that angle between $\vec{v}$ and $\vec{B}$ be θ then due to interaction between the magnetic field produced due to moving charge and magnetic field applied, the charge q experiences a force which is given by

$F = qvB \sin\theta$

If $\theta = 0°$ or $180°$, then $\sin\theta = 0$

$\therefore$ $F = qvB \sin\theta = 0$

Since, force on charged particle is non-zero, so angle between $\vec{v}$ and $\vec{B}$ can have any value other than zero and 180°

Note : Force experienced by the charged particle is Lorentz force.

15. **Key Idea :** To move on circular path in a magnetic field, a centripetal force is provided by the magnetic force.

When magnetic field is perpendicular to motion of charged particle, then

Centripetal force = magnetic force

i.e., $\frac{mv^2}{R} = Bqv$ or $R = \frac{mv}{Bq}$ Further, time period of the motion

$T = \frac{2\pi R}{v} = \frac{2\pi\left(\frac{mv}{Bq}\right)}{v}$ or $T = \frac{2\pi m}{Bq}$ It is independent of both R and v

16. **Key Idea :** Centripetal force is provided by the magnetic force qvB.

The radius of the orbit in which ions moving is determined by the relation as given below.

$$\frac{mv^2}{R} = qvB$$

where m is the mass, v is velocity, q is charge of ion and B is the flux density of the magnetic field, so that qvB is the magnetic force acting on the ion, and $\frac{mv^2}{R}$ is the centripetal force on the ion moving in a curved path of radius R.

The angular frequency of rotation of the ions about the vertical field B is given by

$\omega = \frac{v}{R} = \frac{qB}{m} = 2\pi\nu$ where ν is frequency. Energy of ion is given by

$E = \frac{1}{2}mv^2 = \frac{1}{2}m(R\omega)^2 = \frac{1}{2}mR^2B^2\frac{q^2}{m^2}$ or $E = \frac{1}{2}\frac{R^2B^2q^2}{m}$ ...(i)

If ions are accelerated by electric potential V, then energy attained by ions

$$E = qV$$

From Eqs. (i) and (ii), we get

$$qV = \frac{1}{2}\frac{R^2B^2q^2}{m}$$

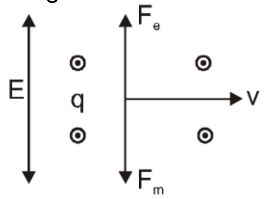
$$\frac{q}{m} = \frac{2V}{R^2B^2}$$

If V and B are kept constant, then

$$\frac{q}{m} \propto \frac{1}{R^2}$$

17. If both electric and magnetic fields are present and perpendicular to each other and the particle is moving perpendicular to both of them with $F_e = F_m$. In this situation $\vec{E} \neq 0$ and $\vec{B} \neq 0$

But if electric field becomes zero, then only force due to magnetic field exists. Under this force, the charge moves along a circle.



18. Inside bar magnet, lines of force are from south to north.

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

$\vec{F} \perp \vec{B} \quad \Rightarrow \quad \vec{a}$ is $\perp^r$ to $\vec{B}$

So $\vec{a} \cdot \vec{B} = 0$

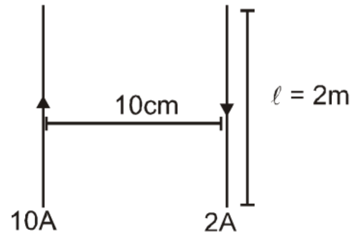
$7x - 21 = 0$

$x = 3.0$ Ans.

SECTION (H)

1. $i = 1.2A$, $\ell = 0.5$, $B = 2.0T$

$F = Bi\ell = 1.2 \times 0.5 \times 2 = 1.2N$



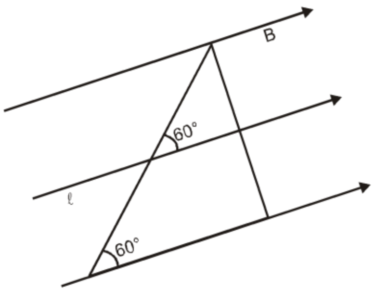
2.

$$F = \frac{\mu_0}{2\pi} \times \frac{i_1 i_2 \times \ell}{r} = 2 \times 10^{-7} \times \frac{10 \times 2 \times 2}{10 \times 10^{-2}} = 8 \times 10^{-5} \text{ N}$$

3. $i = 2A$, $B = 5 \times 10^{-4}$ T, $\theta = 60°$, $\ell = 0.5$ m

$F = Bi\ell \cdot \sin 60$

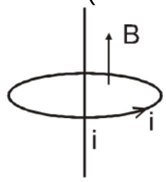
$= 5 \times 10^{-4} \times 2 \times 0.5 \times \frac{\sqrt{3}}{2}$

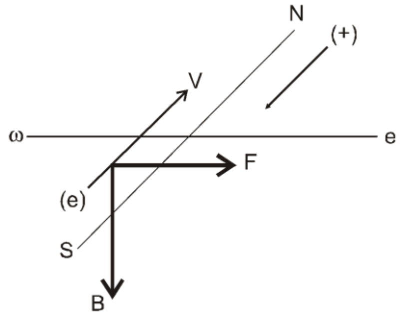


$= 5 \times 10^{-4} \times (0.5) \times 1.732 = 2.5 \times 1.732 \times 10^{-4} = 4.330 \times 10^{-4} = 4.33 \times 10^{-4}$ N

4. Field produced by loop at the centre will be along the axis of the loop i.e. || to st. wire .

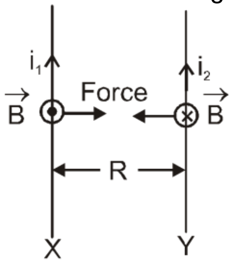
So $F = i(\vec{i} \times \vec{B}) = 0$





5. Electron beam will experience force towards east that is towards proton beam.

6. As shown in the figure, let the conductor Y carry current i_2,

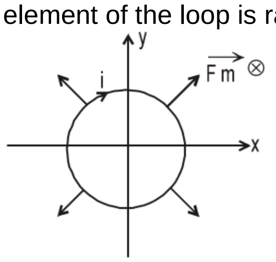


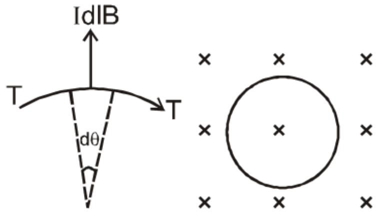
situated in a magnetic field $\vec{B}$ perpendicular to its length. t therefore, experiences a magnetic force, the magnitude ofthe force acting on a length l of Y is

$$F = i_2 B l = = i_2 \left(\frac{\mu_0}{2\pi}\frac{i_2}{R}\right) l$$

From Fleming's left hand rule the direction of this force is towards X. Similarly, force per unit length of X due to Y is directed opposite to Y.
Hence, the conductors attract each other.

7. Net force on a current carrying loop in uniform magnetic field is zero. Hence the loop can't translate. So, options (c) and (d) are wrong. From Flaming's left hand rule we can see that if magnetic field is perpendicular to paper inwards and current in the loop is clockwise (as shown) the magnetic force $\vec{F}_m$ on each element of the loop is radially outwards, or the loops will have a tendency to expand.

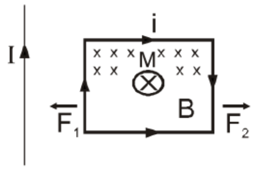




8.

$$2T\sin\left(\frac{d\theta}{2}\right) = IdlB \quad \Rightarrow \quad 2T\frac{d\theta}{2} = IRdlB \quad \Rightarrow \quad T = BIR = \frac{BIL}{2\pi}.$$

9. $\vec{M} \times \vec{B} = 0$



$\tau = 0$

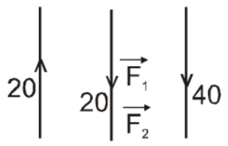
Loop will Not rotate

$F_1 > F_2$

So loop move towards the wire **Ans. (3)**

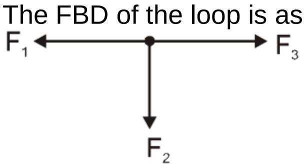
11. $F_1 = \dfrac{\mu_0(20 \times 20)}{2\pi l}$

$F_2 = \dfrac{\mu_0(20 \times 40)}{2\pi l}$



F_1 and F_2 both points in the same direction towards 40 A wire.

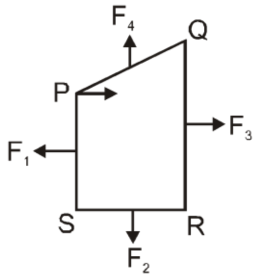
12. The FBD of the loop is as shown

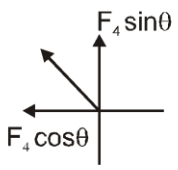


Therefore, force on QP will be equal and opposite to sum of forces on other sides.

Thus, $F_{QP} = \sqrt{(F_3 - F_1)^2 + F_2^2}$

Alternative :





$F_4 \sin\theta = F_2$

$F_4 \cos\theta = (F_3 - F_1)$ $\quad\therefore\quad$ $F_4 = \sqrt{(F_3 - F_1)^2 + F_2^2}$

13. Force acting between two current carrying conductors

$F = \dfrac{\mu_0}{2\pi}\dfrac{I_1 I_2}{d} l$ ....(i)

where d = distance between the conductors,

l = length of each conductor

Again % F' = $\dfrac{\mu_0}{2\pi}\dfrac{(-2I_1)(I_2)}{(3d)} . l = -\dfrac{\mu_0}{2\pi}\dfrac{2I_1I_2}{3d} . l$

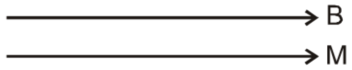
Thus, from equations (i) and (ii)

$\frac{F'}{F} = -\frac{2}{3} \quad \Rightarrow \quad F' = \frac{2}{3} F$

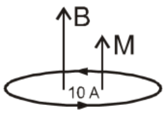
SECTION (I)

2. N = 100, B = 1T, i = 1A
$\tau = NIAB = 100 \times 1 \times (0.1 \times 0.2) = 2$ N-m

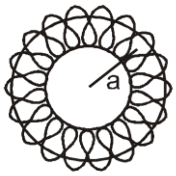
4. $U_i = -MB$
$U_f = MB$



$W = \Delta U = 2\,MB$
$= 2 \times 2.5 \times 0.2$
$= 1$ J

5.


$\vec{\tau} = \vec{M} \times \vec{B} = 0$

6.


$\Sigma \vec{M} = 0$
$\vec{\tau} = \vec{M} \times \vec{B} = 0$

7. When a bar magnet is placed in an external magnetic field a magnetic toruqe acts on it, which is given by $\vec{\tau} = \vec{M} \times \vec{B}$

8. If there are N turns in a coil, i is the current flowing and A is the area of the coil then magnetic dipole moment or simply magnetic moment of the coil is
$M = NiA$

9. r = 5 cm, i = 0.1 A
$M = N \,.\, i \,.\, A = 1 \times 0.1 \times \pi r^2 = 0.1 \times 3.14 \times (5 \times 10^{-2})^2 = 0.1 \times 3.14 \times 25 \times 10^{-4} = 7.85 \times 10^{-4}$ Amp - m^2

11. $r = \frac{L}{2\pi}$
$\vec{\tau} = \vec{M} \times \vec{B} = MB \sin\theta$

$\tau_{max} = MB = I \,.\, \pi r^2 \,.\, B = I \,.\, \pi \left(\frac{L}{2\pi}\right)^2 . B = \frac{I L^2 B}{4\pi}$

12. $M = NIA = IA$
$\because \quad B = \frac{\mu_0}{2} \,.\, \frac{NI}{R}$

$I = \left(\dfrac{2BR}{\mu_0}\right)$

$M = \left(\dfrac{2BR}{\mu_0}\right) \times \pi R_2$

$M = \dfrac{2\pi R^3 B}{\mu_0}$

16. The time period of bar magnet

$T = 2\pi\sqrt{\dfrac{I}{MH}}$

where M = magnetic moment of magnet
I = moment of inertia
and H = horizontal component of magnetic field
when same poles of magnets are placed on same side, then net magnetic moment
$M_1 = M + 2M = 3M$

$T_1 = 2\pi\sqrt{\dfrac{I}{M_1H}} = 2\pi\sqrt{\dfrac{I}{3MH}}$ ...(i)

When opposite poles of magnets are placed on same side, then net magnetic moment
$M_2 = 2M - M = M$

$\therefore \quad T_2 = 2\pi\sqrt{\dfrac{I}{M_2H}} = 2\pi\sqrt{\dfrac{I}{MH}}$ ...(ii)

From Eqs. (i) and (ii), we observe that
$T_1 < T_2$

17. As revolving charge is equivalent to a current, so

$I = qf = q \times \dfrac{\omega}{2\pi}$

But $\omega = \dfrac{v}{R}$

$I = \dfrac{qv}{2\pi R}$

Now, magnetic moment associated with charged particle is given by
$\mu = IA = I \times \pi R_2$

$\mu = \dfrac{qv}{2\pi R} \times \pi R_2$

$= \dfrac{1}{2}qvR$

18. $\Rightarrow \quad W = MB(1 - \cos\theta)$

$\Rightarrow \quad W = \dfrac{MB}{2}$

$\therefore \quad MB = 2W$

Torque, cyk?kw.kZ τ = MB sin 60º

$= \dfrac{MB\sqrt{3}}{2} = \dfrac{2W\sqrt{3}}{2} = W\sqrt{3}$

19. Current, i = (frequency) (charge) = $\left(\frac{\omega}{2\pi}\right)$ (2q) = $\frac{q\omega}{\pi}$

Magnetic moment, M = (i) A = $\left(\frac{q\omega}{\pi}\right)$ (πR^2) = ($q\omega R^2$)

Angular momentum, L = 2Iω = 2 (mR^2) ω $\quad \therefore \frac{M}{L} = \frac{q\omega R^2}{2(mR^2)\omega} = \frac{q}{2m}$

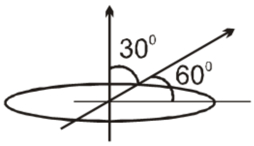
20. $U = \vec{M}\cdot\vec{B} = -MB\cos\theta$

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

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

U is maximum when θ = 180º and minimum when θ = 0º. So as θ decrease from 180º to 0º its P.E. also decreases.

21.



$$\tau = MB\sin 30^0$$
$$= Ni\pi r^2 B \times \frac{1}{2}$$
$$= 500 \times 1 \times \pi \times (0.01)^2 \times 0.4 \times \frac{1}{2}$$
$$= \pi \times 10^{-2} \text{ N-m}$$

SECTION (J)

1. $B_C = \frac{\mu_0}{2}.\frac{i}{R}$ ...(i)

$B = \frac{\mu_0}{4\pi}.\frac{\sqrt{8}\, i.2\pi R^2}{(R^2+x^2)^{3/2}}$ ...(ii)

from (i) and (ii)

$$\frac{\mu_0}{2}.\frac{i}{R} = \frac{\mu_0}{4\pi}\times\frac{\sqrt{8}.i.2\pi R^2}{(R^2+x^2)^{3/2}}$$

$$\frac{1}{R} = \frac{\sqrt{8}.R^2}{(R^2+x^2)^{3/2}}$$

$(R^2 + x^2)^{3/2}$

$(R^2 + x^2)^{3/2} = \sqrt{8}.R^3$

$(R^2 + x^2)^3 = 8R^3 = (2R^2)^3$

$R^2 + x^2 = 2R^2$

$x^2 = R^2 \quad \Rightarrow \quad x = \pm R$

2. When a current is passed through the galvanometer coil, then a magnetic field B is produced at right angles to the plane of the coil, i.e., at right angles to the horizontal component of earth's magnetic field H. Under the influence of two crossed magnetic fields B and H, the magnetic needle of galvanometer undergoes a deflection θ which is given by the tangent law. Using Tangent law, we can find a relation

$I \propto \tan\theta$

which clearly indicates that tangent galvanometer is an instrument used for detection of electric current in a circuit.
Note : A tangent galvanometer is most accurate when its deflection is 45°

SECTION (K)

10. Iron is a ferromagnetic substance. There are no magnetic lines of force inside a frerromagnetic substance. So equipmetn may be protected by placing it inside teh can made of a ferromagnetic substance.Hence, it is placed inside the iron can.

11. According to Ampere's circuital law

$B(2\pi r) = \mu_0 \times 0$

or $B = 0$

So, inside a hollow metallic (copper) pipe carrying current, the magnetic field is zero.
But for external points, the whole current behaves as if it were concentrated at the axis only, so outside

$$B_0 = \frac{\mu_0 i}{2\pi r}$$

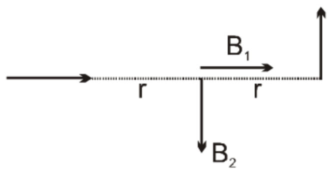
Thus, the magnetic field is produced outside the pipe only

12. Electromagnets are made of soft iron. The soft iron has high retentivity and low coercivity.

13. Attracts N_1 strongly, N_2 weakly and Repel N_3 weakly.

EXERCISE # 2

1. $B_1 = \frac{2\mu_0}{4\pi}\frac{M}{r^3}$

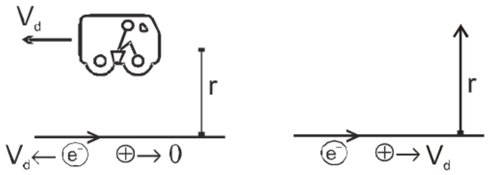


$= \frac{10^{-7} \times 1 \times 2}{(1)^3} = 2 \times 10^{-7}$ T

$B_2 = \frac{\mu_0}{4\pi}\frac{M}{r^3} = 10^{-7}$ T $\Rightarrow$ $B_{net} = \sqrt{5} \times 10^{-7}$ T (2) **Ans.**

2. Charge the rest produces only electric field but charge in motion produces both electric and magnetic field.

3. In observer frame of refernece



$B = \frac{\mu_0 i}{2\pi r}$ **Ans.(1)**

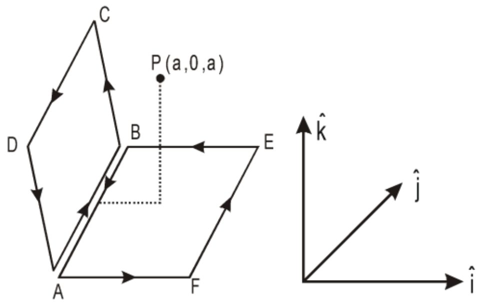
4. H_1 = Magnetic field at M due to PQ + Magnetic field at M due to QR
But magnetic field at M due to QR = 0
∴ Magnetic field at M due to QR = 0
Now H_2 = Magnetic field at M due to PQ (current I)
+ Magnetic field at M due to QS (current I/2) + Magnetic field at M due to QR

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

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

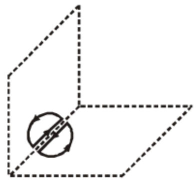
5. The magnetic field at P(a, 0) due to the loop is equal to the vector sum of the magnetic field produced by loops ABCDA and AFEBA as shown in the figure.

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



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

6. $\oint_{ABCDA} \vec{B}.d\vec{l} = \oint_{ABCA} \vec{B}.d\vec{l} + \oint_{CDAC} \vec{B}.d\vec{l}$



$= \mu_0 (i_1 + i_3) + \mu_0 (i_2 - i_3) = \mu_0 (i_1 + i_2)$

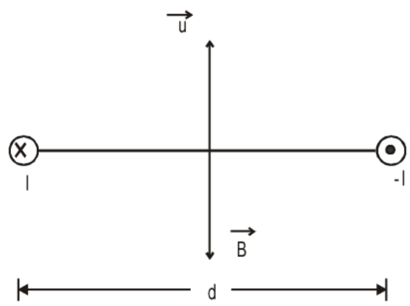
7. Radius of the circular path is given by

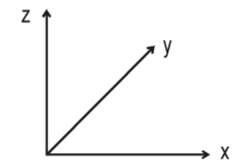
$r = \frac{mV}{Bq} = \frac{\sqrt{2Km}}{Bq}$ Here K is the kinetic energy to the particle

So, $r \propto \frac{\sqrt{m}}{q}$ if K and B are same $\therefore$ $r_p : r_d : r_\alpha = \frac{\sqrt{1}}{1} : \frac{\sqrt{2}}{1} : \frac{\sqrt{4}}{2} = 1 : \sqrt{2} : 1$

Hence $r_\alpha = r_p < r_d$

8.





Wires are in x-y plane and velocity in z-direction

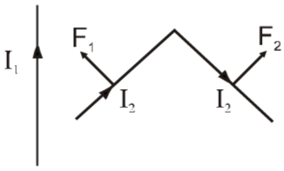
Net magnetic field due to both the wires will be downward as shown above. Since angle between $\vec{v}$ and $\vec{B}$ is 180º

Therefore, magnetic force

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

10. 

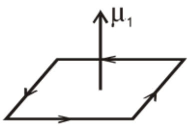
In uniform magnetic filed force acting on a closed loop = 0.

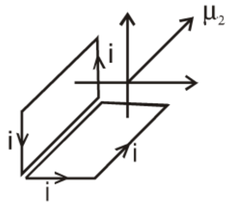
11. 

Resulted force will be at on angle with x as well as y axis

12. $\mu_1 = L^2$

$\mu_2 = \sqrt{2} \times L \times \frac{L}{2}$





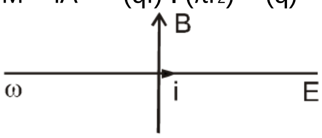
$\mu_2 = \frac{L^2}{\sqrt{2}} \Rightarrow \frac{\mu_1}{\mu_2} = \sqrt{2}$

13. Ratio of magnetic moment and angular momentum is given by

$$\frac{M}{L} = \frac{q}{2m}$$

which is a function of q and m only. This can be derived as follows :

$M = iA = (qf) . (\pi r^2) = (q) \left(\frac{\omega}{2\pi}\right) (\pi r^2) = \frac{q\omega r^2}{2}$ and $L = I\omega = (mr^2 \omega)$ $\therefore$ $\frac{M}{L} = \frac{q\frac{\omega r^2}{2}}{mr^2\omega} = \frac{q}{2m}$

14. 

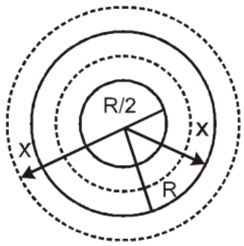
$F = BiL = 10^{-4} \times 10 \times 1 = 10^{-3}$ N

15. $B_H \tan\theta = \frac{\mu_0 Ni}{2r}$

$i = \frac{0.34 \times 10^{-4} \times 2 \times .2}{4\pi \times 10^{-7} \times 20} = \frac{17}{10\pi}$ Ans. (1)

17. Area $= a^2 + \frac{4 \times \pi\left(\frac{a}{2}\right)^2}{2} = a^2 + \frac{\pi a^2}{2}$ $\Rightarrow$ $A = \left(1 + \frac{\pi}{2}\right) a^2 \hat{k}$

18. **Case-I** $x < \frac{R}{2}$



$|B| = 0$

Case-II $\frac{R}{2} \le x < R$

$\oint \vec{B}.d\vec{\ell} = \mu_0 I$

$|B|\, 2\pi x = \mu_0 \left[\pi x^2 - \pi\left(\frac{R}{2}\right)^2\right] J \quad \Rightarrow \quad |B| = \frac{\mu_0 J}{2x}\left(x^2 - \frac{R^2}{4}\right)$

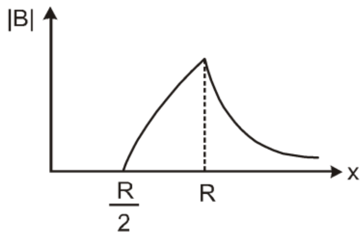
Case-III $x \geq R$

$\oint \vec{B}.\, d\vec{\ell} = \mu_0 I$

$|B|\, 2\pi x = \mu_0 \left[\pi R^2 - \pi\left(\frac{R}{2}\right)^2\right] J \quad \Rightarrow \quad |B| = \frac{\mu_0 J}{2x}\, \frac{3}{2}\, R_2$

$|B| = \frac{3\mu_0 J R^2}{8x}$

so



22. Co(cobalt) is a ferromagnetic substance.

23. Positive charged particle are deviated towards north pole in magnetic field.

24. For paramagnetic materials, magnetic suspectibility is inversely proportional to the temperature i.e,, proportional to T_{-1}.

25. When a loop (of any size)is placed in a uniform magnetic field, then the force acting on the loop is zero.

26. Magnetic field atcentre of a circular coil,

$B = \frac{\mu_0 n i}{2r} \qquad \text{Here} \quad N = \frac{1}{2} \quad \therefore \qquad B = \frac{\mu_0\left(\frac{1}{2}\right) i}{2r} = \frac{\mu_0 i}{4r}$

27. For parallel wires, same direction currents attract and opposite currents repel.

The magnetic force between two parallel wires $\propto \frac{1}{r}$

AB and CD are symmetrical relative to wire EF, so, they exert equal and opposite forces on EF.

As wire BC is nearer to EF as compared to AD and current in both wires is ame, so wire BC exerts larger force than that of AD. So, wire EF will be attracted towards the loop.

28. Magnetic field at the centre of solenoid = $\mu_0 ni$

29. In a uniform magnetic field, the torque acts on a magnetic needle but forcedoes not. Therefore $\tau \neq 0$, $F = 0$

30. The formula for radius of circular path is

$r = \frac{mv}{eB} = \frac{v}{\left(\frac{e}{m}\right)B}$

Given : $\frac{e}{m}$ of electron = 1.7×10^{11} C/kg, $v = 6 \times 10^7$ m/s and $B = 1.5 \times 10^{-2}$ T

$\therefore \quad r = \frac{6 \times 10^7}{1.7 \times 10^{11} \times 1.5 \times 10^{-2}} = 2.35 \times 10^{-2}$ m = 2.35 cm

31. Torque acting on the magnet is given by

$\vec{\tau} = \vec{M} \times \vec{B}$ Here $\vec{M}$ = magnetic moment $\vec{B}$ = magnetic field

32. When a charged particle enters a magnetic field perpendicularly, it moveson a circular path. Therequired centripetal force is provided by magnetic force.

i.e., magnetic force = Centripetal force

or $qvB = \frac{mv^2}{r}$ $\therefore$ $r = \frac{mv}{qB}$

Now kinetic energy of the particle,

$K = \frac{1}{2}mv^2$ $\Rightarrow$ $mv = \sqrt{2mK}$

Therefore, Eq. (i) becomes

$r = \frac{\sqrt{2mK}}{qB}$ or $r \propto \sqrt{m}$ $\therefore \frac{r_e}{r_p} = \sqrt{\frac{m_e}{m_p}}$

As $m_e < m_p$; so, $r_e < r_p$

Hence, trajectory of proton is less curved.

33. $T = IrB$

$T \propto r$

34. Magnetic field at the centre of circular coil of n turns and radius r is

$B = \frac{\mu_0 ni}{2r}$ for first coil, $B_1 = \frac{\mu_0 ni_1}{2r_1}$

For second coil, $B_2 = \frac{\mu_0 ni_2}{2r_2}$ Hence, resultant magnetic field at the centre of concentric loop is

$B = \frac{\mu_0 ni_1}{2r_1} - \frac{\mu_0 ni_2}{2r_2}$ Given, n = 10, i_1 = 0.2A, r_1 = 20cm = 0.20m,

i_2 = 0.3A, r_2 = 40cm = 0.40m $\therefore$ $B = \mu_0\left[\frac{10 \times 0.2}{2 \times 0.20} - \frac{10 \times 0.3}{2 \times 0.40}\right] = \frac{5}{4}\mu_0$

35. Paramagnetic substance is one, whose atoms have a permanent magnetic moment and whose atoms have an excess of electrons spinning in the same direction. Hydrogen atom is one such example. While property of diamagnetism is generally found in those substances whose molecules have even number of electrons which form pairs.

36. Key Idea To move on circular path in a magnetic field, a centripetal force is provided by the magnetic force.
When magnetic field is perpendicular to motion of charged particle, then
Centripetal force = magnetic force

ie, $\frac{mv^2}{R} = Bqv$ or $R = \frac{mv}{Bq}$

Further, time period of the motion

$T = \frac{2\pi R}{v} = \frac{2\pi\left(\frac{mv}{Bq}\right)}{v}$ or $T = \frac{2\pi m}{Bq}$

It is independent of both R and v.

37. As revolving charge is equivalent to a current, so

$I = qf = q \times \frac{\omega}{2\pi}$ But $\omega = \frac{v}{R}$ where R is radius of circle and v is uniform speed of charged particle.

Therefore, $I = \frac{qv}{2\pi R}$ Now, magnetic moment associated with charged particle is given by

$\mu = IA = I \times \pi R_2$

$\mu = \frac{qv}{2\pi R} \times \pi R^2 = \frac{1}{2} qvR$

38. Given $q_y = 2q_x$ radius of circular path in a magnetic field is given by

$r = \frac{mv}{Bq}$ $\Rightarrow$ $v = \frac{Brq}{m}$ $\Rightarrow$ $v_2 = \frac{B^2r^2q^2}{m^2}$

or $mv_2 = \frac{B^2r^2q^2}{m}$

$\therefore$ $KE = \frac{1}{2}mv^2 = \frac{B^2r^2q^2}{2m}$ ...(i)

When charge particle is accelerated by potential V, then its kinetic energy

$KE = Vq$ ...(ii)

From Eqs. (i) and (ii)

$Vq = \frac{B^2r^2q^2}{2m}$ $\Rightarrow$ $m = \frac{B^2r^2q}{2V}$

$\therefore$ $m \propto r_2 q$

$\therefore$ $\frac{m_1}{m_2} = \frac{r_1^2 q_1}{r_2^2 q_2} = \frac{R_1^2}{R_2^2} \times \frac{q}{2q} = \frac{R_1^2}{2R_2^2}$

39. According to tangent law in magnetism,

$B = B_H \tan\theta$

Given, $B_H = 0.34 \times 10_{-4} \times \tan 30°$

$\theta = 30°$

$\therefore$ $B = 0.34 \times 10_{-4} \times \tan 30° = \frac{0.34 \times 10^{-4}}{\sqrt{3}} = 1.96 \times 10_{-5}T$

40. Given, N = 50 turns/cm = 5000 turns/m

$I = 4A$

Magnetic field at an internal point = $\mu_0 nI$

$= 4\pi \times 10^{-7} \times 5000 \times 4 = 8\pi \times 10^{-3} = 25.12 \times 10^{-3}$ Wb/m^2

Magnetic field at one end = $\frac{\mu_0 nI}{2} = \frac{25.12 \times 10^{-3}}{2} = 12.56 \times 10^{-3}$ Wb/m^2

Magnetic field at an internal point = $\mu_0 nI$

41. As particle is moving without deviation, therefore

$Eq = Bqv$

$B = \frac{E}{v} = \frac{10^4}{10} = 10^3$ Wb/m^2

42. Before using the tangent galvanometer, its coil is set up in magnetic meridian.

43. $T_1 = \frac{1}{f_1} = 2\pi\sqrt{\frac{I}{(M_1 + M_2)B}} = \frac{1}{12}$

$T_2 = \frac{1}{f_2} = 2\pi\sqrt{\frac{I}{(M_1 - M_2)B}} = \frac{1}{4}$

Divinding eq. (1) by eq. (2)

$\frac{M_1}{M_2} = \frac{5}{4}$

46. $N = 48$, $A = 4 \times 10^{-2}$ m^2

$B = 0.2$

sensitivity

$\because \ \tau = c\,.\,\theta$

$NIAB = c.\,\theta$

I = $\frac{c}{NAB}.\theta$

I = $\frac{NAB}{c} = \frac{\theta}{I}$ **= sensitivity**

$\frac{N_2AB}{c} = \frac{\frac{5}{4}.\theta}{I}$

$\frac{N_1AB}{c} = \frac{\theta}{I}$

$\frac{N_2}{N_1} = \frac{5}{4}$

$N_2 = \frac{5}{4} \times N_1 = \frac{5 \times 48}{4} = 60$

47. $\omega = \Delta U$

$\omega_1 = PE(\cos\theta_i - \cos\theta_f) \Rightarrow \quad \omega = 0.8$ J

48. Given, $q_y = 2q_x$

Radius of circular path in a magnetic field is

Given by

$r = \frac{mv}{Bq}$ ∴ $v = \frac{Brq}{m}$

$v^2 = \frac{B^2r^2q^2}{m^2}$ or $mv^2 = \frac{B^2r^2q^2}{m^2}$

∴ KE = $\frac{1}{2}mv^2 = \frac{B^2r^2q^2}{2m}$ ......(i)

When charge particle is accelerated by potential V, then its kinetic enrgy

KE = Vq ....(ii)

From Eqs. (i) and (ii)

$Vq = \frac{B^2r^2q^2}{2m}$ $m = \frac{B^2r^2q}{2V}$

∴ $m \propto r^2q$ ∴ $\frac{m_1}{m_2} = \frac{r_1^2q_1}{r_2^2q_2} = \frac{R_1^2}{R_2^2} \times \frac{q}{2q} = \frac{R_1^2}{2R_2^2}$

49. $R = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}$

$\frac{Rp}{Rd} = \frac{\sqrt{m}}{e}\frac{e}{\sqrt{2m}} = \frac{1}{\sqrt{2}}$

so $\frac{R_d}{R_P} = \sqrt{2}$ (None of the given answers)

50. Ratio of $\frac{\mu}{L} = \frac{q}{2m}$

51. Area of loop = 20 × 10 = 200 cm^2

= 2 × 10^{-2} m^2

$\vec{A} = \left(2\times10^{-2}M^2\right)\hat{i}$ (as loop is in yz plane).

so. $\vec{\tau} = \vec{M}\times\vec{B} = i\left(\vec{A}\times\vec{B}\right) = 1$

= 12 × 2 × 10^{-2} ($\hat{i}$) × (0.3$\hat{i}$ + 0.4$\hat{j}$)

= 12 × 2 × 0.4 × 10^{-2} × 10^{-2} ($\hat{k}$) = 9.6 × $10^{-2}\hat{k}$ (Nm)

52. The time period of oscillations of magnet

$T = 2\pi\sqrt{\left(\frac{I}{MH}\right)}$ where I = moment of inertia of magnet = $\frac{mL^2}{12}$

(m, being the mass of magnet)

M = pole strength × L

When the three equal parts of magnet are placed on one another with their like poles together, then

$I' = \frac{1}{12}\left(\frac{m}{3}\right) \times \left(\frac{L}{3}\right)^2 \times 3 = \frac{1}{12}\frac{mL^2}{9} = \frac{I}{9}$

and M' = pole strength × $\frac{L}{3}$ ×3 = M

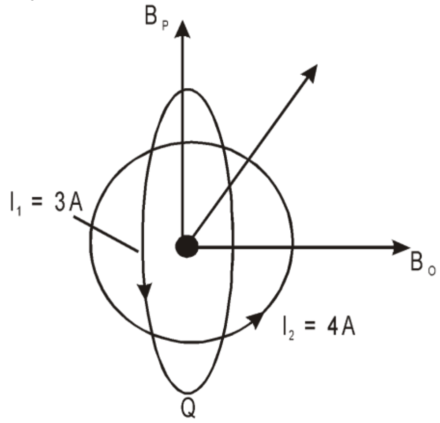
Hence, $T' = 2\pi\sqrt{\left(\frac{I/9}{MH}\right)}$ $\Rightarrow$ $T' = \frac{1}{3} \times T$

$T' = \frac{2}{3}$ sec

53. $B_P = \frac{\mu_0 I_2}{2R}$

$= \frac{4\pi \times 10^{-7} \times 4}{2 \times 0.02\pi} = 4\times10^{-5}$ Wb/m^2

$B_Q = \frac{\mu_0 I_1}{2R}$



$= \frac{4\pi \times 10^{-7} \times 3}{2 \times 0.2\pi}$

$= 3 \times 10^{-5}$ Wb/m^2

$\therefore$ $B = \sqrt{B_P^2 + B_Q^2} = \sqrt{\left(4\times10^{-5}\right)^2 + \left(3\times10^{-5}\right)^2} = 5 \times 10^{-5}$ Wb/m^2

EXERCISE # 3
PART - I

1. When a charge q moves with velocity $\vec{v}$ inside magnetic field of strength $\vec{B}$, then force on charge is called magnetic Lorents force. The magnetic Lorentz force is in direction of vector $\vec{v} \times \vec{B}$
Magnetic Lorenz force. The magnetic Lorentz forcer is in the direction of $\vec{v} \times \vec{B}$.
Magnetic Lorentz force $\vec{F} = q\left(\vec{v} \times \vec{B}\right) = -2 \times 10^{-6}\ [(2\hat{i} + 3\hat{j}) \times 2\hat{j}] \times 10^6 = 8$ N along negative z-axis

2. The work done in rotating a magnetic dipole against the torque acting on it , when placed in magnetic field is stored inside it in the form of potential energy.
When magnetic dipole is rotated from initial position $\theta = \theta_1$ to final position $\theta = \theta_2$, then work done = $MB(\cos\theta_1 - \cos\theta_2)$

$= MB\left(1 - \frac{1}{2}\right) = \frac{2\times10^4 \times 6\times10^{-4}}{2} = 6J$

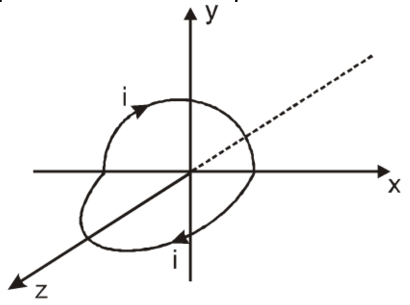
3. Current produced due to circular motion of charge q is
$I = qf$
Magnetic field induction at the centre of the ring of radius R is

$$B = \frac{\mu_0 2\pi I}{4\pi R} = \frac{\mu_0 I}{2R} = \frac{\mu_0 qf}{2R} \qquad \text{(Using (i))}$$

4. Electromagnetics are made of soft iron because soft iron has low retentivity and low coercive force or low coercivity. Soft iron is a soft magnetic material.

5. Net force on a current carrying loop is zero in uniform magnetic field

6. The loop mentioned in the question must look like one as shown in the figure.



Magnetic field at the centre due to semicircular loop lying in x-y plane, $B_{xy} = \frac{1}{2}\left(\frac{\mu_0 i}{2R}\right)$ negative z direction

Similarly field due to loop in x–z plane, $B_{xz} = \frac{1}{2}\left(\frac{\mu_0 i}{2R}\right)$ in negative y direction.

$\therefore$ Magnitude of resultant magnetic field,

$$B = \sqrt{B_{xy}^2 + B_{xz}^2} = \sqrt{\left(\frac{\mu_0 i}{4R}\right)^2 + \left(\frac{\mu_0 i}{4R}\right)^2} = \frac{\mu_0 i}{4R}\sqrt{2} = \frac{\mu_0 i}{2\sqrt{2}R}$$

7. Magnetic moment of the loop.

$M = NIA = 2000 \times 2 \times 1.5 \times 10^{-4} = 0.6$ J/T

torque $\tau = MB\sin 30° = 0.6 \times 5 \times 10^{-2} \times \frac{1}{2} = 1.5 \times 10^{-2}$ Nm

9. The magnetic momentum of a diamagnetic atom is equal to zero.

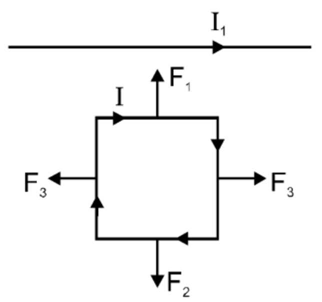
10. Bar magnet exert zero force on stationary charge

11. Net force on a current carrying loop is zero in uniform magnetic field

12. A → diamagnetic
B → paramagnetic
C → Ferromagnetic
D → Non magnetic

13. $\vec{v}$ and $\vec{B}$ are in same direction so that magnatic force on e^{-1} becomes zero only electric force acts. But force on e^{-1} due to electric field opposite to the direction of velocity.

14.



$F_1 > F_2$. hence net attraction force will be towards conductor.

15. $B = \frac{\mu_0 I}{2R}$, $I = \frac{q}{T} = qf$

$B = \frac{\mu_0 qf}{2R}$.

16. For stable equilibrium
$U = -MB = -(0.4)(0.16) = -0.064$ J

17. Since magnetic field is in vertical direction and Needle is free to totate in horizontal plane only so magnitic force can not rotate the needle in horizontal plane so needle can stay in any position.

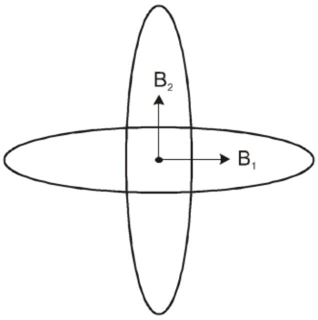
18. Time period of cyclotron is

$T = \frac{1}{\upsilon} = \frac{2\pi m}{eB}$ $\Rightarrow$ $B = \frac{2\pi m}{e}\upsilon$

$R = \frac{mv}{eB} = \frac{p}{eB} \Rightarrow P = eBR = e \times \frac{2\pi m\nu}{e}R = 2\pi m\upsilon R$

K.E $= \frac{p^2}{2m} = \frac{(2\pi m\upsilon R)^2}{2m} = 2\pi^2 m\upsilon^2 R^2$ **Ans 3**

19.



$B_1 = \frac{\mu_0 I}{2R}$

$B_2 = \frac{\mu_0 (2I)}{2R}$

$B_{net} = \sqrt{B_1^2 + B_2^2} = \frac{\mu_0(2I)}{2R}\sqrt{1+4} = \frac{\sqrt{5}\,\mu_0 I}{2R}$

20. $R = \frac{\sqrt{2mK}}{qB}$

$q_\alpha = 2q$, $m_\alpha = 4m$

$R_\alpha = \frac{\sqrt{2(4m)K'}}{2qB}$

$\frac{R}{R_\alpha} = \sqrt{\frac{K}{K'}}$ but $R = R_\alpha$ then $K = K' = 1$ MeV

21. $W = U_{final} - U_{initial} = MB(\cos 0 - \cos 60^\circ)$

$W = \frac{MB}{2} = \sqrt{3}J$ ..... (i)

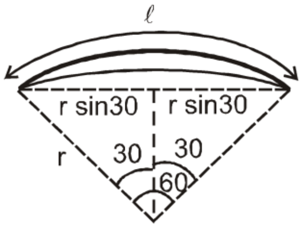
$\tau = \vec{M} \times \vec{B} = MB \sin 60^\circ = \left(\frac{MB\sqrt{3}}{2}\right)$ .....(ii)

From eq. (i) and (ii)

$\tau = \dfrac{2\sqrt{3}\times\sqrt{3}}{2}$ = 3J

22. M = m × ℓ

M' = m × r



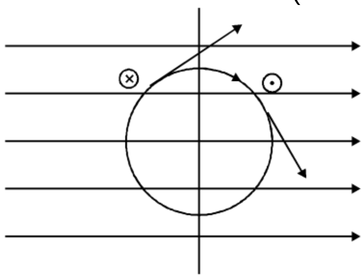
$\ell = \dfrac{\pi r}{3}$

So, m' = $\dfrac{3}{\pi}$ M

23. $\vec{\tau} = \vec{M} \times \vec{B}$

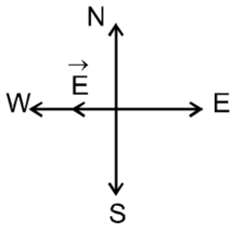
θ = 0 ⇒ τ = 0 (stable)

θ = π ⇒ τ = 0 (instable)



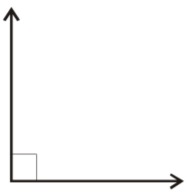
Do not experience a torque in some orientations

Hence option (3) is correct

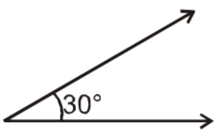


24.

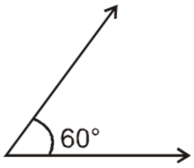
E = $\dfrac{F}{q} = \dfrac{ma_0}{e}$ **(**West) for $3a_0$ towards east we have to apply B = $\dfrac{2ma_0}{ev_0}$ (downward)

25. (a)  $M_{net} = \sqrt{m^2 + m^2 + 2mm\cos 90^\circ} = \sqrt{2}\,m$

(b)  M_{net} = m – m = 0

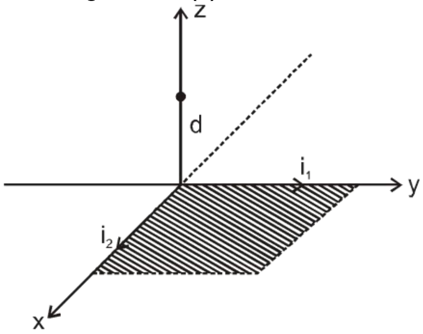
(c) 

$M_{net} = \sqrt{m^2 + m^2 + 2mm\cos 30^\circ} = m\sqrt{2+\sqrt{3}}$

(d) 

$M_{net} = \sqrt{m^2 + m^2 + 2mm\cos 60^\circ} = \sqrt{3}m$

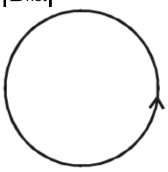
is configuration (c) θ is least so M_{net} is maximum.

26. 

$\vec{B}$ due to wire (1) $\vec{B_1} = \left(\frac{\mu_0 i_1}{2\pi d}\right)\hat{i}$

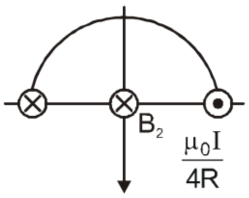
$\vec{B}$ due to wire (2) $\vec{B_2} = \left(\frac{\mu_0 i_2}{2\pi d}\right)(-\hat{j})$

$|B_{net}| = \frac{\mu_0}{2\pi d}\sqrt{i_1^2 + i_2^2}$

27. 

$i = \frac{e}{T} = \frac{e}{(1/n)}$ = en = equivalent cunenl

$B_c = \frac{\mu_0 i}{2r} = \frac{\mu_0 ne}{2r}$

28. 

$\vec{B}_1 = \frac{2\mu_0 I}{4\pi R}$

So, $B = \frac{\mu_0 I}{4\pi R}\left(-2\hat{k} - \pi\hat{i}\right)$

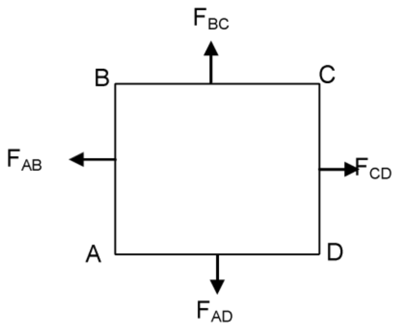
29. If r = radial separation

$B = B_{inside} = \left(\frac{\mu_0 i}{2\pi R^2}\right)r = \frac{\mu_0 i}{(2\pi R^2)}\left(\frac{R}{2}\right) = \frac{\mu_0 i}{2\pi R}\left(\frac{1}{2}\right)$

B = Boutside = $\frac{\mu_0 i}{2\pi r} = \frac{\mu_0 i}{2\pi R}\left(\frac{1}{2}\right)$

B : B = 1 : 1

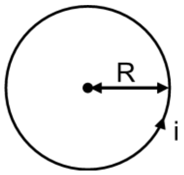
30. $\mu_r = 1 + x$
appropriate is diamagnetic

31.


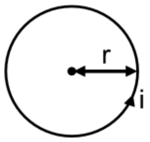
F_{BC} cancels F_{AD}

$$F_{Net} = F_{AB} - F_{CD} = \frac{\mu_0 IiL}{2\pi\left(\frac{L}{2}\right)} - \frac{\mu_0 IiL}{2\pi\left(\frac{3L}{2}\right)} = \frac{2\mu_0 Ji}{3\pi} = \frac{2\mu_0 Ii}{3\pi}$$

32. $\phi_{self} = Li$
$(4 \times 10^{-3})(1000) = (L)(4)$
$L = 1$ Henry

33.


$$B = \frac{\mu_0 i}{2R} = \frac{\mu_0 i(2\pi)}{2(\square)} = \frac{\mu_0 \pi i}{2\square}$$



$$B' = \frac{\mu_0 ni}{2r} = \frac{\mu_0 ni}{2\left(\frac{\square}{2n\pi}\right)} = \frac{n^2 \mu_0 \pi i}{2\square} = n^2 B$$

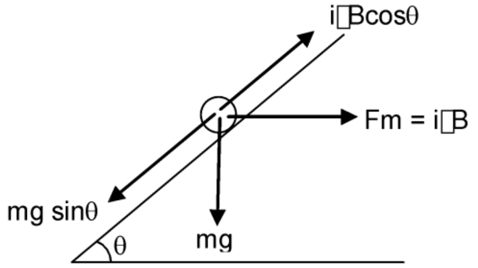
34. $R = \frac{mV}{qB}$

$$\omega = \frac{V}{R} = \frac{qB}{m}$$

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi} \cdot \frac{qB}{m} = \frac{1.76 \times 10^{11} \times 3.57 \times 10^{-2}}{(2 \times 3.14)} = 10^9 \text{Hz}$$

35. For equal
$i\ell B \cos\theta = mg \sin\theta$
$i\ell B \cos\theta = (\lambda\ell)g \sin\theta$

$i = \frac{\lambda g}{B} \tan\theta = \frac{0.5 \times 10}{0.25} \tan 30^o = 11.56$ A



36. From ampere circuital law

$\oint B.d\ell = \mu_0 I' \Rightarrow I' = \frac{I}{\pi R^2} \times \pi r^2$

$B2\pi r = \mu_0 \frac{I}{\pi R^2} \times \pi r^2$

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

$B_{insdie} \alpha$ r

$B_{outside}$

$\oint B.d\ell = \mu_0 I_k$

$B2\pi r = \mu_0 I$

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

$B \alpha \frac{1}{r}$

37. ∵ At point A, angle of dip is positive and earth's magnet north pole is in southern hemisphere so angle of dip is positive in southern hemisphere
A is located in southern hemisphere
B is located in northern hemisphere

38. $r = \frac{mv}{qB} = \frac{p}{qB} \Rightarrow r \alpha \frac{1}{q}$

$\frac{r_n}{r_\alpha} = \frac{q_\alpha}{q_n}$

$= \frac{2}{1}$

= 2 : 1

39. For toroid $B_a = \frac{\mu_0 \times N \times I}{2\pi R}$

$B_{a1} = \frac{\mu_0 \times 200 \times I}{2\pi \times 40 \times 10^{-2}}$, $B_{a2} = \frac{\mu_0 \times 100 \times I}{2\pi \times 20 \times 10^{-2}}$

$B_{a1} = B_{a2}$

40. $\vec{B}_P = \vec{B}_{wire} + \vec{B}_{arc}$

$\therefore \quad \vec{B}_{wire} = 0$

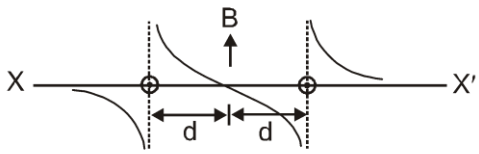
$\vec{B}_{arc} = \frac{\mu_0 \times i_2}{2R} \cdot \frac{\theta_2}{2\pi}(\hat{k}) + \frac{\mu_0 i_1}{2R} \cdot \frac{\theta_1}{2\pi}(-\hat{k}) = \frac{\mu_0 i_2}{8R}\hat{k} + \frac{3\mu_0 i_1}{8R}(-\hat{k})$

$i_1 = \frac{i}{4}$, $i_2 = \frac{3i}{4} \Rightarrow \quad \vec{B}_{arc} = \frac{3\mu_0 i}{32R}\hat{k} - \frac{3\mu_0 i}{32R}\hat{k} = 0$

$\vec{B}_P = 0 + 0 = 0$

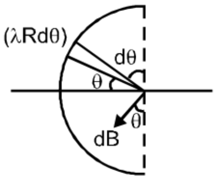
41. AC Emf should change its direction
$\because$ In all graphs direction of Emf is changing hence all are AC.

PART - II

1. 

Towards left of both wires direction of B is downward and at mid point between two wires, magnetic field is zero

2. $v = \frac{I}{\pi R}$



$dB = \left(\frac{\mu_0}{4\pi}\right)\frac{2I}{R}$ $\qquad I = \lambda R\, d\theta$

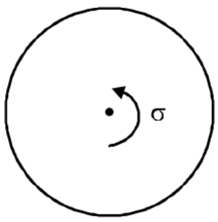
$\therefore \quad B = \int_{-\pi/2}^{\pi/2} dB\cos\theta = \frac{\mu_0\lambda}{2\pi}\int_{-\pi/2}^{\pi/2}\cos\theta\, d\theta = \frac{\mu_0\lambda}{\pi} = \frac{\mu_0 I}{\pi^2 R}$ **Ans.**

3. $\vec{F} = q[\vec{E} + \vec{v} \times \vec{B}] = q\left[3\hat{i} + \hat{j} + \hat{k} + \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 4 & 1 \\ 1 & 1 & -3 \end{vmatrix}\right]$

$= q\,[3\hat{i} + \hat{j} + 2\hat{k} + \hat{i}) - 12 - 1) - \hat{j}(-9 - 1) + \hat{k}(3 - 4)] = q\,[3\hat{i} + \hat{j} + 2\hat{k} - 13\hat{i} + 10\hat{j} - \hat{k}]$

$= q\,[-10\hat{i} + 11\hat{j} + \hat{k}] = F_y = 11q\hat{j}$.

4. $\frac{q}{2M} = \frac{\text{Magnetic dipole moment}}{\text{Angular momentum}}$



$\therefore \quad$ Magnetic dipole moment(M)

$M = \frac{q}{2M} \cdot \left(\frac{MR^2}{2}\right) \cdot \omega = \frac{1}{4} \sigma.\pi R_4 \omega.$

5. $dB = \frac{\mu_0 (dq)}{2r}\left(\frac{\omega}{2\pi}\right)$

$B = \int dB = \frac{\mu_0 \omega}{4\pi} \cdot \frac{Q}{\pi R^2} 2\pi \int_0^R \frac{rdr}{r}$

$B = \frac{\mu_0 \omega Q}{2\pi R^2} .R$

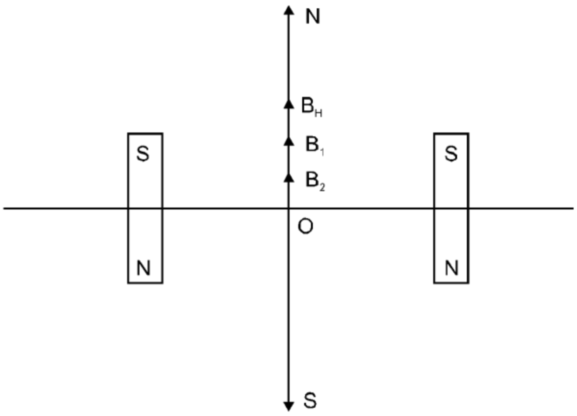
$B = \frac{\mu_0 \omega Q}{2\pi R}$

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

6. $r = \frac{\sqrt{2mE}}{3q} \Rightarrow r \propto \frac{\sqrt{m}}{q} \Rightarrow r_p = k\frac{\sqrt{m}}{q} \Rightarrow r_D = k\frac{\sqrt{2m}}{q}$

$r_\alpha = k\frac{\sqrt{4m}}{2q} = \frac{k\sqrt{m}}{q} \quad \therefore \quad r_p = r_\alpha < r_d$.

7. $B_{net} = B_1 + B_2 + B_H$



$B_{net} = \frac{\mu_0}{4\pi} \frac{(M_1 + M_2)}{r^3} + B_H = \frac{10^{-7}(1.2+1)}{(0.1)^3} + 3.6 \times 10^{-5} = 2.56 \times 10^{-4}$ wb/m^2

8. For solenoid

$\frac{B}{\mu_0} = H$

$B = \mu_0 nI$

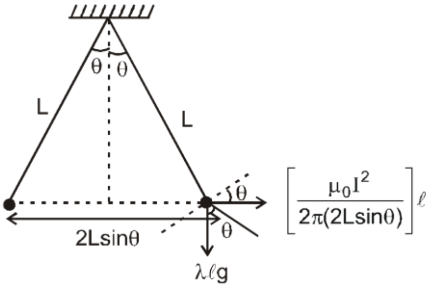
$H = nI$

$\Rightarrow \quad 3 \times 10^3 = \frac{100}{0.2} \times I$

$I = 6A$

9. $\vec{F_1} = \vec{F_2} = 0$

Because net resultant will be zero. and equal because of action and reaction pair

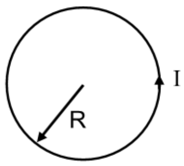


10.

$\lambda \ell g \sin\theta = \dfrac{\mu_0 I^2}{2\pi(2L\sin\theta)}\ell\cos\theta$

$2\sin\theta\sqrt{\dfrac{\lambda g\pi L}{\mu_0\cos\theta}} = I.$

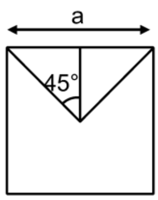
11. For stable equilibrium angle should be zero and for unstable equilibrium angle between $\vec{M}$ and $\vec{B}$ should be π.



12.

Magnetic field at centre of circle

$B_A = \dfrac{\mu_0 I}{2R} = \dfrac{\mu_0 I\pi}{\ell}$ [Also $\ell = 2\pi R$]



Magnetic field at centre = $\dfrac{4\mu_0 I}{4\pi\frac{a}{2}}(2\sin 45^\circ) = \dfrac{16\mu_0 I}{\sqrt{2}\pi\ell}$ [Also $4a = \ell$]

Now $\dfrac{B_A}{B_B} = \dfrac{\pi^2}{8\sqrt{2}}$

13. Since area of hysterics curve of (B) is smaller it is suitable for electromagnet and transformer.

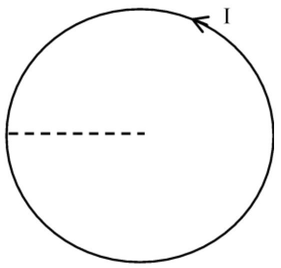
14. $M = 6.7 \times 10^{-2}$ A – m^2

$I = 7.5 \times 10^{-6}$ kgm^2

$T = 2\pi\sqrt{\dfrac{I}{MB}} = 2\pi\sqrt{\dfrac{7.5\times10^{-6}}{6.7\times10^{-2}\times10^{-2}}} = 2\pi\sqrt{\dfrac{7.5}{6.7}\times10^{-2}} = 2\pi\times10^{-1}\sqrt{\dfrac{75}{67}}$

$t = 10T = 2\pi\sqrt{\dfrac{75}{67}} = 6.65$ sec.

15.



Dipole moment (m) = $I\pi R^2$ $\Rightarrow$ Magnetic induction (B) = $\frac{\mu_0 I}{2R}$

$B \alpha \frac{1}{\sqrt{m}}$

$\frac{B_1}{B_2} = \sqrt{\frac{m_2}{m_1}} = \sqrt{2}$

16. For circular path in magnetic field.

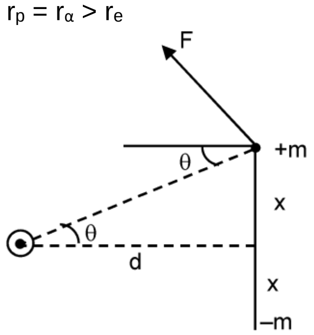
$r = \frac{\sqrt{2mE}}{qB}$ E = kinetic energy

So

	e	p	α
m	1/1836	1	4
q	–e	+e	2e

$r_p = r_\alpha > r_e$

17.



Force one pole

F = $m \times \frac{\mu_0 I}{2\pi\sqrt{d^2 + x^2}}$

Total force = 2 F sinθ. = $2 \times \frac{\mu_0 I m}{2\pi\sqrt{d^2 + a^2}} \times \frac{x}{\sqrt{d^2 + a^2}} = \frac{\mu_0 I \ mx}{\pi(d^2 + a^2)}$

m × 2 = M = I × πa^2 (magnetic moment)

Total force = $\frac{\mu_0 I \ a^2}{2(d^2 + a^2)} \Rightarrow = \frac{\mu_0 I \ a^2}{2d^2}$ (As d >>a)

18. Magnetic field at centre of an arc subtending angle θ at the centre is $\frac{\mu_0 I}{4\pi r}\theta$.

$B = \left(\frac{\mu_0}{4\pi}\right) \times 10\left(\frac{1}{3 \times 10^{-2}} - \frac{1}{5 \times 10^{-2}}\right)\frac{\pi}{4} = \frac{\pi}{4} \times 10^{-7} \times 10^{3}\left(\frac{2}{15}\right)$

$B = \frac{\pi}{30} \times 10^{-4} = \frac{\pi}{3} \times 10^{-5} \approx 10^{-5}$ T

19. $B = \mu_0 H$

$\mu_0 ni = \mu_0 \times H$

$\frac{100}{0.2} \times 5.2 = H$

$H = 2600$ A/m

20. For a circular loop, $L = 2\pi R_1$, $R_1 = \frac{L}{2\pi}$

$B_L = \frac{\mu_0 I}{2R_1} = \frac{\mu_0 I}{2L} \times 2\pi$ for a circular coil of N identical turns

$L = N2\pi R_2$ $\quad$ $R_2 = \frac{L}{2\pi N}$

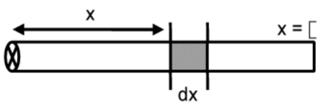
$B_C = N\frac{\mu_0 I}{2R_2} = N\frac{\mu_0 I}{2L} \times 2\pi N$ $\quad \Rightarrow \quad$ $\frac{B_L}{B_C} = \frac{\mu_0 I 2\pi}{2L} \times \frac{2L}{N\mu_0 I \times 2\pi N} = \frac{1}{N^2}$

21. $qE = qVB$ ....(1) & $r = \frac{mV}{qB}$ ....(2) from (1) & (2) :

$m = \frac{qB^2 r}{E}$ $\quad \Rightarrow \quad$ $m = \frac{1.6 \times 10^{-19} \times 0.25 \times 0.5 \times 10^{-2}}{10^2} \approx 2 \times 10^{-24}$ kg

22. Work done = 2MB = 0.02 J

23. $\omega = 2\pi n$ rad/s



$dQ = \rho .\, dx = \frac{\rho_0}{\ell} x dx$

$dI = \frac{dQ.\omega}{2\pi}$

$dM = dI \times A$

$\int dM = \int_0^{\ell} \frac{\omega}{2\pi} . \frac{\rho_0}{\ell} x . \pi x^2 dx$

$\Rightarrow \quad M = \frac{\pi n \rho_0 \ell^3}{4}$

24. At 45°, $B_H = B_V$

$\frac{F\ell}{2} = MB_V = m \times \ell \times B_V$

$\Rightarrow \quad F = \frac{2m\ell B_V}{\ell} = 3.6 \times 18 \times 10^{-6}$ N $= 6.5 \times 10^{-5}$ N

25. $I = xH$

$\frac{20 \times 10^{-6}}{10^{-6}} = x\, 60 \times 10^3$

$\Rightarrow \quad x = \frac{1}{3} \times 10^{-3} = 3.3 \times 10^{-4}$

26. $x_m \propto \frac{1}{T}$

$\frac{2.8}{x} = \frac{300}{350}$

$\Rightarrow \quad x = 3.267 \times 10^{-4}$

27. $I = \frac{B_0^2}{2\mu_0} \times C$

$B_0 = \sqrt{\frac{2\mu_0 I}{C}}$

$\Rightarrow \quad B_{rms} = \sqrt{\frac{\mu_0 I}{C}} = \sqrt{\frac{4\pi \times 10^{-7} \times 10^8}{3 \times 10^8}} \approx 10^{-4}\ T$

28. $r = \frac{\sqrt{2mqv}}{qB}$

$\Rightarrow \quad r \propto \sqrt{\frac{m}{q}}$

$\sqrt{\frac{1}{4} \times \frac{2}{1}} = \frac{1}{\sqrt{2}}$