UNIT # 09

MAGNETIC EFFECT OF CURRENT

EXERCISE –I

1. $\vec{B}_O = \vec{B}_{arc} + \vec{B}_{st.wire} = \frac{\mu_0}{2}\frac{I}{R}\left(-\tilde{k}\right) + \frac{\mu_0}{2\pi}\frac{I}{R}\left(\tilde{k}\right)$

2. $B = \frac{\mu_0}{2}\frac{I}{R} \quad \left(2\pi R = n2\pi r \Rightarrow r = \frac{R}{n}\right)$

$B' = \frac{\mu_0}{2}\frac{In}{(R/n)} = n^2 B$

3. $B_1 = \frac{\mu_0}{2}\frac{I_1}{R} = 3 \times 10^{-5}\,T$

$B_2 = \frac{\mu_0}{2}\frac{I_2}{R} = 4 \times 10^{-5}\,T$

$B = \sqrt{B_1^2 + B_2^2} = 5 \quad 10^{-5}\ T$

4. Total magnetic field at point P is zero.

5. $\vec{B} = \vec{B}_{arc} + \vec{B}_{st.line} = 0 + \left(\frac{\mu_0}{4\pi}\frac{I}{R}\right) \times 2\tilde{k}$

6. $B_{axis} = \frac{1}{2}(B_{centre})$

$\Rightarrow \frac{\mu_0}{4\pi}\frac{2\pi R^2 I}{\left(R^2 + x^2\right)^{3/2}} = \left(\frac{\mu_0}{4\pi}\frac{2\pi I}{R}\right) \times \frac{1}{2}$

$\Rightarrow$ x = 0.766 R

7. B due to closed loop is zero in all cases. B due to straight lead wires is non–zero in case (c).

8. $\vec{B}$ due to XY wire on wire PQ is into the plane.

$\therefore$ Force on wire PQ = $\int i\,\overrightarrow{d\ell} \times \vec{B}$

= $\int i\,\overrightarrow{d\ell}\left(-\tilde{i}\right) \times B\left(-\tilde{k}\right)$ = $\int i\,\overrightarrow{d\ell}B\left(-\tilde{j}\right)$ (downward)

9. For radial component of magnetic field, the total force will be either in the upward or in the downward direction depending on the direction of current.
$\therefore$ Force = $ILB_{\perp}$ = I $(2\pi a)$ $B\sin\theta$

10. Force = I (L_{eff})B
L_{eff} = length normal to $\vec{B} = \overrightarrow{RQ}$

$\therefore$ Force = 5 $\quad \frac{4}{100} \quad$ 2 = 0.4 N

11. For constant velocity $a=0 = g\sin\theta - \frac{i\ell B\cos\theta}{m}$

$\Rightarrow B = \frac{mg\tan\theta}{i\ell}$

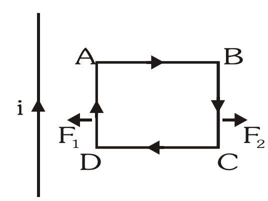
12. If I_1 and I_2 are in same direction, the attractive force, F (per unit length) = $\frac{\mu_0}{2\pi}\ \frac{I_1 I_2}{d}$

Now $F' = -\frac{\mu_0}{2\pi}\frac{(2I_1)I_2}{(3d)} = -\frac{2F}{3}$

13. $F = \frac{\mu_0}{2\pi}\ \frac{I_1 I_2}{d} = \frac{2 \times 10^{-7} \times 1 \times 1}{1} = 2 \quad 10^{-7}$ N/m

14. Angle between $\vec{M}$ and $\vec{B}$ is $\left(\frac{\pi}{2} + \theta\right)$

15. $F_1 > F_2 \therefore F_{net} = F_1 - F_2$ (attractive)



16. $\vec{M} = NIA\tilde{n}$

$= 1 \quad 10 \quad 0.1 \quad 0.1 \left(\hat{i}\cos 60° - \tilde{k}\cos 30°\right)$

$= 0.05 \left(\tilde{i} - \sqrt{3}\tilde{k}\right) A - m^2$

17. $B = \frac{\mu_0}{4\pi}\frac{(2e)}{r}\left(\frac{2\pi}{T}\right) = \frac{\mu_0 \times 1.6 \times 10^{-19}}{0.8 \times 2} = \mu_0 \times 10^{-19}\,T$

18. $\vec{L}$ is along the axis of rotation but $\vec{M}$ is opposite to it as it is negative charged.

19. Force on electron, $\vec{F} = q\vec{v} \times \vec{B}$

$\Rightarrow F\left(\tilde{j}\right) = -ev\left(\tilde{i}\right) \times B\left(\tilde{B}\right) \Rightarrow \tilde{B} = \tilde{k}$

20. Force on cosmic rays,
$\vec{F} = ev\left(-\tilde{k}\right) \times B\left(\tilde{j}\right) = evB\tilde{i}$ (towards East)

21. $F_e = \frac{1}{4\pi \in_0}\ \frac{e^2}{r^2}$

$F_m = \frac{\mu_0}{4\pi}\frac{e^2 v^2}{r^2} \Rightarrow \frac{F_e}{F_m} = \frac{1}{\in_0 \mu_0 v^2} = \frac{c^2}{v^2}$

22. $R = \dfrac{mv}{qB} = \dfrac{\sqrt{2mK}}{qB}$

$\therefore \dfrac{R_1}{R_2} = \sqrt{\dfrac{m_1}{m_2}} \Rightarrow \dfrac{m_1}{m_2} = \left(\dfrac{R_1}{R_2}\right)^2$

23. Electrostatic force on electron, $\vec{F}_e = -eE\hat{j}$

$\therefore$ Magnetic force on electron,

$\vec{F}_m = -ev(-\hat{j}) \times B\hat{k} = evB\hat{i}$

The electron moves in circle with radius on x–axis.

24. Positive charge moves to the left and negative charge to the right.

25. Magnetic force acts normal to velocity and hence KE does not change but momentum changes.

26. $R = \dfrac{\sqrt{2mK}}{qB}$; $R_\alpha = \dfrac{\sqrt{8mK}}{2qB}$;

$R_P = \dfrac{\sqrt{2mK}}{qB}$; $R_d = \dfrac{\sqrt{4mK}}{qB}$

27. The velocity, vector normal to $\vec{B}$ gives rise to magnetic force which rotates the charge particle in a circle. The velocity vector parallel to $\vec{B}$ moves it in a straight line. The resultant is a helical path.

28. $B = \dfrac{\mu_0}{4\pi}\dfrac{I}{(a\cos 30°)}(\sin 30 + \sin 30)$

$\left[1 - \dfrac{1}{2} + \dfrac{1}{3} - ....\right] \Rightarrow \vec{B} = \dfrac{\mu_0}{4\pi}\dfrac{I\,\ell n4}{\sqrt{3}a}\hat{k}$

29. $\vec{F} = q(\vec{v} \times \vec{B} + \vec{E}) = 0 \Rightarrow q(10\hat{i} \times B\hat{j} - 10^4\hat{k}) = 0$

$\Rightarrow B = 10^3 \text{ Wb/m}^2$

30. $\vec{B} = \left[\dfrac{\mu_0}{4\pi}\dfrac{I}{2r}\pi + \dfrac{\mu_0}{4\pi}\dfrac{I}{r}\pi\right] \otimes = \dfrac{3\mu_0 I}{8r} \otimes$

31. Magnetic field around a current carrying wire has circular symmetry. Hence zero $\vec{B}$ line lies in the same plane of wires. The locus of zero $\vec{B}$ is a straight line.

32. $\vec{B}_{z\text{ wire}} = 0$; $\vec{B}_{y\text{ wire}} = (-\hat{i})\left(\dfrac{\mu_0}{2\pi a}\right)$;

$\vec{B}_{x\text{ wire}} = (\hat{j})\left(\dfrac{\mu_0 i}{2\pi a}\right)$ $\therefore \vec{B} = \dfrac{\mu_0 i}{2\pi a}(\hat{j} - \hat{i})$

33. $qE = \dfrac{mv_0^2}{r_1}$ and $qvB = \dfrac{mv_0^2}{r_2} \Rightarrow \dfrac{r_1}{r_2} = \dfrac{v_0 B}{E}$

34. $R = \dfrac{mv}{qB} = d \Rightarrow v = \dfrac{qBd}{m}$

35. $q\left[|\vec{E}| - |v\vec{B}|\right] = 0 \Rightarrow v = \dfrac{E}{B}$

$\therefore$ Radius, $R = \dfrac{mv}{qB} = \dfrac{mE}{qB^2}$

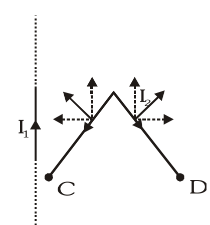
$= \dfrac{9.1 \times 10^{-31} \times 3.2 \times 10^5}{1.6 \times 10^{-19} \times 4 \times 10^{-6}} = 0.455\text{m}$

36. $R = \dfrac{mv}{qB} = \dfrac{\sqrt{2mqV}}{qB} = \dfrac{d}{2} \Rightarrow m = \dfrac{qB^2d^2}{8V}$

37. $v = (g \sin\theta)t$

$N = mg\cos\theta - qvB = 0 \Rightarrow t = \dfrac{m\cot\theta}{qB}$

38. Net force will have –x and +y components



39. $\vec{M} \times \vec{B} = I\vec{\alpha}$

$\Rightarrow$ NIA B sin90 $= \dfrac{MR^2}{2}\alpha$

$\Rightarrow$ 1 4 πR^2 10 1 $= \dfrac{2}{2}R^2$ α

$\Rightarrow \alpha = 40\pi \text{ rad/s}^2$

40. $\left[\dfrac{E^2\mu_0 \in}{B^2}\right] = \left[\dfrac{v^2}{c^2}\right] = M^0L^0T^0$

EXERCISE –II

1. $\dfrac{B_1}{B_2} = \dfrac{\mu_0 i_1}{2r} \times \dfrac{2(2r)}{\mu_0 i_2} = \dfrac{1}{3} \Rightarrow \dfrac{i_1}{i_2} = \dfrac{1}{6}$

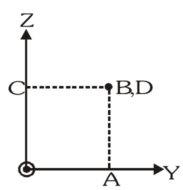
2. Effective resistance in each upper and lower arms are equal. Hence equal currents flows and produces zero M.F. in P and R configuration.

3. $I_g = \dfrac{150}{10}\ \ 10^{-3} = 0.015$ A

$V_g = \dfrac{150}{2}\ \ 10^{-3} = 0.075$ V $\therefore$ G $= \dfrac{V_g}{I_g} = 5\ \Omega$

If R = resistance to be added in series, I (G+R)=V
$\Rightarrow$ 0.015 (5+R) = 150   1 $\Rightarrow$ R = 9995 Ω

4. A and B observe electrostatic fields. But B observes magnetic field due to moving charge.

5. 

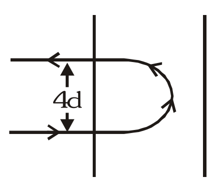
A and C have same M.F. and B and D have same M.F.

6. In B_1 and B_4 M.F. add up.
In B_2 and B_3, M.F. oppose each other.

7. $\vec{B} = \dfrac{\mu_0}{2\pi}\dfrac{I_1}{(AP)}\hat{k} + \dfrac{\mu_0}{2\pi}\dfrac{I_2}{(PB)}\hat{j}$

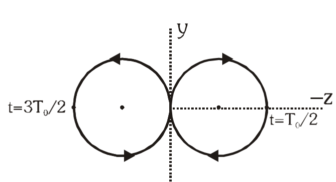
$= \left[\dfrac{2\times10^{-7}\times2}{10^{-2}}\right]\hat{k} + \left[\dfrac{2\times10^{-7}\times3}{2\times10^{-2}}\right]\hat{j}$

$= (3\times10^{-5}\,T)\hat{j} + (4\times10^{-5}\,T)\hat{k}$

8. $R = \dfrac{mv}{qB} = \dfrac{v}{\alpha B} = 2d$ 

Angle substended at the centre = π

Time to stay in magnetic field $= \dfrac{T}{2} = \dfrac{\pi}{\alpha B}$

9. 

10. $T = \dfrac{2\pi m}{qB} = 2\pi \Rightarrow R = \dfrac{mv}{qB} = \dfrac{|x|}{|x|} = 1m$

At t = π; charge will complete half circle.

$\therefore$ x = 0; y $= \dfrac{1}{2}\left(\dfrac{qE}{m}\right)t^2 = \dfrac{1}{2}\left(\dfrac{1\times1}{1}\right)\pi^2 = \dfrac{\pi^2}{2}$

z = 2R = 2m

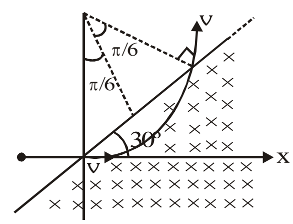
11. $\vec{F} = q\vec{v}\times\vec{B} = 1\dfrac{1}{2}(\sqrt{3}\hat{i}+\hat{j})\times1\hat{k} = \left(\dfrac{\hat{i}-\sqrt{3}\hat{j}}{2}\right)$

$R = \dfrac{mv}{qB} = \dfrac{1\times1}{1\times1} = 1 \Rightarrow \vec{R} = \vec{r}_2 - \vec{r}_1 = \left(\dfrac{\hat{i}-\sqrt{3}\hat{j}}{2}\right)$

$\Rightarrow \vec{r}_2$ =centre's coordinates $= \left(\dfrac{\hat{i}-\sqrt{3}\hat{j}}{2}\right) + (-\sqrt{3}\hat{i}-\hat{j})$

12. Effective length, length normal to $\vec{B}$, remains same.

13. $t = \dfrac{\theta}{\omega} = \dfrac{2\times\pi/6}{qB/m} = \dfrac{\pi m}{3qB}$



Distance travelled

$= RQ = \dfrac{\pi m v}{3qB}$

Velocity of exit = $v_0(\cos 60\hat{i} + \sin 60\hat{j})$

14. $\dfrac{\theta}{t} = \dfrac{\pi/2}{t} = \dfrac{2\pi}{T} = \dfrac{2\pi}{(2\pi m/qB)}$

$\Rightarrow t = \dfrac{\pi m}{2qB} = \dfrac{\pi R}{2v}\left(\because R = \dfrac{mv}{qB}\right)$

15. Work done by E.F. = qE2a $= \dfrac{1}{2}m(4v^2 - v^2)$

$\Rightarrow E = \dfrac{3mv^2}{4qa}$

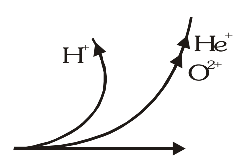
Rate of work done by E.F. at

P = $q\vec{E}.\vec{v} = \left(\dfrac{3}{4}\dfrac{mv^2}{qa}\right)qv = \dfrac{3mv^3}{4a}$

Rate of work done by E.F. and

M.F. at Q : $q(\vec{E}.\vec{v} + (\vec{v}\times\vec{B}).\vec{v})$ = 0

16. $R_{H^+} = \dfrac{\sqrt{2mK}}{qB} = R$



$R_{He^+} = \dfrac{2\sqrt{2mK}}{qB} = 2R$

$R_{O^{2+}} = 2\dfrac{\sqrt{2mK}}{qB} = 2R$

H^+ is deflected most

17. Ampere's Law $\Rightarrow B2\pi\frac{d}{2} = \mu_0 J\left(\frac{\pi d^2}{4}\right)$

$B = \left(\frac{\mu_0}{4\pi}.\pi dJ\right)\tilde{j}$ $\therefore$ $B_{net} = 2B = \left(\frac{\mu_0}{2\pi}\right)\pi dJ\tilde{j}$

18. $\vec{F} = -qv\left(\frac{\hat{i}-\hat{j}}{\sqrt{2}}\right)\times B(-\hat{k}) = qvB\left(\frac{-\hat{i}-\hat{j}}{\sqrt{2}}\right)$

$\therefore \hat{F} = -\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

19. From work energy theorem

$W = \Delta KE \Rightarrow qE_0x_0 = \frac{1}{2}mv^2$

$\Rightarrow \alpha E_0 x_0 = \frac{1}{2}(4^2+3^2) \Rightarrow x_0 = \frac{25}{2\alpha E_0}$

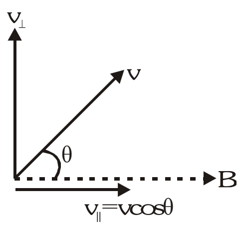
20. $\vec{F} = -e\vec{v}\times\vec{B}$

$\Rightarrow -2\hat{j} = -e\left[2\hat{i}\times(B_1\hat{i}+B_2\hat{j}+B_3\hat{k})\right] \Rightarrow B_2 = 0$

$\Rightarrow 2\hat{i} = -e\left[2\hat{j}\times(B_1\hat{i}+B_2\hat{j}+B_3\hat{k})\right] \Rightarrow B_1 = 0$

Then $\vec{F} = -e\left[2\hat{k}\times(B_3\hat{k})\right] = 0$

21. $T_1 = \frac{2\pi M}{QB} = T_0$



$T_2 = \frac{2\pi(2M)}{QB} = 2T_0$

They will meet at time $2T_0$.

$\therefore$ Distance from origin=vcos θ $2T_0 = \frac{4\pi Mv\cos\theta}{QB}$

22. Impulse = change in momentum

$\Rightarrow (i\ell B\Delta t) = m(\sqrt{2gh}-0) \Rightarrow (i\Delta t) = \Delta q = \frac{m\sqrt{2gh}}{\ell B}$

23. $\Sigma F = 0 \Rightarrow mg\sin\theta - f = 0,\ f = mg\sin\theta$ ...(i)
$\Sigma T = 0 \Rightarrow MB\sin\theta - fR = 0$

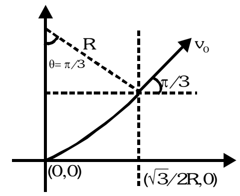
$\Rightarrow i\pi R^2 B\sin\theta = mg\sin\theta R \Rightarrow B = \frac{mg}{\pi iR}$

24. $\vec{\tau} = \vec{M}\times\vec{B} = \frac{IA}{2}(-\hat{k})\times B(-\hat{j}) = \frac{IAB}{2}(-\hat{i})$ (Leftward)

25. In configurations (C) and (D) , equal currents flow in each arm. Hence $\vec{B}$ at centre will be zero.

26. $\vec{F} = q(v\cos\alpha\hat{j}+v\sin\alpha\hat{k})\times B\hat{j} = qvB\sin\alpha(-\hat{i})$
Hence the x-coordinate of proton can never be +ve.

27. $R\sin\theta = \frac{\sqrt{3}}{2}\frac{mv_0}{qB_0} = \frac{\sqrt{3}}{2}\frac{v_0}{\alpha B_0} = \frac{\sqrt{3}}{2}R$; $\theta = \pi/3$



$\therefore$ x-coordinate

$= \frac{\sqrt{3}}{2}R + v_0\cos\theta\left(t-\frac{\theta}{\omega}\right)$

$= \frac{\sqrt{3}v_0}{2B_0\alpha} + \frac{v_0}{2}\left(t-\frac{\pi}{3B_0\alpha}\right)$

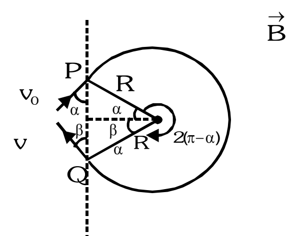
28. $\vec{F} = q\vec{v}\times\vec{B} = qv_0(\hat{i}+\hat{j})\times\vec{B} = (-)qv_0B\hat{k}$

$T = \frac{2\pi m}{qB}$ $\therefore$ $\omega t = \frac{2\pi}{T}t = \frac{2\pi qB}{2\pi m}\times\frac{\pi}{qB} = \pi$

$\therefore X = v_0 t = \frac{v_0\pi}{B_0\alpha}$; $Y = 0$

$Z = -2R = \frac{-2Mv_0}{2B_0} = -\frac{2v_0}{\alpha B_0}$

29. In magnetic fieldy the path is circle and the motion is uniform.



$\therefore v = v_0$

$PQ = 2R\sin\alpha = \frac{2mv_0}{qB}\sin\alpha \Rightarrow \frac{2\pi}{T} = \frac{\theta}{t}$

$\Rightarrow \frac{2\pi}{\left(\frac{2\pi m}{qB}\right)} = \frac{2(\pi-\alpha)}{t} \Rightarrow t = \frac{2m(\pi-\alpha)}{Bq}$

30. $L_{effective} = AB = 4\hat{j}$

$\therefore |\vec{F}| = |I\vec{L}\times\vec{B}| = IL_{eff}B = 2.4\hat{j}\ \ 4(-\hat{k}) = -32\hat{i}$ N

31. $\vec{F} = I\vec{L}\times\vec{B} \Rightarrow I\left(R\left(-\hat{j}\right)\times B\hat{B}\right) = \sqrt{2}IRB_0\hat{k}$

Possible values of $\therefore$ $\vec{B} = \frac{B_0}{\sqrt{2}}\hat{i}$ and $\vec{B} = \frac{B_0}{\sqrt{2}}(\hat{i}+\hat{j})$

32. Force acting on unit length = $B_0 I$

33. $\vec{T} = \vec{M} \times \vec{B}$

Torque is directed at right angle to hour hand. Hence minute hand will be in the direction of torque after 20 minutes.

T = M B sin θ = NIAB sin 90

$= \dfrac{6 \times 2 \times \pi(0.15)^2 \times 70 \times 1}{1000}$ = 0.0594 Nm

34. The lines of force will be concentric circles with centres on wire.

All points lying on the circle have same magnitude of magnetic field.

Magnetic field at a point from the wire varies inversely with distance from the wire.

35. Magnetic field exerts force on a moving charge normal to it and the force also acts normal to both of them and hence kinetic energy remains same.

36. $a = \dfrac{T_1}{T_2} = \dfrac{2\pi m}{qB} \Big/ \dfrac{2\pi m}{qB} = 1$

$b = \dfrac{mv\sin 30°}{qB} \Big/ \dfrac{mv\sin 60}{qB} = \tan 30°$

$c = v_{\|}\ T = \dfrac{v\sin 60° T}{v\sin 30 T}$ = tan 60

∴ bc = 1 = a ⇒ abc = 1

38. $\vec{F} = q[\vec{E} + \vec{v} \times \vec{B}] = 0 \Rightarrow |\vec{E}| = |-\vec{v} \times \vec{B}| = |-vB| = vb$

$v = \dfrac{E}{B} = \dfrac{2E}{2B}$ (direction remaining same)

39. $\vec{F} = q[\vec{E} + \vec{v} \times \vec{B}] = 0 \Rightarrow |\vec{E}| = |\vec{v} \times \vec{B}| = vB$

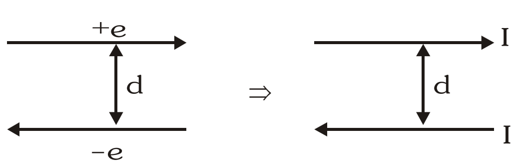
∴ $E = |1.5\ 10^{-6}(-\hat{j})\quad 1(-\hat{k})|$

$= |1.5\quad 10^{-6}(-\hat{i})|$ N/C

$\dfrac{R_A}{R_B} = \dfrac{(mv/qB)_A}{(mv/qB)_B} = \dfrac{m_A}{m_B} = \dfrac{12}{13}$

40. $\vec{B}_P = \dfrac{\mu_0}{4\pi}\dfrac{I}{R/\sqrt{2}}(\sin 90° - 45°) = \dfrac{(\sqrt{2}-1)\mu_0 I}{4\pi R}(-\tilde{k})$

41.



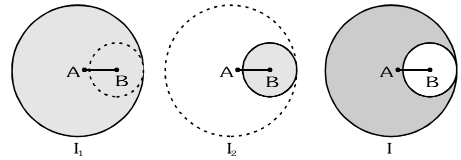
$\vec{B}$ at mid point = 0 Equivalent form

42. For inner cylinder $B = \dfrac{\mu_0}{2\pi}\dfrac{ir}{R_1^2}$

For air space $B = \dfrac{\mu_0}{2\pi}\dfrac{i}{r}$

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

43.



$I_1 = \dfrac{IR^2}{\pi\left(\dfrac{3R^2}{4}\right)}; I_2 = \dfrac{I(R/2)^2}{\pi\left(\dfrac{3R^2}{4}\right)}$

Field at A $= B_{I_1} + B_{I_2} = 0 + \dfrac{\mu_0 i}{3\pi R}\tilde{j}$

Field at B $= B_{I_1} + B_{I_2} = \dfrac{\mu_0 I}{3\pi R}\tilde{j} + 0$

44. $B_C = B_{I_1} + B_{I_2} = \dfrac{\mu_0 ic}{2\pi(b^2 - a^2)} + 0$

45. $\vec{B}$ add up is the left and the right zone. But in the middle zone $\vec{B}$ becomes zero.

46. $B_{\text{axial point}}$

$= 2\left(\dfrac{\mu_0}{4\pi}\right)\dfrac{M}{r^3} = \dfrac{2 \times 10^{-7} \times 8}{(0.2)^3} = 2 \times 10^{-4}\,T$

$B_{\text{eq. point}} = \left(\dfrac{\mu_0}{4\pi}\right)\dfrac{M}{r^3} = 10^{-4}\,T$

47. W = MB (1−cos 60) = $\dfrac{MB}{2}$

$|\vec{T}|$ = MB sin60 $= \sqrt{3}\dfrac{MB}{2} = \sqrt{3}$ W

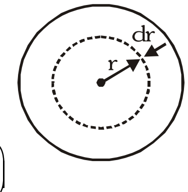
48. MB sinθ = T ⇒ M 0.16 $\dfrac{1}{2}$ = 0.032

⇒ M = 0.4 J/T

49. Both rings experience torque due to other's magnetic field .

50. Charge per unit area = $\dfrac{Q}{\pi R^2}$

Charge on elemental ring,



$dQ = \left(\dfrac{Q}{\pi R^2}\right)2\pi r dr = \dfrac{2Qrdr}{R^2}$

∴ B at centre $= \int \dfrac{\mu_0}{2}\left(\dfrac{dQ}{r}\dfrac{\omega}{2\pi}\right)$

$= \dfrac{\mu_0\omega}{4\pi}\left(\dfrac{2Q}{R^2}\right)\int_0^R dr = \dfrac{\mu_0 Q\omega}{2\pi R}\odot$

51. $\vec{F} = q\vec{v} \times \vec{B} \Rightarrow (4\tilde{i} + 3\tilde{j}) \times 10^{-13} = -1.6 \times 10^{-19}$

$$\left[(2.5\times10^{7})\tilde{k}\times\left(B_1\tilde{i}+B_2\tilde{j}+B_3\tilde{k}\right)\right]$$

$$\Rightarrow B_1 = -\ 0.075,\ B_2 = +\ 0.1$$

Again : $\vec{F}=q\vec{v}\times\vec{B}$; q= – 1.6 10^{-19}

$$\left[(1.5\tilde{i}-2\tilde{j})10^{7}\right]\times\left(0.075\tilde{i}+0.1\tilde{j}+B_3\tilde{k}\right)$$

$$\Rightarrow B_3=0\quad \therefore \vec{B}=-0.075\tilde{i}+0.1\tilde{j}$$

52. $$\vec{B}_0=\frac{\mu_0}{4\pi}\frac{I}{R}\theta(-\tilde{k})+\frac{\mu_0}{4\pi}\frac{I}{R\cos\frac{\theta}{2}}\left(\sin\frac{\theta}{2}+\sin\frac{\theta}{2}\right)\tilde{k}$$

$$\Rightarrow\ \vec{B}_0=\frac{\mu_0}{4\pi}\frac{I}{R}\left(2\tan\frac{\theta}{2}-\theta\right)\tilde{k}>0$$

$\therefore$ $\vec{B}_0$ is directed outwards.

53. $v_y = v_0$

$$v_x=\left(\frac{qE_0}{m}\right)t\ ;v=\sqrt{v_0^2+\left(\frac{qE_0}{m}t\right)^2}=2v_0\Rightarrow t=\frac{\sqrt{3}mv_0}{qE}$$

54. $T=\dfrac{2\pi m}{qB}$ (Time period of rotation)

For motion in E.F.

$$s = ut + \frac{1}{2}at^2 \Rightarrow\ 0 = vt - \frac{1}{2}\left(\frac{qE}{m}\right)t^2$$

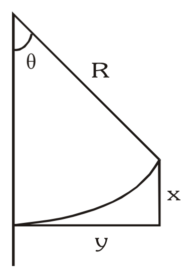
$$\Rightarrow t=\frac{2mv}{qE}=nT\Rightarrow\ n=\frac{vB}{\pi E}=\text{An integer}$$

55. Radius, $R=\dfrac{mv}{qB}\Rightarrow mv = qBR$

where R sinθ = y; R (1–cosθ) =x

$$\Rightarrow R=\frac{1}{2}\left(\frac{y^2}{x}+x\right)$$

$$\therefore\ mv=\frac{qB}{2}\left(\frac{y^2}{x}+x\right)$$

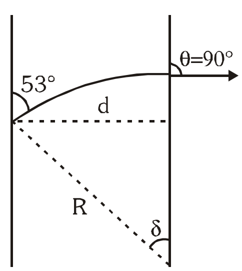


56. Rsinδ= d

$$\frac{mv}{qB}\sin\delta=\frac{3mv}{5qB}$$

δ = 37

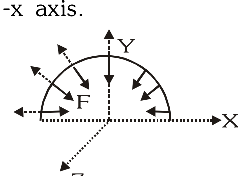
∴θ = 53 + δ = 90



57. $R=\dfrac{mv}{qB}$

The radius may be decease if v decreases or B increases.

58. Since $\vec{B}$ depends on x-coordinate the net force acts along -x axis.



EXERCISE –III

Fill in the blanks :

1. Magnetic field exerts force on moving charges (free electrons).

2. L= 2πR ∴ M = iA = $i\pi R^2 = i\pi\left(\dfrac{L}{2\pi}\right)^2=\dfrac{iL^2}{4\pi}$

3. M=(qf) A=(1.6 10^{-19}) (10^{16}) π (0.5 $10^{-10})^2$

= 126 10^{-23} Am^2

4. $\vec{F}_{electrons}=-ev(-\hat{i})\times B\hat{j}$ = $evB\hat{k}$

All negative charges accumulate one face ABCD. Hence the potential of this face decreases.

Match the column

1. (A) $I=\dfrac{q}{T}\left(T=\dfrac{2\pi m}{qB}\right)\Rightarrow I\propto v^0$

(B) M= IA $=\dfrac{q}{T}\pi R^2=\dfrac{q}{T}\pi\left(\dfrac{Mv}{qB}\right)^2$ $\Rightarrow M\propto v^2$

(C) $B=\dfrac{\mu_0}{4\pi}\dfrac{qv}{r^2}$ $B\propto v^2$

2. $R=\dfrac{mv}{qB}=R_0$

	Position
$R_A = 2R_0$	→ 4
$R_B = -4R_0$	→ 1
$R_C = -2R_0$	→ 2
$R_D = +R_0$	→ 3

3. (A) Magnetic moment = NIA$\hat{k}$

(B) Torque = $M\hat{k}\times B\hat{k}=0$

(C) P.E. $=-M\hat{k}.B\hat{k}=-MB$

(D) P.E. is minimum, equilibrium is stable

4. (A) $\oint_{loop-1}\vec{B}.d\vec{\ell}$ = μ_0 (i – i – i) = $-\mu_0 i$

(B) $\oint_{loop-2}\vec{B}.d\vec{\ell}$ = μ_0 (i + i – i) = $\mu_0 i$

(C) $\oint_{loop-3}\vec{B}.d\vec{\ell}$ = μ_0 (i – i – i) = $-\mu_0 i$

(D) $\oint_{loop-4}\vec{B}.d\vec{\ell}$ = μ_0 (i – i + i) = $\mu_0 i$

5. Since magnetic moment = 0 hence torque = 0

(A) $\vec{B} = B_0\hat{i} \Rightarrow |\vec{F}| = \left(\frac{i}{2}\ell B\right) \times 2 = i\ell B$

(B) $\vec{B} = B_0\hat{j} \Rightarrow |\vec{F}| = \left(\frac{i}{2}\ell B\right) \times 2 = i\ell B$

(C) $\vec{B} = B_0(\hat{i}+\hat{j}) \Rightarrow |\vec{F}| = \frac{i}{2} \times \ell_{eff} \times B = 0$ (L_{eff} =0)

(D) $\vec{B} = B_0\hat{k} \Rightarrow \vec{F} = \sqrt{\left(\frac{i\ell B}{2}\times 2\right)^2 + \left(\frac{i\ell B}{2}\times 2\right)^2} = \sqrt{2}\, i\ell B$

6. A charge at rest produces E.F.
A charge with uniform velocity produces M.F. + E.F.
An accelerated charge produces M.F. + E.F. +EM waves.

7. (A) $M = \frac{q\omega}{2\pi} \times \pi r^2 = \frac{q\omega r^2}{2}$

(B) $M = \frac{q\omega}{2\pi} \times \pi r^2 = \frac{q\omega r^2}{2}$

(C) $M = \int_0^R \frac{q(2\pi r dr)}{\pi R^2} \times \frac{\omega}{2\pi} \times \pi r^2 = \frac{q\omega r^2}{4}$

(D) $M = \int_{-\pi/2}^{+\pi/2} \frac{q}{4\pi R^2}(2\pi R\cos\theta)(Rd\theta) \times \frac{\omega}{2\pi} \times \pi(R\cos\theta)^2$

$= \frac{q\omega r^2}{3}$

(E) $M = \int_{-R}^{+R} \frac{q}{\left(\frac{4}{3}\pi R^3\right)} \pi(R^2 - y^2)dy \times \frac{\omega}{2\pi} \times \pi(R^2 - y^2)$

$= \frac{q\omega r^2}{5}$

Comprehension#1

1. $\tau = I\alpha \Rightarrow \vec{M} \times \vec{B} = I\alpha$

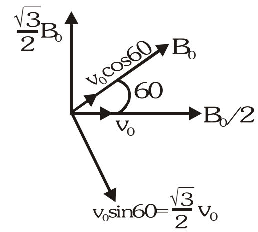
$\Rightarrow (3\hat{i} - 4\hat{j}) \times (4\hat{i} + 3\hat{j}) = I\alpha = 10^{-2}\alpha$

$\Rightarrow \alpha = 2500 \text{ rad/s}^2$

2. $\frac{1}{2}I\omega^2 = \Delta U \Rightarrow \frac{1}{2}\ 10^{-2}\ \omega^2 = U_{max} - U_{min} = 25$

$\Rightarrow \omega = 50\sqrt{2}$ rad/s

Comprehension#2



1. Pitch = $v_0\cos60\left(\frac{2\pi m}{qB_0}\right) = v_0 \times \frac{1}{2}\left(\frac{2\pi m}{qB_0}\right) = \frac{\pi M v_0}{qB_0}$

2. z component of velocity is $\frac{\sqrt{3}}{2}v_0$ after

$t = \frac{T}{4} = \frac{\pi m}{2B_0 q}$

3. $(\text{z-coordinate})_{max} \Rightarrow 2R = 2\left(\frac{mv_0}{qB_0}\frac{\sqrt{3}}{2}\right)$

$= \frac{\sqrt{3}mv_0}{qB_0}$

4. When z-co-ordinate has maximum value its velocity

$= v_0\cos60\ (\hat{i}\cos60 + \hat{j}\sin60)$

$= \left(\frac{\hat{i}+\sqrt{3}\hat{j}}{2}\right)\frac{v_0}{2} = \frac{v_0}{4}(\hat{i}+\sqrt{3}\hat{j})$

Comprehension#5

From graph :

1. $r_c > r_a$

2. $(B_{max})_a > (B_{max})_c$

3. $B = \frac{\mu_0 Jr}{2}$ for a and c : $J_a r_a = J_c r_c$

$J_a > J_c$ ($\because$ $r_c > r_a$)

Comprehension#6

1. Force per unit length

$= \frac{mg}{\ell} = \lambda g = \frac{\mu_0 I_1 I_2}{2\pi d} \Rightarrow d = \frac{\mu_0 I_1 I_2}{2\pi\lambda g}$

2. For equilibrium, the magnetic force must be repulsive for the upper wire. Hence currents must be opposite in each wire.

3. Total mechanical energy changes due to displacement from mean position.

4. If P.E. due to M.F. is same, the P.E. due to gravity is different.

EXERCISE –IV(A)

1. From Biot–Savart law :

$$\vec{B}_P = \frac{\mu_0}{4\pi}\frac{i\vec{d\ell}\times\vec{r}}{r^3} = \frac{10^{-7}\times 10\left(\Delta x\tilde{i}-\Delta y\tilde{j}\right)\times\left(\tilde{i}+\tilde{j}\right)}{\left(1^2+1^2\right)^{3/2}}$$

$$= 7.07\times 10^{-10}\tilde{k}\ T$$

where $\left(\Delta x = \Delta y = 10^{-3}m\right)$

2. $\vec{B}_O = \vec{B}_{SM} + \vec{B}_{SQ} + \vec{B}_{LR} + \vec{B}_{RP}$

$$= 0 + \left(\frac{\mu_0}{4\pi}\frac{i}{d}\right)\tilde{k} + 0 + \left(\frac{\mu_0}{4\pi}\frac{i}{d}\right)\tilde{k}$$

$= 10^{-4}\hat{k}$ T (d = 0.02 m, i = 10A)

3. $\vec{B}_P = \vec{B}_{\substack{\text{due to}\\ \text{long wire}}} + \vec{B}_{\substack{\text{due to}\\ \text{square}}}$

$$= \left[\frac{\mu_0}{2\pi}\frac{i}{(a/2)} - \frac{\mu_0}{4\pi}\frac{i}{(a/2)}\left(\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{2}}\right)\times 4\right]\tilde{k}$$

$$\left|\vec{B}_P\right| = \frac{\left(2\sqrt{2}-1\right)\mu_0 i}{\pi a}$$

4. $\vec{B}_O = \vec{B}_{PQ} + \vec{B}_{QS} + \vec{B}_{SR} + \vec{B}_{RP} = 2\vec{B}_{PQ} + 2\vec{B}_{QS}$

$$= 2\ \frac{\mu_0}{4\pi}\times\frac{I}{(b/2)}\left[\frac{a}{\sqrt{a^2+b^2}}+\frac{a}{\sqrt{a^2+b^2}}\right]\tilde{k}$$

$$+2\times\frac{\mu_0}{4\pi}\times\frac{I}{(a/2)}\left[\frac{b}{\sqrt{a^2+b^2}}+\frac{b}{\sqrt{a^2+b^2}}\right]\hat{k}$$

$$\Rightarrow \left|\vec{B}_0\right| = \frac{2\mu_0 I}{\pi ab}\sqrt{a^2+b^2}$$

5. $B_0 = B_{arc} + B_{st.\ wires} = \frac{\mu_0}{4\pi}\frac{I\theta}{R} - \left(\frac{\mu_0}{4\pi}\frac{I}{R}\right)\times 2 = 0$

$\Rightarrow \theta = 2$ radian

6. $\vec{B}_0 = \frac{\mu_0}{4\pi}I\theta\left(\frac{1}{r}-\frac{1}{2r}+\frac{1}{3r}\right) = \frac{5\mu_0 I\theta}{24\pi r}\otimes$

7. $\vec{B}_O = \vec{B}_{arc} + \vec{B}_{MN}$

$$= \frac{\mu_0}{4\pi}\frac{I}{R}\left(\frac{3\pi}{2}\right) + \frac{\mu_0}{4\pi}\frac{I}{\left(R/\sqrt{2}\right)}\times\left(\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{2}}\right)$$

$\Rightarrow B_0 = 3.35 \quad 10^{-5}$ T $\odot$

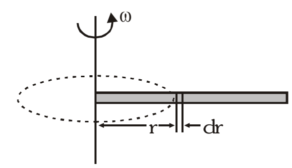
8. $\oint\vec{B}\cdot\vec{d\ell} = \mu_0 I = \mu_0\ (I_1 + I_2 + I_3 - I_4 - I_6)$

$= \mu_0\ (1 + 2 + 3 - 1 - 4) = \mu_0$

9. $F = qv_dB = e\left(\frac{J}{\rho e}\right)B = e\left(\frac{I}{A\rho e}\right)B$

$$= \frac{IB}{A\rho} = \frac{5\times 0.1}{10^{-5}\times 10^{29}} = 5 \quad 10^{-25}N$$

10. Magnetic moment of the system



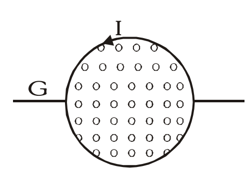
$$= \int Adi = \int\frac{Adq}{T} = \int_0^{\ell}\pi r^2\left[\frac{\left(\frac{q}{\ell}dr\right)}{2\pi}\omega\right] = \frac{q\omega\ell^2}{6}$$

11. For wire $\pi r + 2r = \ell$; $r = \frac{\ell}{\pi+2}$

$\therefore$ Magnetic moment, $M = \frac{I\pi r^2}{2} = \frac{I\pi}{2}\left(\frac{\ell}{\pi+2}\right)^2$

12. (i) Initial torque = $\left|\vec{M}\times\vec{B}\right|$ = MB sin90 = MB

Final torque = MB sin 0 = 0



(ii) $\Delta KE = -\Delta U;\ \frac{1}{2}I\omega^2 = MB,\ \omega = \sqrt{\frac{2MB}{I}}$

13. (i) Magnetic moment, M = NIA

$= 2000 \quad 4 \quad 1.6 \quad 10^{-4} = 1.28 \text{ Am}^2$

(ii) Torque, $T = |\vec{M} \times \vec{B}| = MB\sin\theta$

$= 1.28 \quad 7.5 \quad 10^{-2} \quad \frac{1}{2} = 0.048 \text{ Nm}$

Force, $F_{net} = 0$

14. (i) Torque on solenoid = MBsinθ

$= NIA\ B \sin 30$

$= 1000 \quad 2 \quad 2 \quad 10^{-4} \quad 0.16 \quad 1/2$

$= 3.2 \quad 10^{-2}$ Nm

(ii) Work done = ΔU

= MB (cos 0 – cos 90)

$= 1000 \quad 2 \quad 2 \quad 10^{-4} \quad 0.16 \quad (1-0)$

= 0.064 J

15. (i) Configurations AB_1 and AB_2 have zero force and non–zero torques.

(ii) Potential energy of the configurations are

$U_{AB_1} = 0; U_{AB_4} > 0\ ;\ U_{AB_3} < 0\ ;\ U_{AB_2} = 0$

$U_{AB_5} > 0\ ;\ U_{AB_6} > 0$

AB_4 and AB_5 are unstable and AB_3 and AB_6 are stable configurations.

(iii) Configuration AB_6 has lower energy than configuration AB_3 as magnetic field due to A at B_3 is half of the magnitude of magnetic field at B_6.

16. Net force on electron

$\Rightarrow I = 4A \quad e\vec{E} + e\vec{v} \times \vec{B} = 0 \quad \Rightarrow \frac{v}{d}\hat{i} + v\hat{j} \times \vec{B} = 0$

$\Rightarrow |\vec{B}| = \frac{600}{3 \times 10^{-3} \times 2 \times 10^{6}} = 0.1$ T and $\vec{B} = -\tilde{k}$

18. $\vec{B} = \vec{B}_{\text{smaller arc}} + \vec{B}_{\text{bigger arc}} + \vec{B}_{\text{st. line}}$

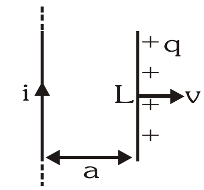
$= \frac{1}{4}\frac{\mu_0 I}{2R}\tilde{k} + \frac{1}{4}\frac{\mu_0 I}{4R}\tilde{k} + \frac{\mu_0 I}{4\pi R}\tilde{j} = \frac{\mu_0}{4}\frac{I}{R}\left(\frac{3}{4}\tilde{k} + \frac{\tilde{j}}{\pi}\right)$

19. Force on arc = I L_{eff} B = I $(\sqrt{2}R)$B

where L_{eff} is the shortest length of the arc.

EXERCISE –IV(B)

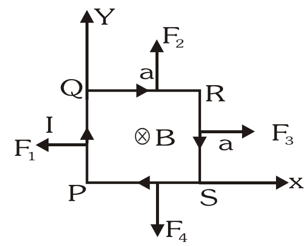
1.



$\vec{F} = qv\hat{i} \times B(-\hat{k}) = qvB\,\hat{j}$

$\vec{F}_{\text{external}} = -\vec{F} = qvB(-\hat{j})$

2.



$\vec{F}_4 = iL(-\hat{i}) \times B(-\hat{k}) = 0$ as (B=0)

$\vec{F}_1 + \vec{F}_3 = 0$

$\vec{F}_2 = iL\hat{i} \times B(-\hat{k}) = iLB\,\hat{j} = ia(\alpha a)\,\hat{j} = i\alpha a^2\,\hat{j}$

3. For interval point :

(i) $B.2\pi r_1 = \mu_0 \int_0^{r_1} br(2\pi r dr) = \frac{\mu b(2\pi)r_1^3}{3}$

$\therefore\ B = \frac{\mu_0 b r_1^2}{3}$

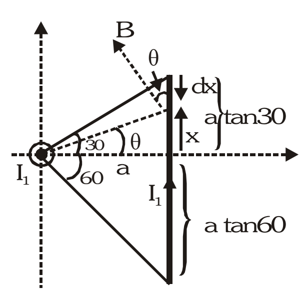
(ii) For external point :-

$B2\pi r_2 = \mu_0 \int_0^{R} (br)(2\pi r dr) \Rightarrow B = \frac{\mu_0 b R^3}{2r_2}$

4. Current I = ñ e (ñ no. of protons falling per sec)

Force , F = mvñ $= mv\ \frac{I}{e} = \frac{mIE}{eB}$ [∵ E = vB]

6. $F = \int I_2 dx B \sin\theta = \int_{-a\tan 60}^{+a\tan 30} I_2 dx \frac{\mu_0 I_1}{2\pi\sqrt{a^2+x^2}} \frac{x}{\sqrt{a^2+x^2}}$



$= \frac{\mu_0 I_1 I_2}{2\pi} \int_{-\sqrt{3}a}^{+a/\sqrt{3}} \frac{x dx}{a^2 + x^2} = \frac{\mu_0}{4\pi} I_1 I_2 \ell n 3$ (along –z axis)

7. From work energy theoram :

$W_{MF} + W_{gravity} = \Delta KE$

$\Rightarrow -\Delta U_{MF} - \Delta U_g = 0 \Rightarrow MB = \dfrac{mg\ell}{2}$

$\Rightarrow I\ell^2 B = \dfrac{mg\ell}{2} \Rightarrow B = \dfrac{mg}{2I\ell}$

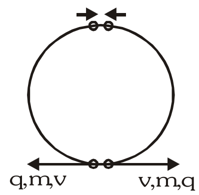
8. $F.\Delta T = m(v-u)$

$\Rightarrow ILB\Delta t = m(\sqrt{2gh} - 0) \Rightarrow qLB = m\sqrt{2gh}$

$\Rightarrow q = \dfrac{10}{1000} \times \sqrt{2 \times 10 \times 3} \times \dfrac{1}{0.2 \times 0.1}$

$\Rightarrow q = \sqrt{15}$ C

9. Both particles collide after completing semi-circle.



Time to collide $= \dfrac{T}{2} = \dfrac{2\pi m}{2qB} = \dfrac{\pi m}{qB}$

10. Let $\vec{v} = v_x\tilde{i} + v_y\tilde{j}$

We know $\sqrt{v_x^2 + v_y^2} = v_0$ ...(i)

$$\vec{F} = q(\vec{v} \times \vec{B}) = q\begin{vmatrix} \tilde{i} & \tilde{j} & \tilde{k} \\ v_x & v_y & 0 \\ 0 & 0 & -B_0\left(1+\dfrac{y}{d}\right) \end{vmatrix}$$

$$\Rightarrow m\vec{a} = -qB_0\left(1+\frac{y}{d}\right)v_y\tilde{i} + \tilde{j}qv_xB_0\left(1+\frac{y}{d}\right)$$

$$m\left(a_x\tilde{i} + a_y\tilde{j}\right) = -qB_0v_y\left(1+\frac{y}{d}\right)\tilde{i} + qB_0v_x\left(1+\frac{y}{d}\right)$$

$$\Rightarrow ma_x = -qB_0v_y\left(1+\frac{y}{d}\right) \;\&\; ma_y = qB_0v_x\left(1+\frac{y}{d}\right)$$

$$\Rightarrow mv_y\frac{dv_y}{dy} = qB_0\sqrt{v_0^2 - v_y^2}\left(1+\frac{y}{d}\right)$$

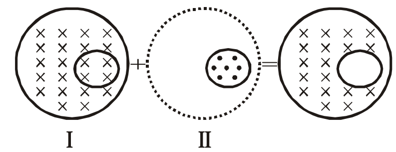
{By using equation (i)}

$$\Rightarrow \int_0^{v_y}\frac{v_y}{\sqrt{v_0^2 - v_y^2}}dv_y = \frac{qB_0}{m}\int_0^d\left(1+\frac{y}{d}\right)dy$$

$$\Rightarrow v_y = \sqrt{v_0^2 - \left(v_0 - \frac{3qB_0d}{2m}\right)^2}$$

$$\Rightarrow v_x = v_0 - \frac{3}{2}\left(\frac{qB_0d}{m}\right)$$

11. (i)

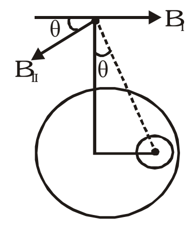


$\vec{B}_I .2\pi\ (2R) = \mu_0 J\pi R^2(-\hat{k})$

$\vec{B}_{II}.2\pi(2R - b) = \mu_0 J\pi a^2(\hat{k})$

$\therefore\ \vec{B}_{x=2R} = \mu_0 J\left[\dfrac{R}{4} - \dfrac{a^2}{4R - 2b}\right](-\hat{k})$

(ii)



$B = \sqrt{(B_I - B_{II}\cos\theta)^2 + (B_{II}\sin\theta)^2}$

$$= \sqrt{\left(\frac{\mu_0 JR}{4} - \frac{\mu_0 JRa^2}{4R^2 + b^2}\right)^2 + \left(\frac{\mu_0 Ja^2b}{2(4R^2 + b^2)}\right)^2}$$

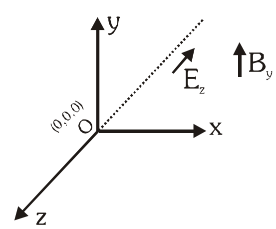
12. $m = 1 \times 10^{-26}$ kg

$q = 1.6 \times 10^{-19}$ C

$v = 1.28 \times 10^6$ m/s

$E_z = -102.4 \dfrac{kV}{m}$

$B_y = 8 \times 10^{-2}$ wb/m^2



Force by electric field

$\vec{F}_E = q\vec{E} = 1.6 \times 10^{-19} \times 102.4 \times 10^3(-\hat{k})$N

Force by magnetic field = $F_m = q(\vec{v} \times \vec{B})$

$= 1.6 \times 10^{-19} \times 1.28 \times 10^6\,\tilde{i} \times 8 \times 10^{-2}\,\tilde{j}$N

$= 1.6 \times 10^{-19} \times 102.4 \times 10^3\,\hat{k}$N

$\vec{F}_E = -\vec{F}_M$ {Till t = 6 10^{-6} sec}

So till t = 5 10^{-6} sec it moves without deflection

So x coordinate = vt = 1.28 10^6 5 10^{-6} = 6.4 m

So coordinate = (6.4 m, 0, 0)

After 2 sec $\vec{E}$ is switched off, so force on the particle is due to magnetic field which is towards +z axis.

t_2 = 7.45 10^{-6} sec

$t_2 - t_1$ = 2.45 10^{-6} sec

$T = \frac{2\pi m}{qB} = \frac{2 \times 3.14 \times 10^{-26}}{1.6 \times 10^{-19} \times 8 \times 10^{-2}} = 4.90\ 10^{-6}$ sec

So $t_2 - t_1 = \frac{T}{2}$

So particle cover 2r distance in +z direction in circle

So z-coordinate

$= \frac{2 \times m \times v}{qB} = \frac{2 \times 10^{-26} \times 1.28 \times 10^{6}}{1.6 \times 10^{-19} \times 8 \times 10^{-2}} = 2m$

So coordinates = (6.4m, 0, 2m)

13. (A) $\vec{B}$ at centre = $(B_{st.wire} - B_{arc})\ (-\hat{k})$

$$= \left[\frac{\mu_0}{4\pi}\frac{I}{R\cos 60}(2\sin 60) - \frac{\mu_0}{4\pi}\frac{I}{R}\left(\frac{2\pi}{3}\right)\right](-\hat{k})$$

$$= \frac{\mu_0 I}{6a}\left(\frac{3\sqrt{3}}{\pi} - 1\right)(-\hat{k})$$

For charge particle - qvB = ma

$$\Rightarrow a = \frac{qv\mu_0 I}{6ma}\left(\frac{3\sqrt{3}}{\pi} - 1\right)$$

(B) $\vec{T} = \vec{M} \times \vec{B} = NIA(\hat{k}) \times B\hat{i}$

$$\Rightarrow \vec{T} = I\left(\frac{\pi}{3}a^2 - \frac{\sqrt{3}}{4}a^2\right)B\hat{j}$$

14. (A) $\vec{M} \times \vec{B} + \vec{R} \times M\vec{g} = 0 \Rightarrow |\vec{M} \times \vec{B}| = |\vec{R} \times M\vec{g}|$

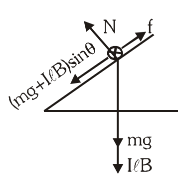
$$\Rightarrow NIA\quad B = mgr \Rightarrow I = \frac{mg}{\pi r\sqrt{B_x^2 + B_y^2}}$$

(B) $I = \frac{mg}{\pi r B x}$ (B_z has no effect on torque)

15. Work done by external agent in rotating the conductor in one full turn = $F2\pi r$ = iLB_0. $2\pi r$

Power = W.n = $i\ell B_0(2\pi r)n$

16. $f = \mu N$; N = $mg\cos\theta + I\ell B\cos\theta$



$\therefore f_{ext} = (mg + I\ell B)\sin\theta \pm f$

$= (mg + I\ell B)\sin\theta \pm \mu\,(mg\cos\theta + I\ell B\cos\theta)$

$= \frac{3}{4} \pm \frac{\sqrt{3}}{2}\ \ \frac{3}{2}\ \ 0.1 = 0.75 \pm 0.13$

$\Rightarrow f_{ext}$ = 0.62 N or 0.88 N

17. $v_{\parallel}$ = velocity parallel to $\vec{B}$ = v cos 60

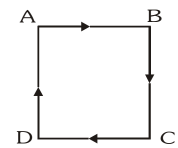
Pitch = $v_{\parallel}\quad T = v\cos 60\left(\frac{2\pi m}{eB}\right) = \frac{2\pi\cos 60}{eB}\sqrt{2mk}$

$$0.1 = \frac{2\pi \times \left(\frac{1}{2}\right)}{B} \times \sqrt{\frac{2 \times 9.1 \times 10^{-31} \times 2 \times 10^{3}}{1.6 \times 10^{-19}}}$$

$\Rightarrow B = 4.7\quad 10^{-3}$ T

18. $\vec{B}_{centre} = 4\vec{B}_{AB} = 4 \times \frac{\mu_0}{4\pi}\frac{I}{(a/2)}\left[\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right]$

$$= \frac{2\sqrt{2}\mu_0 I}{\pi a}\otimes$$



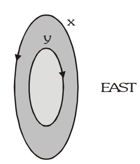
$\vec{B}_{vertex'A'} = \vec{B}_{AB} + \vec{B}_{BC} + \vec{B}_{CD} + \vec{B}_{DA}$

$$= 0 + \frac{\mu_0}{4\pi}\frac{I}{a}\left(\frac{1}{\sqrt{2}}\right) + \frac{\mu_0}{4\pi}\frac{I}{a}\left(\frac{1}{\sqrt{2}}\right) + 0 = \frac{\sqrt{2}\mu_0}{4\pi}\frac{I}{a}\otimes$$

$$\frac{B_{centre}}{B_{vertex}} = \frac{2\sqrt{2}}{\sqrt{2}} \times 4 = 8 : 1$$

19. $\vec{B}_{centre} = \left[\frac{\mu_0}{4\pi}\frac{I_x(N_x 2\pi)}{R_x} - \frac{\mu_0}{4\pi}\frac{I_y(N_y 2\pi)}{R_y}\right]\tilde{i}$

$= -1.6\quad 10^{-3}\,\tilde{i}\,T$



20. For B to be zero at P, current in B should directed upward

(i) $B_P = \frac{\mu_0}{2\pi}\left[\frac{I_A}{\left(2 + \frac{10}{11}\right)} - \frac{I_B}{\left(\frac{10}{11}\right)}\right] = 0 \Rightarrow I_B = 3A$

(ii) $\vec{B}_S = \vec{B}_A + \vec{B}_B$ and $\left(\vec{B}_A \perp \vec{B}_B\right)$

$$\vec{B}_S = \sqrt{B_A^2 + B_B^2} = \sqrt{\left(\frac{\mu_0}{2\pi}\frac{9.6}{1.6}\right)^2 + \left(\frac{\mu_0}{2\pi}\frac{30}{1.2}\right)^2}$$

$= 13\quad 10^{-7}$ T

(iii) Force per unit length on the wire B_1

$$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d} = \frac{2\times10^{-7}\times9.6\times3}{2}$$

$= 2.88 \quad 10^{-6}$ N/m

21. (i) Force on electron, $evB = F$

$\Rightarrow 1.6 \quad 10^{-19} \quad 4 \quad 10^{5} \quad B = 3.2 \quad 10^{-20}$

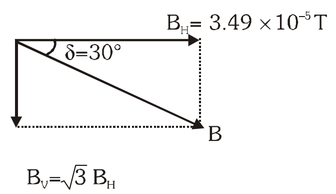
$$\Rightarrow B = 5 \quad 10^{7}\ T = \frac{\mu_0}{2\pi}\left(\frac{2.5}{5}+\frac{I}{2}\right) \Rightarrow I = 4A$$

(ii) For $\vec{B}$ to be zero at R; the position of third wire

$$= \frac{\mu_0}{2\pi}\frac{I}{B} = \frac{2\times10^{7}\times2.5}{5\times10^{7}} = 1m$$

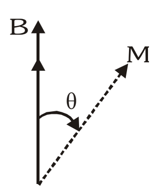
22. For vertical coil, $\frac{\mu_0}{2}\frac{I_1N_1}{r_1} = B_H$

$$\Rightarrow I_1 = \frac{3.49\times10^{-5}\times2\times0.2}{100\times4\pi\times10^{-7}} = 0.111A$$



For horizontal coil; $\frac{\mu_0}{2}\frac{I_2N_2}{r_2} = B_V \Rightarrow I_2 = 0.096$ A

23. For the coil



If the coil is turned through angle 'θ', the restoring torque, $-MB\sin\theta \simeq -MB\theta = I\alpha$

$$\Rightarrow -Ia^2B\theta = \frac{ma^2}{6}\alpha = \frac{ma^2}{6}(-\omega^2\theta)$$

$$\Rightarrow \omega = \sqrt{\frac{6IB}{m}} = \frac{2\pi}{T} \Rightarrow T = 2\pi\sqrt{\frac{m}{6IB}} = 0.57 \text{ s}$$

(where a = side of square)

EXERCISE –V-A

1. Magnetic field at the centre of the coil is $\frac{\mu_0 i}{2R}$

$$\therefore B_A = \frac{\mu_0 i}{2R};\ B_B = \frac{\mu_0 2i}{2(2R)} \text{ Hence } \frac{B_A}{B_B} = 1$$

2. Radius of the circular path in magnetic field,

$$r = \frac{mv}{qB} = \frac{p}{qB}$$

If momenta of two charged particles is same then

$$r \propto \frac{1}{q}$$

As electrons and protons have same charges; so their radius of curvature will be same; though their sense of rotation will be opposite.

3. Parallel currents attract and antiparallel currents repel each other. If a current is made to pass through the spring; the spring will compress as due to parallel currents; the turns will attract each other.

4. Time period of a charge particle in a magnetic field is $T = \frac{2\pi m}{qB}$

The time period is independent of radius or speed of the charged particle.

5. $$F = \left|i_2\left(d\vec{\ell}\times\vec{B}\right)\right| = i_2\left(\frac{\mu_0 i_1}{4\pi r}(2\cos\theta)\right)d\ell$$

$$= \frac{\mu_0 i_1 i_2 d\ell\cos\theta}{2\pi r}$$

6. $\vec{F} = q\left(\vec{v}\times\vec{B}\right)$; The force due to magnetic field is always perpendicular $\vec{v}$ (i.e. $d\vec{s}$); hence this force can never do the work on a charged particle.

7. For the charged particle to pass undeflected through a cross $\vec{E}$ and $\vec{B}$; the necessary condition is $\vec{F} = \vec{F}_E + \vec{F}_B = 0$ i.e., $q\vec{E} + q\left(\vec{v}\times\vec{B}\right) = 0$

or $\vec{E} = -\left(\vec{v}\times\vec{B}\right)$

If $\vec{v}\perp\vec{B}$ then $\left|\vec{E}\right| = \left|\vec{v}\vec{B}\right|$

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

8. $W = U_f - U_t = -MB\cos 60^0 - (-MB\cos 0)$

$$= \frac{-MB}{2} + MB = \frac{MB}{2} \Rightarrow MB = 2W$$

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

$\tau = MB\sin 60°$

$$\tau = MB\left(\frac{\sqrt{3}}{2}\right) \Rightarrow \tau = (2W)\left(\frac{\sqrt{3}}{2}\right) = \sqrt{3}W$$

9. Inside a bar magnet; magnetic lines of force run from south to north pole.

10. No magnetic field is ever present at any point inside thin walled current carrying tube.

11. $B_{\text{centre of circular loop}} = \frac{\mu_0}{4\pi}\frac{2\pi ni}{R}$ ...(i)

For a given length $L = n2\pi R$

$R = \frac{L}{n2\pi}$ ...(ii)

From equations (i) and (ii), we get

$$B = \frac{\mu_0}{4\pi}\frac{2\pi ni}{L}(n2\pi) \Rightarrow B \propto n^2$$

So, $\frac{B_f}{B_i} = \frac{n^2}{1^2} \Rightarrow B_f = n^2 B_i$

13. When they are carrying current in same direction, they attract each other with a force

$$\frac{F_1}{l_1} = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d}$$

When the direction of current in one of the conductors is reversed, the force will become repulsive with a value

$$\frac{F_2}{l_1} = \frac{\mu_0}{4\pi}\frac{2(2I_1)I_2}{3d}; \ \frac{F_2}{\ell_1} = \frac{2}{3}\frac{F_1}{\ell_1}; \ \vec{F}_2 = -\frac{2}{3}\vec{F}_1$$

14. Resistance of galvanometer

$$R_g = \frac{\text{current sensitivity}}{\text{voltage sensitivity}} = \frac{10}{2} = 5\Omega$$

As galvanometer is to be converted into a voltmeter of range 1   150 = 150V.

So resistance to be connected in series

$$= \frac{V}{I_g} - R_g = \frac{150}{\left(\frac{150}{10}\times 10^{-3}\right)} - 5 = 10000 - 5 = 9995\ \Omega$$

16. Magnetic induction due to a coil at its centre is along the axis of the coil. When two coils are held perpendicular to each other, their axes are also perpendicular to each other, hence the magnetic induction will also be perpendicular to each other, so B_{net} at their common centre will be

$$B = \sqrt{B_1^2 + B_2^2}$$

$$B = \sqrt{\left[\frac{\mu_0}{4\pi}\frac{2\pi i_1}{R_1}\right]^2 + \left[\frac{\mu_0}{4\pi}\frac{2\pi i_2}{R_2}\right]^2} = \frac{\mu_0}{4\pi}\frac{2\pi}{R}\sqrt{i_1^2 + i_2^2}$$

$$= 10^{-7}\quad \frac{2\pi}{2\pi\times 10^{-2}}\sqrt{3^2+4^2} = 5 \quad 10^{-5}T$$

17. The time taken by charged particle to complete circle will be $T = \frac{2\pi m}{qB}$

18. Magnetic needle kept in non-uniform field experiences both force as well as torque.

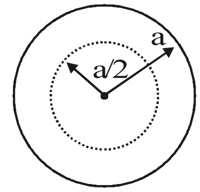
19. In a parallel uniform electric and magnetic field , if a charged particle is released then it experiences an electric force due to which it moves in a straight line.

20. $B_{solenoid} = \mu_0 ni$

$$\frac{B_2}{B_1} = \frac{n_2 i_2}{n_1 i_1} = \frac{100 \times i/3}{200 \times i}$$

$$B_2 = \frac{B_1}{6} = \frac{6.28\times 10^{-2}}{6} = 1.05 \quad 10^{-2}T$$

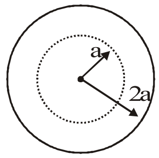
21. Magnetic field at a point inside the straight long conductor at a distances $\frac{a}{2}$ from its centre will be obtained.



On applying Ampere's circulated law, we get

$$B_1 2\pi\left(\frac{a}{2}\right) = \mu_0 \frac{I}{\pi a^2}\times \pi\left(\frac{a}{2}\right)^2$$

$$B_1 = \frac{\mu_0 I}{4\pi a} \quad ...(i)$$



Magnetic field at a point outside the conductor at a distance 2a from the centre will be obtained as

$$B_2\left[2\pi(2a)\right] = \mu_0 I$$

$$B_2 = \frac{\mu_0 I}{4\pi a} \quad ...(ii)$$

On dividing equation (i) by (ii), we get $\frac{B_1}{B_2} = 1$

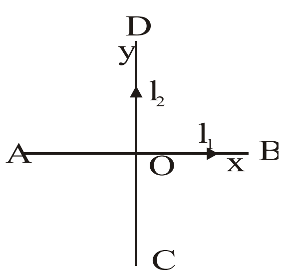
22. As the thin walled pipe does not enclose any net current, hence the net magnetic field at any point inside the thin walled pipe will be zero, whereas for the outside points it behaves as a straight long current carrying conductor.

23. When charged particle goes undeflected then

$$q\vec{E} = q\vec{v} \times \vec{B} \Rightarrow qE = qvB \Rightarrow v = \frac{E}{B}$$

These two forces must be opposite to each other if and only if $\vec{v}$ is along $\vec{E} \times \vec{B}$

$$\therefore v = \frac{EB}{BB} = \left|\frac{\vec{E} \times \vec{B}}{B^2}\right| \Rightarrow \vec{v} = \left(\frac{\vec{E} \times \vec{B}}{B^2}\right)$$

24. 

$\vec{B}_P = \vec{B}_1 + \vec{B}_2$

Let the point P is situated at 'd' from O outside the plane of the paper

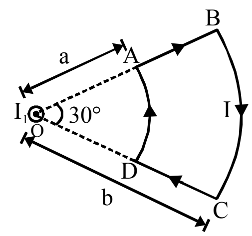
$$\vec{B}_1 = \frac{\mu_0}{4\pi}\frac{2I_1}{d}(-\hat{j})\ ;\ \vec{B}_2 = \frac{\mu_0}{4\pi}\frac{2I_2}{d}\hat{i}$$

$$\vec{B}_P = \frac{\mu_0}{4\pi}\frac{2}{d}\left[I_1(-\hat{j}) + I_2\hat{i}\right]$$

$$\left|\vec{B}_P\right| = \frac{\mu_0}{2\pi d}\sqrt{I_1^2 + I_2^2}$$

25. The magnetic field can never produce a charge in the speed of the charged particle, hence it can never produce a change in kinetic energy.
Whereas it produces a change in velocity of the charged particle by changing the direction of motion of charged particle.
From this we can conclude that magnetic field cannot produce a change in kinetic energy whereas it can produce change in momentum of the charged particle.

26. $B = \frac{\mu_0}{2\pi}\frac{i}{R} = \frac{4\pi \times 10^{-7}}{4} = 5 \times 10^{-6}$ T southward

27. 

$$B_0 = B_1 - B_2 = \frac{\mu_0 I}{2a}\left(\frac{\pi}{6 \times 2\pi}\right) - \frac{\mu_0 I}{2b}\left(\frac{\pi}{6 \times 2\pi}\right)$$

$$= \frac{\mu_0 I}{24ab}(b - a)$$

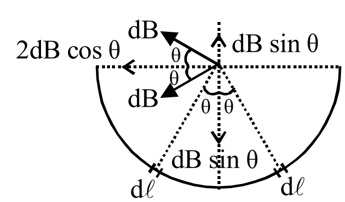
30. Net megnet field due to both elements
$= 2\ (dB)\cos\theta$

$= 2\ \frac{\mu_0}{2\pi R} dI\ \cos\theta \qquad \left(\text{here } dI = \frac{I}{\pi R} d\ell\right)$

$= 2\ \frac{\mu_0}{2\pi R}\frac{I}{\pi R} d\ell\ \cos\theta$

$= 2\ \frac{\mu_0}{2\pi R}\frac{I}{\pi R}\ R d\theta\ \cos\theta$

$$B = \int_0^{\pi/2} \frac{\mu_0}{\pi^2 R}\ \cos\theta\ d\theta = \frac{\mu_0 I}{\pi^2 R}$$



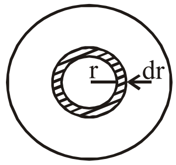
31. $\vec{F} = q\left[\vec{E} + \left(\vec{v} \times \vec{B}\right)\right]$

$$= q\left[3\tilde{i} + \tilde{j} + 2\tilde{k} + \left(3\tilde{i} + 4\tilde{j} + \tilde{k}\right) \times \left(\tilde{i} + \tilde{j} - 3\tilde{k}\right)\right]$$

$$= q\left[3\tilde{i} + \tilde{j} + 2\tilde{k} + \left(3\tilde{i} + 4\tilde{j} + \tilde{k}\right) \times \left(\tilde{i} + \tilde{j} - 3\tilde{k}\right)\right]e$$

$\left|\vec{F}_y\right| = 11q$

32 Magnetic moment of elements ring



$$dM = di \quad A = \frac{dq}{T}\pi r^2 = \frac{\sigma dA}{T}\pi r^2$$

$$= \frac{\sigma \times 4\pi r^2 dr}{2\pi}\pi r \quad \omega$$

33. $r \propto \frac{\sqrt{2mK}}{qB}$ As K & B are constant

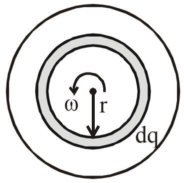
So $r \propto \frac{\sqrt{m}}{q}$

$$r_p : r_d : r_\alpha :: \frac{\sqrt{m_p}}{q_p} : \frac{\sqrt{m_d}}{q_d} : \frac{\sqrt{m_\alpha}}{q_\alpha}$$

$$:: \frac{\sqrt{m_p}}{e} : \frac{\sqrt{2m_p}}{e} : \frac{\sqrt{4m_p}}{2e}$$

$$:: 1 : \sqrt{2} : 1 \Rightarrow \qquad r_\alpha = r_p < r_d$$

34. Magnetic field at the centre due to element ring

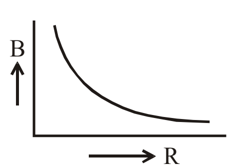


$$dB = \frac{\mu_0 di}{2r} = \frac{\mu_0}{2r}\left(\frac{dq}{T}\right) = \frac{\mu_0 \sigma ds}{2rT}$$

$$= \frac{\mu_0}{2r}\left(\frac{Q}{\pi R^2}\right)\frac{(2\pi r dr)}{2\pi/\omega} = \frac{\mu_0 Q dr\omega}{\pi R^2}$$

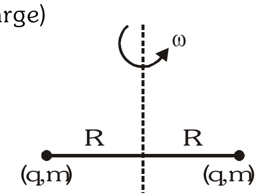
$$B = \frac{\mu_0 Q\omega}{\pi R^2}\int_0^R dr = \frac{\mu_0 Q\omega}{\pi R^2}R = \frac{\mu_0 Q\omega}{\pi R} \Rightarrow B \propto \frac{1}{R}$$

So graph



EXERCISE –V-B

1. Current, i = (frequency) (charge)



$$= \left(\frac{\omega}{2\pi}\right)(2q) = \frac{q\omega}{\pi}$$

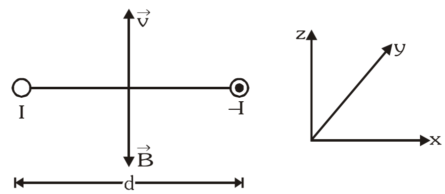
Magnetic moment

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

Angular momentum $L = 2I\omega = 2(mR^2)\omega$

$$\therefore \frac{M}{L} = \frac{q\omega R^2}{2(mR^2)\omega} = \frac{q}{2m}$$

2. Net magnetic field due to both the wires will be downwards as shown in the figure.



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

Therefore, magnetic force

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

3. 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.

4. Total magnetic flux passing through whole of the X-Y palne will be zero, because magnetic lines from a closed loop. So, as many lines will move in –Z direction same will return to +Z direction from the X-Y plane.

5. H_1 = Magnetic field at M due to PQ + Magnetic field at M due to QR. But magnetic field at M due to QR = O

$\therefore$ Magnetic field at M due to PQ (or due to current I in PQ) = H_1

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

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

6. We can write

$$\vec{E} = E.\hat{i} \text{ and } \vec{B} = B\hat{k}$$

Velocity of the particle will be along q. $\vec{E}$ direction.

Therefore, we can write $\vec{v} = AqE\hat{i}$

In $\vec{E}, \vec{B}$ and $\vec{v}$, A, E and B are positive constants while q can be positive or negative.
Now, magnetic force on the particle will be

$$\vec{F}_m = q(\vec{v} \times \vec{B}) = q\{AqE\hat{i}\} \times \{B\hat{k}\}$$

$$= q^2AEB(\hat{i} \times \hat{k})$$

$$\vec{F}_m = q^2AEB(-\hat{j})$$

Since, $\vec{F}_m$ is along negative y-axis, no matter what is the sign of charge q. Therefore, all ions will deflect towards negative y-direction.

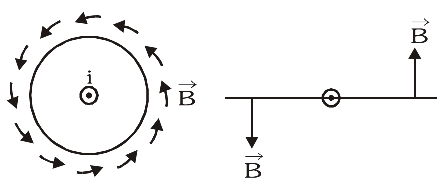
7. Ratio of magnetic moment and angular momentum is given by $\frac{M}{L} = \frac{q}{2m}$
which is a function of q and m only. This can be derived as follows :

$$M = i\,A = (q\,f).(\pi r)^2 = (q)\left(\frac{\omega}{2\pi}\right)(\pi r^2) = \frac{q\omega r^2}{2}$$

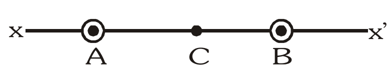
and $L = I\omega = (mr^2\,\omega)$

$$\therefore \frac{M}{L} = \frac{q\frac{\omega r^2}{2}}{mr^2\omega} = \frac{q}{2m}$$

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

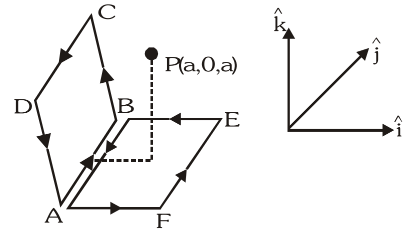


Now, let us come to the problem.
Magnetic field at C = 0
Magnetic field in region BX' will be upwards (+ve) because all points lying in this region are to the right of both the wires.



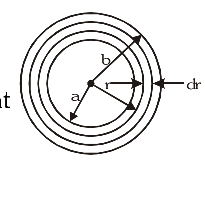
Magnetic field in region AC will be upwards (+ve), because points are closer to A, compared to B. Similarly magnetic field in region BC will be downwards (–ve). Graph (b) satisfies all these conditions.

9. The magnetic field at P(a,0,a) due to the loop is equal to the vector sum of the magnetic fields produced by loops ABCDA and AFFBA 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 $\frac{1}{2}(\hat{i} + \hat{k})$

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



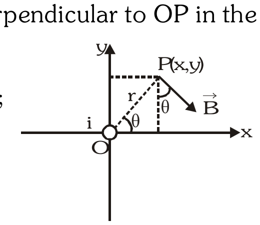
Magnetic field due to this element at the centre of the coil will be-

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

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

11. Radius of the circle = $\frac{mv}{Bq}$
or radius $\propto$ mv if B and q are same.
$(\text{Radius})_A > (\text{Radius})_B \therefore m_A v_A > m_B v_B$

12. Magnetic field at P is $\vec{B}$, perpendicular to OP in the direction shown in figure.



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

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

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

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

13. Magnetic lines form closed loop. Inside magnet these are directed from south to north pole.

14. If $(b-a) \geq r$ (r= radius of circular path of particle)
The particle cannot enter the region $x > b$
So, to enter in the region $x > b$ $\quad r > (b-a)$

$$\Rightarrow \frac{mv}{Bq} > (b-a) \Rightarrow v > \frac{q(b-a)B}{m}$$

15. Electric field can deviate the path of the particle in the shown direction only when it is along negative y-direction. In the given options $\vec{E}$ is either zero or along x-direction. Hence, it is the magnetic field which is really responsible for its curved path. Options (a) and (c) cannot be accepted as the path will be helix in that case (when the velocity vector makes an angle other than 0 , 180 or 90 with the magnetic field, path is a helix) option (d) is wrong because in that case component of net force on the particle also comes in $\tilde{k}$ direction which is not acceptable as the particle is moving in x-y plane. Only in option (b) the particle can move in x-y plane.

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

Initial velocity is along x-direction. So, let $\vec{v} = v\tilde{i}$

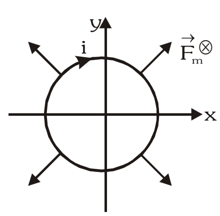
$\therefore \vec{F}_{net} = qa\tilde{i} + q[(v\tilde{i}) \times (c\tilde{k} + b\tilde{j})]$

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

In option (b) :

$\vec{F}_{net} = q(a\tilde{i}) + q[(v\tilde{i}) \times (c\tilde{k} + a\tilde{i})] = qa\tilde{i} - qvc\tilde{j}$

16. Net force on a current carrying loop in uniform magnetic field is zero. Hence, the loop cannot translate. So, options (c) and (d) are wrong. From Fleming's left hand rule we can see that if magnetic field is perpendicular to paper inwards and current in the loop is closkwise (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.



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

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

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

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

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

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

20. Ans. (AC)

$\vec{F}_{BA} = 0$,

because magnetic lines are parallel to this wire.

$\vec{F}_{CD} = 0$,

because magnetic lines are antiparallel to this wire.

$\vec{F}_{CB}$ is perpendicular to paper outwards and $\vec{F}_{AD}$ is perpendicular to paper inwards. These two forces (although calculated by integration) cancel each other but produce a torque which tend to rotate the loop in clockwise direction about an axis OO'.

21. Ans. (ACD)

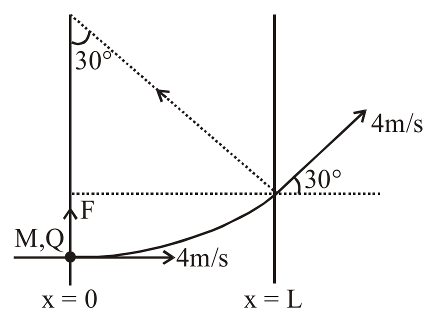
Radius of circular path of charged particle $R = \dfrac{mV}{qB}$

- Particle enters region III if $R > \ell \Rightarrow \dfrac{mV}{qB} > \ell$
- Path length in region II is maximum is $R = \ell \Rightarrow V = \dfrac{q\ell B}{m}$
- Time spent in region II $t = \dfrac{T}{2} = \dfrac{\pi m}{qB}$

22. Ans. (C)

23. By direction of $\vec{F}$ from equation $\vec{F} = q(\vec{v} \times \vec{B})$

Magnetic field is in –z direction



$$\text{Time} = \frac{\theta}{\omega} = \frac{\pi/6}{QB/M} = \frac{M\pi}{6QB}$$

$$\Rightarrow B = \frac{M\pi}{6Q(10\times10^{-3})} = \frac{50\pi M}{3Q}$$

Comprehension#1

1. If $B_2 > B_1$, critical temperature, (at which resistance of semiconductors abrupty becomes zero) in case 2 will be less than compared to case 1.

2. With increase in temperature, T_C is decreasing.

$T_C(0)$ = 100 K

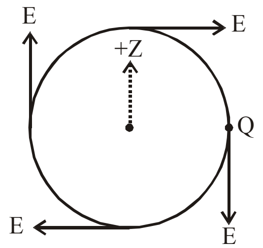
T_C = 75 K at B = 7.5 T

Hence, at B = 5T, T_C should line between 75 K and 100 K.

Comprehension#2

1. induce electric field = $\frac{R}{2}\frac{dB}{dt} = \frac{BR}{2}$

torque on charge = $\frac{QBR^2}{2}\left(-\tilde{k}\right)$



by $\vec{\tau} = \frac{d\vec{L}}{dt} \Rightarrow \int d\vec{L} = \int_0^1 \vec{\tau}dt$

$\Delta\vec{L} = \frac{QBR^2}{2}\left(-\tilde{k}\right)$

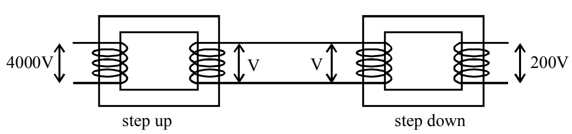
Change magnetic dipole moment = $\gamma\Delta\vec{L}$

$$\frac{\gamma QBR^2}{2}\left(-\hat{k}\right)$$

2. Magnitude of induced electric field= $\frac{R}{2}\frac{dB}{dt} = \frac{BR}{2}$

Comprehension#3

1.



for step up transformer $\frac{V}{4000} = \frac{10}{1}$

$\Rightarrow$ V = 40,000 Volt

for step down transformere

$$\frac{N_1}{N_2} = \frac{V}{200} = \frac{4000}{200} = 200$$

2. Current in transmission line

$$= \frac{\text{Power}}{\text{Voltage}} = \frac{600 \times 10^3}{40,000} = 150\text{A}$$

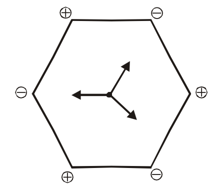
Resistance of line = 0.4 20 = 8Ω

Power loss in line = i^2R = $(150)^2 8$= 180 KW

percentage of power dissipation in during transmission = $\frac{180 \times 10^3}{600 \times 10^3} \times 100 = 30\%$

Match the column

4. (p)



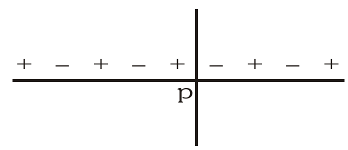
(A) All electric field vector at an angle of 120
$\therefore$ electric field at centre is zero.
Individually due to +ve and (–ve) charge

(B) Electric potential due to negative charges and positive charges is equal therefore it is zero

(C) On rotating the hexagon current in the loop becomes zero
$\therefore$ magnetic field at the centre is zero

(D) As current in the whole loop iz zero therefore magnetic moment is zero

(q)



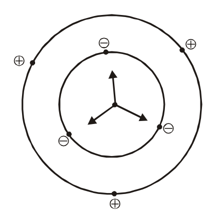
(A) Electric field will be non zero due combination of two charge electric field is additive in nature

(B) Electric potential due to negative charges and positive charges is equal therefore its potential is zero

(C) On rotating about the axis current is zero magnetic field is zero [$\because$ total charge is zero]

(D) Magnetic moment due to rod is zero

(r)



$\vec{E} = \frac{Kq}{a^2} + \frac{k^2}{b^2}$

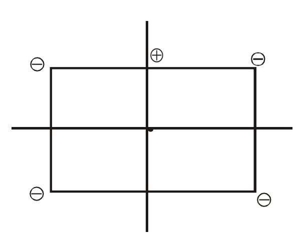
(A) Same charges are spread at an Angle of 120 therefore electric field at centre is zero

(B) Electric potential due to negative charges and positive charges is not equal therefore it is non-zero

(C) Current in the individual loop is non zero therefore magnetic field is non zero

(D) As current is non zero magnetic moment will be non zero

(s)



(A) Electric field at the centre due to symmetrical distribution is zero

(B) Electric potential due to negative charges and positive charges is not equal therefore its potential is non-zero

(C) Current non-zero

$\therefore$ Magnetic field is non-zero

(D) As current is non-zero magnetic moment is also non-zero

(t)

(A) Electric field at M is additive therefore it is non-zero

(B) Electric potential due to negative charges and positive charges is equal therefore its potential is zero

(C) Current is zero because summation of charge is zero

$\therefore$ Magnetic field is zero

(D) As current is zero magnetic moment is also zero

Subjective

1. Magnetic moment of the loop,

$$\vec{M} = (iA)\tilde{k} = (I_0L^2)\tilde{k}$$

Magnetic field,

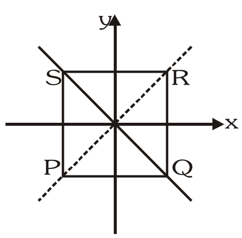
$$\vec{B} = (B\cos 45°)\tilde{i} + (B\sin 45°)\tilde{j} = \frac{B}{\sqrt{2}}(\tilde{i} + \tilde{j})$$

(i) Torque acting on the loop,

$$\vec{\tau} = \vec{M} \times \vec{B} = (I_0L^2\tilde{k}) \times \left[\frac{B}{\sqrt{2}}(\tilde{i} + \tilde{j})\right]$$

$$\therefore\ \vec{\tau} = \frac{I_0L^2B}{\sqrt{2}}(\tilde{j} - \tilde{i}) \Rightarrow |\ \vec{\tau}\ | = I_0L^2B$$

(ii) Axis of rotating coincides with the torque and since torque is in $\tilde{j} - \tilde{i}$ direction or parallel to QS. Therefore, the loop will rotate about an axis passing through Q and S as shown in the figure.



Angular acceleration, $a = \dfrac{|\ \vec{\tau}\ |}{I}$

where I = moment of inertia of loop about QS.

$I_{QS} + I_{PR} = I_{ZZ}$ (From theorem of perpendicular axis)

But $I_{QS} = I_{PR}$

$$\therefore\quad 2I_{QS} = I_{ZZ} = \frac{4}{3}ML^2 \Rightarrow I_{QS} = \frac{2}{3}ML^2$$

$$\therefore\quad \alpha = \frac{|\ \vec{\tau}\ |}{I} = \frac{I_0L^2B}{2/3ML^2} = \frac{3}{2}\frac{I_0B}{M}$$

$\therefore$ Angle by which the frame roates in time Δt is

$$\theta = \frac{1}{2}\alpha(\Delta t)^2 \Rightarrow \theta = \frac{3}{4}\frac{I_0B}{M}.(\Delta t)^2$$

2. (i) $\theta = 30 \Rightarrow \sin\theta = \dfrac{L}{R}$

Here, $R = \dfrac{mv_0}{B_0q}$

$$\therefore\ \sin 30° = \frac{L}{\dfrac{mv_0}{B_0q}} \Rightarrow \frac{1}{2} = \frac{B_0qL}{mv_0}\quad \therefore L = \frac{mv_0}{2B_0q}$$

(ii) In part (i)

$$\sin 30 = \frac{L}{R} \Rightarrow \frac{1}{2} = \frac{L}{R} \Rightarrow L = R/2$$

Now when L' = 2.1 L $\Rightarrow \dfrac{2.1}{2}R \Rightarrow L' > R$

Therefore, deviation of the particle is θ=180 is as shown

$$\therefore\ \vec{v}_f = -v_0\tilde{i} = \vec{v}_B \text{ and } t_{AB} = T/2 = \frac{\pi m}{B_0q}$$

3. (i) Magnetic field $(\vec{B})$ at the origin = magnetic field due to semicircle KLM + Magnetic field due to other semicircle KNM $\therefore \vec{B} = \dfrac{\mu_0 I}{4R}(-\tilde{i}) + \dfrac{\mu_0 I}{4R}(\tilde{j})$

$$\vec{B} = \frac{\mu_0 I}{4R}\tilde{i} + \frac{\mu_0 I}{4R}\tilde{j} = \frac{\mu_0 I}{4R}\left(-\tilde{i} + \tilde{j}\right)$$

$\therefore$ Magnetic force acting on the particle

$$\vec{F} = q\left(\vec{v} \times \vec{B}\right) = q\{(-v_0\tilde{i}) \times (-\tilde{i} + \tilde{j})\}\frac{\mu_0 I}{4R}$$

$$\vec{F} = -\frac{\mu_0 q v_0 I}{4R}\tilde{k}$$

(ii) $\vec{F}_{KLM} = \vec{F}_{KNM} = \vec{F}_{KM}$

And $\vec{F}_{KM} = BI(2R)\tilde{i} = 2BIR\,\tilde{i}$

$$\vec{F}_1 = \vec{F}_2 = 2BIR\tilde{i}$$

Total force on the loop, $\vec{F} = \vec{F}_1 + \vec{F}_2 \Rightarrow \vec{F} = 4BIR\tilde{i}$

Then, $\vec{F}_{ADC} = \vec{F}_{AC}$ or $\left|\vec{F}_{ADC}\right| = \tilde{i}(AC)B$

4. (i) Given : $i = 10A$, $r_1 = 0.08m$ and $r_2 = 0.12m$. Straight portions i.e., CD etc., will produce zero magnetic field at the centre. Rest eight arcs will produce the magnetic field at the centre in the same direction i.e., perpendicular to the paper outwards or vertically upwards and its magnitude is

$B = B_{\text{inner arcs}} + B_{\text{outer arcs}}$

$$= \frac{1}{2}\left\{\frac{\mu_0 i}{2r_1}\right\} + \frac{1}{2}\left\{\frac{\mu_0 i}{2r_2}\right\} = \left(\frac{\mu_0}{4\pi}\right)(\pi i)\left(\frac{r_1 + r_2}{r_1 r_2}\right)$$

Substituting the values, we have

$$B = \frac{(10^{-7})(3.14)(10)(0.08 + 0.12)}{(0.08 \times 0.12)} T$$

$B = 6.54 \;\; 10^{-5}$ T (Vertically upward or outward normal to the paper)

(ii) Force on AC

Force on circular portions of the circuit i.e., AC etc., due to the wire at the centre will be zero because magnetic field due to the central wire at these arcs will be tangential ($\theta = 180$) as shown.

Force on CD

Current in central wire is also i=10A. Magnetic field at P due to central wire, $B = \frac{\mu_0}{2\pi}.\frac{i}{x}$

$\therefore$ Magnetic force on element dx due to this magnetic field $dF = (i)\left(\frac{\mu_0}{2\pi}.\frac{i}{x}\right).dx = \left(\frac{\mu_0}{2\pi}\right)i^2\frac{dx}{x}$

$(F = i\ell B \sin 90\ )$

Therefore, net force on CD is-

$$F = \int_{x=r_1}^{x=r_2} dF = \frac{\mu_0 i^2}{2\pi}\int_{0.08}^{0.12}\frac{dx}{x} = \frac{\mu_0}{2\pi}i^2 \ell n\left(\frac{3}{2}\right)$$

Substituting the values,

$F = (2 \;\; 10^{-7})\,(10)^2\,\ell n(1.5)$ or

$F = 8.1 \;\; 10^{-6}$ N(inwards)

Force on wire at the centre

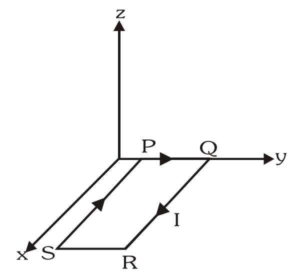
Net magnetic field at the centre due to the circuit is in vertical direction and current in the wire in centre is also in vertical direciton. Therefore, net force on the wire at the centre will be zero. ($\theta = 180$). Hence,

(i) Force acting on the wire at the centre is zero.

(ii) Force on arc AC = 0

(iii) Force on segment CD is $8.1 \;\; 10^{-6}$ N (inwards).

5. Let the direction of current in wire PQ is from P to Q and its magnitude be I.



The magnetic moment of the given loop is :

$$\vec{M} = -Iab\hat{k}$$

Torque on the loop due to magnetic forces is :

$\vec{\tau}_1 = \vec{M} \times \vec{B}$

$= (-Iab\hat{k}) \times (3\hat{i} \times 4\hat{k})B_0\hat{i} = -3IabB_0\hat{j}$

Torque of weight of the loop about axis PQ is :

$$\vec{\tau}_2 = \vec{r} \times \vec{F} = \left(\frac{a}{2}\hat{i}\right) \times (-mg\hat{k}) = \frac{mga}{2}\hat{j}$$

We see that when the current in the wire PQ is from P to Q, $\vec{\tau}_1$ and $\vec{\tau}_2$ are in opposite direction, so they can cancel each other and the loop may remain in equilibrium. So, the direction of current I in wire PQ is from P to Q. Further for equilibrium of the loop:

$$|\vec{\tau}_1| = |\vec{\tau}_2| \Rightarrow 3IabB_0 = \frac{mga}{2} \Rightarrow I = \frac{mg}{6bB_0}$$

(ii) Magnetic force on wire RS is :

$$\vec{F} = I(\vec{l} \times \vec{B}) = I\left[(-b\hat{j}) \times \left\{(3\hat{i} + 4\hat{k})B_0\right\}\right]$$

$$\vec{F} = IbB_0(3\hat{k} - 4\hat{j})$$

6. In equilibrium, $2T_0 = mg \Rightarrow T_0 = \frac{mg}{2}$ ....(i)

Magnetic moment, $M = iA = \left(\frac{\omega}{2\pi}Q\right)(\pi R^2)$

$$\tau = MB\sin 90° = \frac{\omega BQR^2}{2}$$

Let T_1 and T_2 be the tensions in the two strings when magnetic field is switched on ($T_1 > T_2$).

For translational equilibrium of ring is vertical direction, $T_1 + T_2 = mg$ ....(ii)

For rotational equilibrium,

$$(T_1 - T_2)\frac{D}{2} = \tau = \frac{\omega BQR^2}{2}$$

$$\Rightarrow T_1 - T_2 = \frac{\omega BQR^2}{2} \text{ ....(iii)}$$

Solving equations (ii) and (iii), we have

$$T_1 = \frac{mg}{2} + \frac{\omega BQR^2}{2D}$$

As $T_1 > T_2$ and maximum values of T_1 can be

$\frac{3T_0}{2}$, we have $\frac{3T_0}{2} = T_0 + \frac{\omega_{max} BQR^2}{2D} \left(\frac{mg}{2} = T_0\right)$

$$\therefore \omega_{max} = \frac{DT_0}{BQR^2}$$

7. $r = \frac{\sqrt{2qvm}}{Bq} \Rightarrow r \propto \sqrt{\frac{m}{q}}$

$$\frac{r_p}{r_\alpha} = \sqrt{\frac{m_p}{m_\alpha}}\sqrt{\frac{q_\alpha}{q_p}} = \sqrt{\frac{1}{4}}\sqrt{\frac{2}{1}} = \frac{1}{\sqrt{2}}$$

8. (i) $\tau = MB = ki$ ($\theta=90$)

$$\therefore k = \frac{MB}{i} = \frac{(NiA)B}{i} = NBA$$

(ii) $\tau = k.\theta = BiNA$ (k = Torsional constant)

$$\therefore k = \frac{2BiNA}{\pi} \qquad (\text{as } \theta = \pi/2)$$

(iii) $\tau = BiNA \Rightarrow \int_0^t \tau dt = BNA\int_0^t i dt$

$$\Rightarrow I\omega = BNAQ \Rightarrow \omega = \frac{BNAQ}{I}$$

At maximum deflection whole kinetic energy (rotational) will be converted into potential energy of spring. Hence, $\frac{1}{2}I\omega^2 = \frac{1}{2}k\theta^2_{max}$

Substituting the values, we get $\theta_{max} = Q\sqrt{\frac{BN\pi A}{2I}}$

9. $B = \frac{\mu_0 i}{4\pi d}$ (sin 37 + sin 53)

$$= \frac{\mu_0 i}{4\pi\left(\frac{12}{5}\pi\right)}\left[\frac{7}{5}\right]$$

$$\Rightarrow \frac{7\mu_0 i}{48\pi x} \Rightarrow k = 7$$