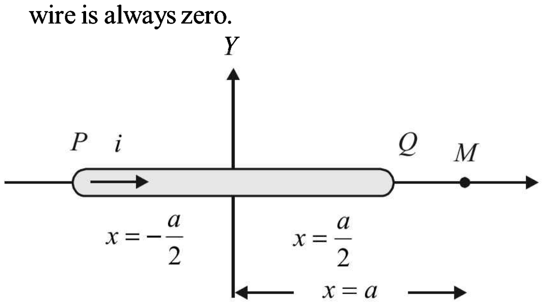
Chapter-18 : Moving Charges and Magnetism

1. **(d)** Magnetic field at a point on the axis of a current carrying wire is always zero.



2. **(d)** Force on proton = qvB

$\therefore$ Acceleration of proton due to change of direction

$$=\frac{qvB}{m}=\frac{1.6\times10^{-19}\times5\times10^{5}\times0.17}{1.7\times10^{-27}}=8\times10^{12}\ m/s^2.$$

3. **(a)** $m = NiA = 100\times4\times\pi r^2$

$= 400\times3.14\times25\times10^{-4} = 3.14\ Am^2.$

4. **(d)**

5. **(c)** $r=\frac{mv}{qB}$ or $r\propto v$

As v is doubled, the radius also becomes double. Hence radius $= 2\times2 = 4$ cm

6. **(b)**

7. **(b)** We know that magnetic field at the centre of circular coil,

$$B=\frac{\mu_0 In}{2r}=\frac{4\pi\times10^{-7}\times2\times50}{2\times0.5}=1.25\times10^{-4}T$$

8. **(c)** K.E. of electron = 10 eV

$$\Rightarrow \frac{1}{2}mv^2=10\ eV$$

$$\Rightarrow \frac{1}{2}(9.1\times10^{-31})v^2=10\times1.6\times10^{-19}$$

$$\Rightarrow v^2=\frac{2\times10\times1.6\times10^{-19}}{9.1\times10^{-31}}$$

$\Rightarrow v^2 = 3.52\times10^{12} \Rightarrow v = 1.88\times10^{6}$ m

Also we know that for circular motion

$$\frac{mv^2}{r}=Bev \Rightarrow r=\frac{mv}{Be}=11\ cm$$

9. **(a)** The force acting on a charged particle in magnetic field is given by

$F=q(\vec{v}\times\vec{B})$ or $F = qvB\sin\theta$

when angle between v and B is 180°,

$F = 0$

10. **(a)** According to Ampere's circular law

$$\oint \vec{B}.d\vec{l}=\mu_0 I_{enclosed}=\mu_0(2A-1A)=\mu_0$$

11. **(a)** $\tau_{max} = MB$ or $\tau_{max} = ni\pi a^2B$

Let number of turns in length ℓ is n

$\ell = n(2\pi a)$ or $a=\frac{\ell}{2\pi n}$

$$\tau_{max}=\frac{ni\pi B\ell^2}{4\pi^2n^2}=\frac{\ell^2 iB}{4\pi^2 n_{min}}.\frac{\ell^2 iB}{4\pi n_{min}}$$

$$\therefore \tau_{max}\propto\frac{1}{n_{min}}=,\ n_{min}=1$$

12. **(d)** $\tau = MB\sin\theta \Rightarrow \tau_{max} = NIAB$,

$(\theta = 90°)$

13. **(a)** $F=\frac{\mu_0}{4\pi}\times\frac{2i_1i_2}{r}=10^{-7}\times\frac{2\times1\times1}{1}$

$= 2\times10^{-7}$ N/m. Here F is force per unit length.

14. **(b)** $i=\frac{C\theta}{NAB}\Rightarrow i\propto\theta$

15. **(a)** $\frac{i}{i_g}=1+\frac{G}{S}\Rightarrow\frac{iG}{V_g}=1+\frac{G}{S}$

$$\Rightarrow\frac{100\times10^{-3}\times40}{800\times10^{-3}}=1+\frac{40}{S}$$

$\Rightarrow S = 10\Omega$

16. **(b)** $F = Bi\ell = 2\times1.2\times0.5 = 1.2$ N

17. **(c)** As electron move with constant velocity without deflection. Hence, force due to magnetic field is equal and opposite to force due to electric field.

$$qvB=qE\Rightarrow v=\frac{E}{B}=\frac{20}{0.5}=40\ m/s$$

18. (d) If r is the radius of the circle,

then $l = 2\pi r$ or, $r = \frac{l}{2\pi}$

Area $= \pi r^2 = \pi l^2/4\pi^2 = l^2/4\pi$

$\therefore$ Magnetic moment $= IA = \frac{Il^2}{4\pi}$

19. (c) $I_g G = (I - I_g)s$

$\therefore 10^{-3} \times 100 = (10 - 10^{-3}) \times S$

$\therefore S \approx 0.01\,\Omega$

20. (b) $M = iA = i \times \pi R^2$

also $i = \frac{Q\omega}{2\pi} \Rightarrow M = \frac{1}{2} Q\omega R^2 \left[\because i = \frac{Q}{t}\right]$

21. (b) $m = \text{current x area} = i\left(\frac{1}{2}\pi a^2 + \frac{1}{2}\pi b^2\right)$

$= \frac{1}{2} i\pi (a^2 + b^2)$

22. (a) $B \propto \frac{1}{r} \Rightarrow r' = 3r$

$\therefore \quad B' = \frac{1}{3}B = \frac{1}{3} \times 10^{-3} = 3.33 \times 10^{-4}\,T$

23. (a) Current (I) = 12 A and magnetic field (B) = 3×10^{-5} Wb/m^2.

Consider magnetic field $\vec{B}$ at distance r.

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

$\Rightarrow r = \frac{\mu_0 I}{2\pi B} = \frac{(4\pi \times 10^{-7}) \times 12}{2 \times \pi \times (3 \times 10^{-5})} = 8 \times 10^{-2}\,m$

24. (a) $\frac{\mu_0 I_c}{2R} = \frac{\mu_0 I_e}{2\pi H} \Rightarrow H = \frac{I_e R}{\pi I_c}$

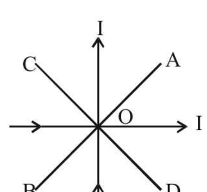
25. (b) $B = 10^{-7} \frac{2\pi i}{r}$; according to question $B_H = B$

$\Rightarrow 5 \times 10^{-5} = 10^{-7} \times \frac{2 \times 3.14 \times i}{5 \times 10^{-2}} \Rightarrow i = 4A$

26. (c) $i\vec{L} = \frac{1}{2}\hat{i}; \vec{B} = (2\hat{i} + 4\hat{j})T$

$\vec{F} = (i\vec{L}) \times \vec{B} = 2\hat{k}N$

27. (a)



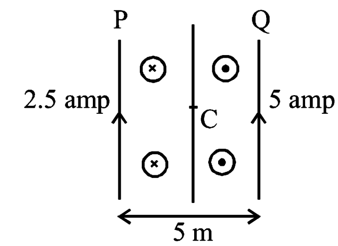
Net magnetic field on AB is zero because magnetic field due to both current carrying wires is equal in magnitude but opposite in direction.

28. (c) When the current flows in both wires in the same direction then magnetic field at half way due to the wire P,

$\vec{B}_p = \frac{\mu_0 I_1}{2\pi \frac{5}{2}} = \frac{\mu_0 I_1}{\pi \cdot 5} = \frac{\mu_0}{2\pi}$

(where $I_1 = 5$ amp)

The direction of $\vec{B}_p$ is downward ⊙



Magnetic field at half way due to wire Q

$\vec{B}_Q = \frac{\mu_0 I_2}{2\pi \frac{5}{2}} = \frac{\mu_0}{\pi}$ [upward ⊙]

[where $I_2 = 5$amp.]

Net magnetic field at half way

$\vec{B} = \vec{B}_P + \vec{B}_Q = -\frac{\mu_0}{2\pi} + \frac{\mu_0}{\pi} = \frac{\mu_0}{2\pi}$ (upward)

Hence, net magnetic field at midpoint $= \frac{\mu_0}{2\pi}$

29. (a) $F = Bil\sin\theta \Rightarrow 7.5 = 2 \times 5 \times 1.5 \sin\theta \Rightarrow \theta = 30°$

30. (b) Current carrying conductors will attract each other, while electron beams will repel each other.

31. (c) The torque on a closed flat current loop of any shape, placed in a magnetic field of flux density B is given by $\tau = Bi\,NA\sin\theta$,

According to the question the area of this coil is

A = (1/2) base × height

A = (1/2) (0.2 × 0.1732) = 1.732×10^{-4} m^2

$\tau = 1 \times 0.1 \times 1.732 \times 10^{-4} \times (5 \times 10^{-2}) \times 1$

$\tau = 8.66 \times 10^{-7}$ N-m.

32. (a) $F' = \frac{\mu_0 i_1 i_2}{2\pi r}$

or $F' = \frac{4\pi \times 10^{-7} \times 30 \times 30}{2 \times \pi \times 5 \times 10^{-2}} = 3.6 \times 10^{-3}$ N/m.

33. (a) $\frac{F}{\ell} = \frac{\mu_0 i^2}{2\pi d} = 9.8 \times 4 \times 10^{-6}$

$\Rightarrow i = \sqrt{\frac{4 \times 10^{-6} \times 9.8 \times 0.12}{2 \times 10^{-7}}} = 4.85\,A$

34. (b) The wires A and C carry current in same direction, therefore they attract each other. The force on C due to A is towards the wire A and is given by.

$$F_{CA}=\frac{\mu_0}{4\pi}.\frac{2i_A\, i_C}{r_{AC}}$$

$$=\frac{10^{-7}\times 2\times 10\times 10}{0.10}\,0.15$$

or $F_{CA}=3\times 10^{-5}$ N (towards left).

Similarly, the wires B and C attract each other as they also carry the currents in same direction. the force on C due to current in B is towards right hand side. Therefore, the force on C due to B is given by

$$F_{BC}=\frac{\mu_0}{4\pi}.\frac{2i_B\, i_C}{r_{BC}}\ell$$

$$=\frac{10^{-7}\times 2\times 20\times 10\times 0.15}{0.10}$$

or $F_{BC}=6\times 10^{-5}$ N (towards right)

Therefore, the net force on C is

$F=(6\times 10^{-5}-3\times 10^{-5})$

$=3\times 10^{-5}$ N (towards right).

35. (a) $\tau_{max}=MB=niAB=ni(\ell\times b)B$

$\tau_{max}=600\times 10^{-5}\times 5\times 10^{-2}\times 12\times 10^{-2}\times 0.10=3.6\times 10^{-6}$ N-m.

36. (a) $B_{solenoid}=\mu_0 n_s i_s=\dfrac{\mu_0 N_S i_S}{L_S}$,

$$\tau=B_S iNA=\frac{\mu_0 N_S i_S iN\pi r^2}{L_S}$$

$$\tau=\frac{4\pi\times 10^{-7}\times 500\times 3\times 0.4\times 10\times \pi\times (0.01)^2}{0.4}$$

$=5.92\times 10^{-6}$ N-m.

37. (d) For a charged particle orbiting in a circular path in a magnetic field

$$\frac{mv^2}{r}=Bqv\Rightarrow v=\frac{Bqr}{m}$$

or $mv^2=Bqvr$

Also, $E_K=\frac{1}{2}mv^2=\frac{1}{2}Bqvr=Bq\frac{r}{2}.\frac{Bqr}{m}=\frac{B^2q^2r^2}{2m}$

For deuteron, $E_1=\dfrac{B^2q^2r^2}{2\times 2m}$

For proton, $E_2=\dfrac{B^2q^2r^2}{2m}$

$$\frac{E_1}{E_2}=\frac{1}{2}\Rightarrow\frac{50\text{keV}}{E_2}=\frac{1}{2}\Rightarrow E_2=100\text{keV}$$

38. (b) For circular path in magnetic field,

$$mr\omega^2=qvB\Rightarrow\omega^2=\frac{qvB}{mr}$$

As $v=r\omega$

$$\therefore\ \omega^2=\frac{q(r\omega)B}{mr}\Rightarrow\omega=\frac{qB}{m}$$

$\therefore$ If ν is frequency of roatation, then

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

39. (c) $B=\mu_0 ni$

$$B_1=(\mu_0)\left(\frac{n}{2}\right)(2\,i)=\mu_0 ni=B\Rightarrow B_1=B$$

40. (d) $$B=\frac{\mu_0}{4\pi}\frac{(2\pi-\theta)i}{R}-\frac{\mu_0}{4\pi}\frac{\left(2\pi-\frac{\pi}{2}\right)\times i}{R}=\frac{3\mu_0 i}{8R}$$

41. (d) $$\frac{B_A}{B_C}=\left(\frac{R^2}{x^2+R^2}\right)^{3/2}$$

$$\frac{1}{8}=\left(\frac{R^2}{x^2+R^2}\right)^{3/2}\Rightarrow\frac{1}{4}=\frac{R^2}{x^2+R^2}$$

$$\Rightarrow x^2+R^2=4R^2\Rightarrow x=\sqrt{3}R\cdot$$

42. (d)

43. (b) Here, $v=3\times 10^6\ ms^{-1}$.

$B=2\times 10^{-4}\ wb\,m^{-2}=2\times 10^{-4}$ T

$R=6$ cm $=6\times 10^{-2}$m. As $Bq\upsilon=\dfrac{m\upsilon^2}{R}$ or $\dfrac{q}{m}=\dfrac{\upsilon}{BR}$

Substituting the given values, we get

$$\frac{q}{m}=\frac{3\times 10^6}{2\times 10^{-4}\times 6\times 10^{-2}}=0.25\times 10^{12}\ C/kg$$

$=2.5\times 10^{11}$ C/kg.

44. (c) $$r=\frac{\sqrt{2mK}}{qB}\Rightarrow r\propto\frac{\sqrt{m}}{q}\Rightarrow\frac{r_{He^+}}{r_{O^{++}}}=\sqrt{\frac{m_{He^+}}{m_{O^{++}}}}\times\frac{q_{O^{++}}}{q_{He^+}}$$

$=\sqrt{\frac{4}{16}}\times\frac{2}{1}=\frac{1}{1}$. They will deflect equally.

45. (b) B at the centre of a coil carrying a current, i is

$B_{coil}=\dfrac{\mu_0 i}{2r}$ [upward]

B due to wire $B_{wire}=\dfrac{\mu_0 i}{2\pi r}$ [downward]

Given i = 8A; $r=10\times 10^{-2}$ m

$\dfrac{\mu_0}{4\pi}=10^{-7}$

magnetic field at centre C,

$B_C=B_{coil}+B_{wire}$

$=\dfrac{\mu_0 i}{2r}$(upward) $+\dfrac{\mu_0 i}{2\pi r}$[downward]

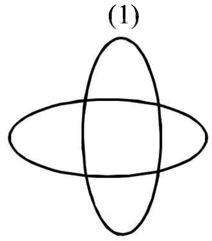
$= \frac{\mu_0 i}{2r} - \frac{\mu_0 i}{2\pi r} = \frac{\mu_0 i}{2r}\left(1 - \frac{1}{\pi}\right)$ upward

$= \frac{4\pi \times 10^{-7} \times 8}{2 \times 10 \times 10^{-2}}\left(1 - \frac{1}{3.14}\right)$ upward

$= \frac{4 \times 3.14 \times 10^{-7} \times 8 \times 2.14}{2 \times 10 \times 10^{-2} \times 3.14} = 3.424 \times 10^{-5}$ upward.

46. (c) Net force on a current carrying closed loop is always zero if it is placed in a uniform magnetic field.

47. (d)



The magnetic field due to circular coil,

$$B_1 = \frac{\mu_0 i_1}{2r} = \frac{\mu_0 i_1}{2(2\pi \times 10^{-2})} = \frac{\mu_0 \times 3 \times 10^2}{4\pi}$$

$$B_2 = \frac{\mu_0 i_2}{2(2\pi \times 10^{-2})} = \frac{\mu_0 \times 4 \times 10^2}{4\pi}$$

$$B = \sqrt{B_1^2 + B_2^2} = \frac{\mu_0}{4\pi} . 5 \times 10^2$$

$\Rightarrow B = 10^{-7} \times 5 \times 10^2 \Rightarrow B = 5 \times 10^{-5}\ \text{Wb/m}^2$

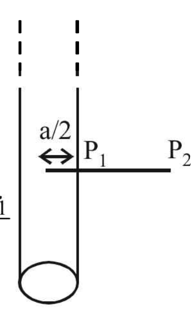
48. (d) Here, current is uniformly distributed across the cross-section of the wire, therefore, current enclosed in the amperean path formed at a distance $r_1 \left(= \frac{a}{2}\right)$

$= \left(\frac{\pi r_1^2}{\pi a^2}\right) \times I$, where I is total current

$\therefore$ Magnetic field at P_1 is

$$B_1 = \frac{\mu_0 \times \text{current enclosed}}{\text{Path}}$$

$$\Rightarrow B_1 = \frac{\mu_0 \times \left(\frac{\pi r_1^2}{\pi a^2}\right) \times I}{2\pi r_1} = \frac{\mu_0 \times I r_1}{2\pi a^2}$$



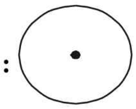
Now, magnetic field at point P_2,

$$B_2 = \frac{\mu_0}{2\pi} . \frac{I}{(2a)} = \frac{\mu_0 I}{4\pi a}.$$

$\therefore$ Required ratio $= \frac{B_1}{B_2} = \frac{\mu_0 I r_1}{2\pi a^2} \times \frac{4\pi a}{\mu_0 I}$

$$= \frac{2r_1}{a} = \frac{2 \times \frac{a}{2}}{a} = 1.$$

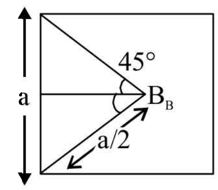
49. (b) Case (a) :



$$B_A = \frac{\mu_0}{4\pi}\frac{I}{R} \times 2\pi = \frac{\mu_0}{4\pi}\frac{I}{\ell/2\pi} \times 2\pi \qquad (2\pi R = \ell)$$

$$= \frac{\mu_0}{4\pi}\frac{I}{\ell} \times (2\pi)^2$$

Case (b) :



$$B_B = 4 \times \frac{\mu_0}{4\pi}\frac{I}{a/2}[\sin 45° + \sin 45°]$$

$$= 4 \times \frac{\mu_0}{4\pi} \times \frac{I}{\ell/8} \times \frac{2}{\sqrt{2}} = \frac{\mu_0}{4\pi}\frac{I}{\ell} \times 32 \times \sqrt{2} \qquad [4a = l]$$

50. (c) $\int E d\ell = \frac{-d\phi}{dt} = -\pi r^2 \frac{dB}{dt}$

Force $= N = \int \lambda E d\ell = -\lambda \pi r^2 \frac{dB}{dt}$

($\lambda \rightarrow$ charge per unit length)

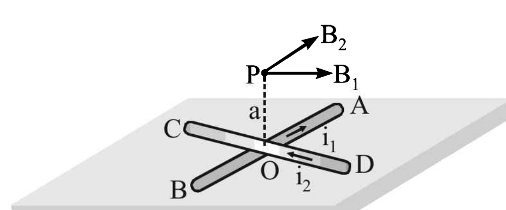
Change in momentum $= \int N dt = -\lambda \pi r^2 \int dB$

Change in angular momentum $= r\lambda \pi r^2 B = I\omega$

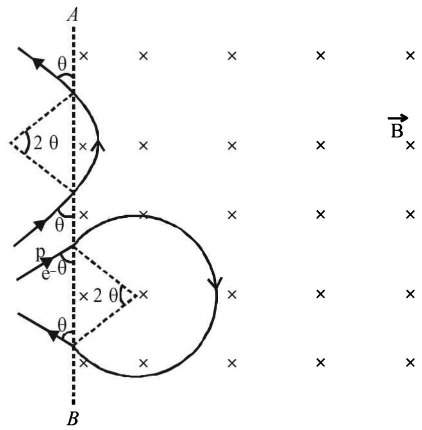
$\Rightarrow r\, \pi r^2 B \frac{q}{2\pi r} = mr^2 \omega \Rightarrow \omega = \frac{qB}{2m}$

51. (c) At P : $B_{net} = \sqrt{B_1^2 + B_2^2}$

$$= \sqrt{\left(\frac{\mu_0}{4\pi}\frac{2i_1}{a}\right)^2 + \left(\frac{\mu_0}{4\pi}\frac{2i_2}{a}\right)^2} = \frac{\mu_0}{2\pi a}(i_1^2 + i_2^2)^{1/2}$$



52. (d) Figure shows that the magnetic field $\vec{B}$ is present on the right hand side of AB. The electron (e) and proton (p) moving on straight parallel paths with the same velocity enter the region of uniform magnetic field. The entry and exit of electron & proton in the magnetic field makes the same angle with AB as shown. Therefore both will come out travelling in parallel paths.



The time taken by proton

$$t_p = \frac{\text{distance}}{\text{speed}} = \frac{\text{arc}}{\text{speed}} = \frac{\text{angle} \times \text{radius}}{\text{speed}} = \frac{2\theta \times R_p}{v}$$

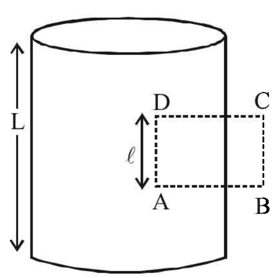
$$= \frac{2\theta}{v} \times \left(\frac{m_p v}{eB}\right) = \frac{2\theta m_p}{eB}$$

The time taken by electron is

$$t_e = \frac{(2\pi - 2\theta) R_e}{v} = \frac{(2\pi - 2\theta)}{v}\left(\frac{m_e v}{eB}\right) = \frac{(2\pi - 2\theta) m_e}{eB}$$

clearly t_e is not equal to t_p as $m_p >> m_e$

53. (a) Let us consider an amperian loop ABCD which is a rectangle as shown in the figure.
Applying ampere's circuital law we get



$$\oint \vec{B}.\vec{d\ell} = \mu_o \times (\text{current passing through the loop})$$

$$\therefore \quad \oint \vec{B}.\vec{d\ell} = \mu_o \left(\frac{I}{L}\right) \times \ell$$

$$\therefore \quad B \times \ell = \mu_o \frac{I}{L} \times \ell$$

$$\therefore \quad B = \frac{\mu_o I}{L} = \frac{\mu_o}{L} I_o \cos(300\,t)$$

The magnetic moment of the loop
= (current in the loop) × πr^2

$$= \frac{1}{R}\left(-\frac{d\phi}{dt}\right) \times \pi r^2$$

$$= -\frac{1}{R}\left[\frac{d}{dt}(B \times \pi r^2)\right] \times \pi r^2 = -\frac{\pi^2 r^4}{R}\frac{dB}{dt}$$

$$= \left[\frac{\pi^2 r^4}{R} \times \frac{\mu_o}{L} I_o \sin(300t)\right] \times 300$$

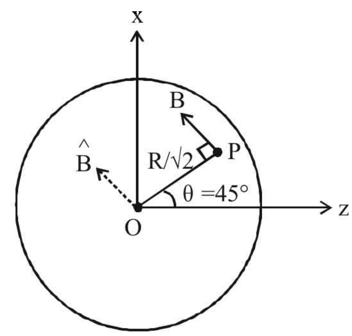
Comparing it with the expression given in the question we get

$$N = \frac{300\pi^2 r^4}{R} \times \frac{1}{L} = \frac{300(3.14)^2 \times (0.1)^4}{0.005 \times 10} = 6$$

54. (a) The magnitude of magnetic field at P $\left(\frac{R}{2}, y, \frac{R}{2}\right)$ is

$$B = \frac{\mu_0 Jr}{2} = \frac{\mu_0 i}{2\pi R^2} \times \frac{R}{\sqrt{2}} = \frac{\mu_0 i}{2\sqrt{2}\pi R}$$

(independent on y-coordinate)

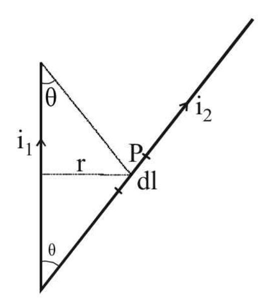


Unit vector in direction of magnetic field is

$$\hat{B} = \frac{\hat{i} - \hat{k}}{\sqrt{2}} \quad \text{(shown by dotted lines)}$$

$$\therefore \quad \vec{B} = B\hat{B} = \frac{\mu_0 i}{4\pi R}(\hat{i} - \hat{k})$$

55. (c) Magnetic field due to current in wire 1 at point *P* distant *r* from the wire is



$$B = \frac{\mu_0}{4\pi}\frac{i_1}{r}[\cos\theta + \cos\theta]$$

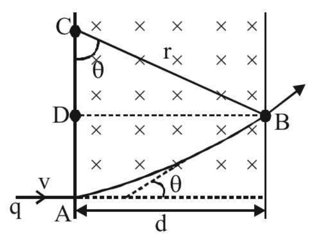
$B = \frac{\mu_0}{2\pi}\frac{i_1 \cos\theta}{r}$ (directed perpendicular to the plane of paper, inwards)

The force exerted due to this magnetic field on current element $i_2\,dl$ is

$dF = i_2\,dl\,B \sin 90°$

$$\therefore dF = i_2\,dl\left[\frac{\mu_0}{2\pi}\frac{i_1 \cos\theta}{r}\right] = \frac{\mu_0}{2\pi r} i_1 i_2\,dl \cos\theta$$

56. (a) $\frac{1}{2}mv^2 = qV$; $v = \sqrt{\frac{2qV}{m}}$



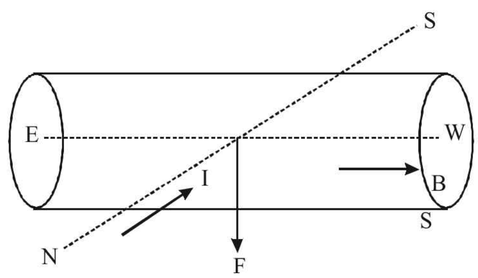
$$r = \frac{mv}{qB} = \frac{m}{qB}\sqrt{\frac{2qV}{m}}$$

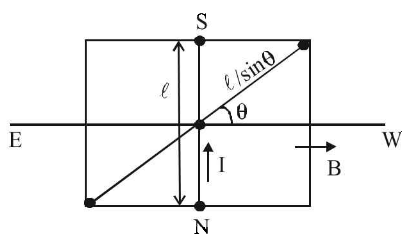
$$r = \frac{1}{B}\sqrt{\frac{2mV}{q}}$$

In ΔCBD, $\sin\theta = \frac{d}{r} = Bd\sqrt{\frac{q}{2mV}}$

$$\theta = \sin^{-1}\left\{Bd\sqrt{\frac{q}{2mV}}\right\}$$

57. (c)





Initially $1.2N = I.(\vec{\ell} \times \vec{B}) \downarrow$

In the given condition :

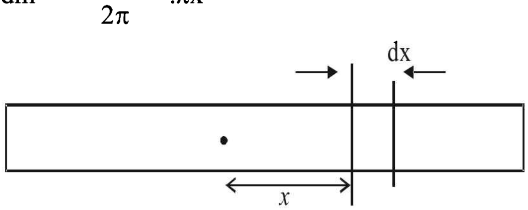
$$F = I\frac{\ell}{\sin\theta}B\sin\theta = I\ell B = 1.2N \downarrow$$

58. (b) $r = \frac{mv}{qB} \Rightarrow r \propto mv$ [q and B are constant]

$\because$ $r_A > r_B \Rightarrow m_A v_A > m_B v_B$

59. (a) At a distance x consider small element of width dx. Magnetic moment of the small element is

$$dm = \frac{\left(\frac{q}{\ell}dx\right)\omega}{2\pi}.\pi x^2$$



$$M = \int_{-\ell/2}^{\ell/2} \frac{q\omega}{2\ell}x^2 dx \; ; \; M = \frac{q\omega\ell^2}{24} = \frac{q\pi f\ell^2}{12}$$

60. (b) Here, $\vec{E}$ and $\vec{B}$ are perpendicular to each other and the velocity $\vec{v}$ does not change; therefore

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

Also,

$$\left|\frac{\vec{E} \times \vec{B}}{B^2}\right| = \frac{E\,B\sin\theta}{B^2}$$

$$= \frac{E\,B\,\sin 90°}{B^2} = \frac{E}{B} = |\vec{v}| = v$$