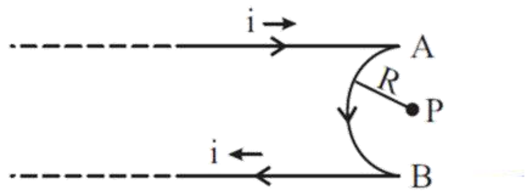
Moving Charges and Magnetism

1. A very long conducting wire is bent in a semi-circular shape from A to B as shown in figure. The magnetic field at point P for steady current configuration is given by: **(2023)**



(a) $\frac{\mu_0 i}{4R}\left[1-\frac{2}{\pi}\right]$
(b) $\frac{\mu_0 i}{4R}$ pointed into the page
(c) $\frac{\mu_0 i}{4R}$ pointed away from the page
(d) $\frac{\mu_0 i}{4R}\left[1-\frac{2}{\pi}\right]$

2. A wire carrying a current I along the positive x-axis has length L. It is kept in a magnetic field $\vec{B}=(2\hat{\imath}+3\hat{\jmath}-4\hat{k})T$. The magnitude of the magnetic force acting on the wire is: **(2023)**
(a) $\sqrt{3}$ IL
(b) IL
(c) $\sqrt{3}$ IL
(d) 5 IL

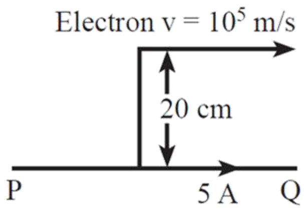
3. Given below are two statements:
Statement I: Blot-Savart's Law gives us the expression for the magnetic field strength of an infinitesimal current element(Idl) of a current carrying conductor only.
Statement II: Biot-Smarts law is analogous to Coulomb's inverse square law of change q, with the former being related to the field produced by a scalar source. Idl while the latter being produced by a vector source, q.
In light of above statement choose the most appropriate answer from the options given below: **(2022)**
(a) Both statement I and Statement II are incorrect
(b) Statement I is correct and Statement II is incorrect
(c) Statement I is incorrect and Statement II is correct
(d) Both statement I and Statement II are correct

4. From Ampere's circuital law for a long straight wire of circular cross-section carrying a steady current. the variation of magnetic field in the inside and outside region of the wire is: **(2022)**
(a) A linearly increasing function of distance upto the boundary of the wire and then linearly decreasing for the outside region.
(b) A linearly increasing function of distance r upto the boundary of the wire and then decreasing one with 1/r dependence for the outside region.
(c) A linearly decreasing function of distance upto the boundary of the wire and then a linearly increasing one for the outside region.
(d) Uniform and remains constant for both the regions.

5. A long solenoid of radius 1 mm has 100 toms per mm. If 1A current flows in the solenoid, the magnetic field strength at the centre of the solenoid is **(2022)**
(a) $12.56\times10^{-2}T$
(b) $12.56\times10^{-4}T$
(c) $6.28\times10^{-4}T$
(d) $6.28\times10^{-2}T$

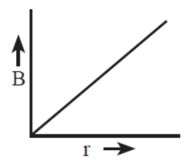
6. Polar molecules are the molecules: **(2021)**
(a) Acquire a dipole moment only in the presence of electric field due to displacement of charges.
(b) Acquire a dipole moment only when magnetic field is absent.
(c) Having a permanent electric dipole moment.
(d) Having zero dipole moment.

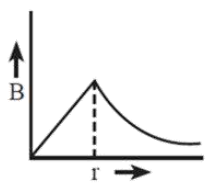
7. An infinitely long straight conductor carries a current of 5 A as shown. An electron is moving with a speed of 10^5m/s parallel to the conductor. The perpendicular distance betwen the electron and the conductor is 20 cm at an instant. Calculate the magnitude of the force experienced by the electron at that instant. **(2021)**

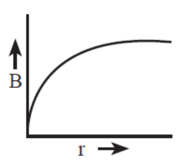


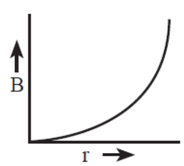
(a) $8\pi \times 10^{-20} N$
(b) $4\pi \times 10^{-20} N$
(c) $8 \times 10^{-20} N$
(d) $4 \times 10^{-20} N$

8. A thick current carrying cable of radius 'R' carries current 'I' uniformly distributed across its cross-section. The variation of magnetic field B(r) due to the cable with the distance 'r' from the axis of the cable is represented by: **(2021)**

(a) 

(b) 

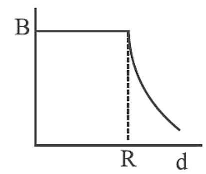
(c) 

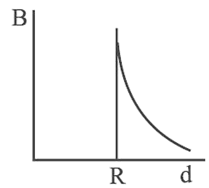
(d) 

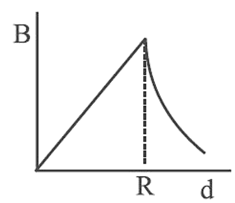
9. In the product **(2021)**
$\vec{F} = q(\vec{v} \times \vec{B})$
$= q\vec{v} \times (B\vec{\imath} + B\vec{\jmath} + B_0\vec{k})$
For q = 1 and $\vec{v} = 2\hat{\imath} + 4\hat{\jmath} + 6\hat{k}$ and
$\vec{F} = -4\hat{\imath} + 20\hat{\jmath} + 12\hat{k}$
What will be the complete expression for $\vec{B}$?
(a) $-6\hat{\imath} + 6\hat{\jmath} + 8\hat{k}$
(b) $8\hat{\imath} + 8\hat{\jmath} - 6\hat{k}$
(c) $6\hat{\imath} + 6\hat{\jmath} - 8\hat{k}$
(d) $-8\hat{\imath} - 8\hat{\jmath} - 6\hat{k}$

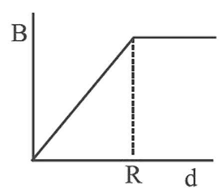
10. A long solenoid of 50 cm length having 100 turns carries a current of 2.5 A. The magnetic field at the centre of the solenoid is: $(\mu = 4\pi \times 10^{-7} TmA^{-1})$ **(2020)**
(a) $3.14 \times 10^{-4} T$
(b) $6.28 \times 10^{-5} T$
(c) $3.14 \times 10^{-5} T$
(d) $6.28 \times 10^{-4} T$

11. A cylindrical conductor of radius R is carrying a constant current. The plot of the magnitude of the magnetic field B with the distance d from the centre of the conductor, is correctly represented by the figure: **(2019)**

(a) 

(b) 

(c) 

(d) 

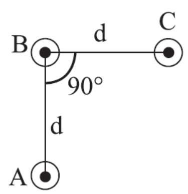
12. Ionized hydrogen atoms and α-particles with same momenta enters perpendicular to a constant magnetic field, B. The ratio of their radii of their paths $r_H : r_\alpha$ will be: **(2019)**
(a) 2 : 1
(b) 1 : 2
(c) 4 : 1
(d) 1 : 4

13. Current sensitivity of a moving coil galvanometer is 5 div/mA and its voltage sensitivity (angular deflection per unit voltage applied) is 20 div/V. The resistance of the galvanometer is : **(2018)**
(a) 250 Ω
(b) 25 Ω

(c) 40 Ω
(d) 500 Ω

14. An electron falls from rest through a vertical distance h in a uniform and vertically upward directed electric field E. The direction of electric field is now reversed, keeping its magnitude the same. A proton is allowed to fall from rest in it through the same vertical distance h. The time of fall of the electron, in comparison to the time of fall of the proton is **(2018)**
(a) 10 times greater
(b) 5 times greater
(c) Smaller
(d) Equal

15. An arrangement of three parallel straight wires placed perpendicular to plane of paper carrying same current 'I' along the same direction is shown in figure. Magnitude of force per unit length on the middle wire 'B' is given by: **(2017-Delhi)**



(a) $\frac{2\mu_0 i^2}{\pi d}$
(b) $\frac{\sqrt{2}\mu_0 i^2}{\pi d}$
(c) $\frac{\mu i^2}{\sqrt{2}\pi d}$
(d) $\frac{\mu_0 i^2}{2\pi d}$

16. Inside a parallel plate capacitor the electric field E varies with time as t^2. The variation of induced magnetic field with time is given by: **(2017-Gujrat)**
(a) t^2
(b) No variation
(c) t^3
(d) t

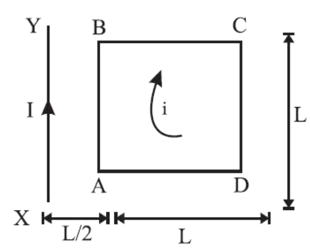
17. An electron is moving in a circular path under the influence of a transverse magnetic field of $3.57 \times 10^{-2} T$. If the value of e/m is $1.76 \times 10^{11} C/kg$, the frequency of revolution of the electron is: **(2016-II)**
(a) 62.8 MHz
(b) 6.28 MHz
(c) 1 GHz
(d) 100 MHz

18. A bar magnet is hung by a thin cotton thread in a uniform horizontal magnetic field and is in equilibrium state. The energy required to rotate it by 60° is W. Now the torque required to keep the magnet in this new position is: **(2016-II)**
(a) $\frac{\sqrt{3}W}{2}$
(b) $\frac{2W}{\sqrt{3}}$
(c) $\frac{W}{\sqrt{3}}$
(d) $\sqrt{3}W$

19. A long wire carrying a steady current is bent into a circular loop of one turn. The magnetic field at the center of the loop is B. It is then bent into a circular coil of n turns. The magnetic field at the center of this coil of n turns will be: **(2016-II)**
(a) 2nB
(b) $2n^2B$
(c) nB
(d) n^2B

20. A long straight wire of radius a carries a steady current I. The current is uniformly distributed over its cross-section. The ratio of the magnetic fields B and B′ at radial distances a/2 and 2a respectively, from the axis of the wire is: **(2016-I)**
(a) 1/4
(b) 1/2
(c) 1
(d) 4

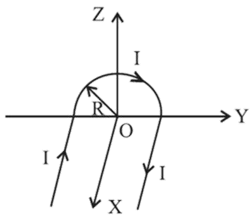
21. A square loop ABCD carrying a current i, is placed near and coplanar with a long straight conductor XY carrying a current I, the net force on the loop will be: **(2016-I)**



(a) $\frac{2\mu_0 Ii}{3\pi}$
(b) $\frac{\mu_0 Ii}{2\pi}$
(c) $\frac{2\mu_0 IiL}{3\pi}$
(d) $\frac{\mu_0 IiL}{2\pi}$

22. A wire carrying current I has the shape as shown in adjoining figure. Linear parts of the wire are very long and parallel to X-axis while semicircular portion of radius R is

lying in Y-Z plane. Magnetic field at point O is: **(2015)**



(a) $\vec{B} = -\frac{\mu_0}{4\pi}\frac{I}{R}\left(\pi\hat{\imath} - 2\hat{k}\right)$

(b) $\vec{B} = -\frac{\mu_0}{4\pi}\frac{I}{R}\left(\pi\hat{\imath} + 2\hat{k}\right)$

(c) $\vec{B} = \frac{\mu_0}{4\pi}\frac{I}{R}\left(\pi\hat{\imath} - 2\hat{k}\right)$

(d) $\vec{B} = \frac{\mu_0}{4\pi}\frac{I}{R}\left(\pi\hat{\imath} + 2\hat{k}\right)$

23. An electron moving in a circular orbit of radius r makes n rotations per second. The magnetic field produced at the center has magnitude: **(2015)**

(a) Zero

(b) $\frac{\mu_0 n^2 e}{r}$

(c) $\frac{\mu_0 ne}{2r}$

(d) $\frac{\mu_0 ne}{2\pi r}$

24. A proton and an alpha particle both enter a region of uniform magnetic field, B, moving at right angles to the field B. If the radius of circular orbits for both the particles is equal and the kinetic energy acquired by proton is 1 MeV, the energy acquired by the alpha particle will be: **(2015 Pre)**

(a) 1 MeV

(b) 4 MeV

(c) 0.5 MeV

(d) 1.5 MeV

25. A rectangular coil of length 0.12 m and width 0.1 m having 50 turns of wire is suspended vertically in a uniform magnetic field of strength 0.2 Weber/m^2. The coil carries a current of 2 A. If the plane of the coil is inclined at an angle of 30° with the direction of the field, the torque required to keep the coil in stable equilibrium will be: **(2015 Pre)**

(a) 0.12 Nm

(b) 0.15 Nm

(c) 0.20 Nm

(d) 0.24 Nm

26. Two identical long conducting wires AOB and COD are placed at right angle to each other, with one above other such that O is their common point for the two. The wires carry I_1 and I_2 currents, respectively. Point P is lying at distance d from O along a direction perpendicular to the plane containing the wires. The magnetic field at the point P will be: **(2014)**

(a) $\frac{\mu_0}{2\pi d}\left(\frac{I_1}{I_2}\right)$

(b) $\frac{\mu_0}{2\pi d}(I_1 + I_2)$

(c) $\frac{\mu_0}{2\pi d}(I_1^2 + I_2^2)$

(d) $\frac{\mu_0}{2\pi d}(I_1^2 + I_2^2)^{1/2}$

27. When a proton is released from rest in a room, it starts with an initial acceleration a_0 towards west. When it is projected towards north with a speed v_0 it moves with an initial acceleration $3a_0$ toward west. The electric and magnetic fields in the room are: **(2013)**

(a) $\frac{ma_0}{e} east, \frac{3ma_0}{ev_0} down$

(b) $\frac{ma_0}{e} west, \frac{2ma_0}{ev_0} up$

(c) $\frac{ma_0}{e} west, \frac{2ma_0}{ev_0} down$

(d) $\frac{ma_0}{e} east, \frac{3ma_0}{ev_0} up$

28. A current loop in a magnetic field: **(2013)**

(a) Can be in equilibrium in two orientations, one stable while the other is unstable

(b) Experiences a torque whether the field is uniform or non uniform in all orientations

(c) Can be in equilibrium in one orientation

(d) Can be in equilibrium in two orientations, both the equilibrium states are unstable

Answer Key

S1. Ans. (d)

S2. Ans. (d)

S3. Ans. (b)

S4. Ans. (b)

S5. Ans. (a)

S6. Ans. (c)

S7. Ans. (c)

S8. Ans. (b)

S9. Ans. (a)

S10. Ans. (d)

S11. Ans. (c)

S12. Ans. (a)

S13. Ans. (a)

S14. Ans. (c)

S15. Ans. (c)

S16. Ans. (d)

S17. Ans. (c)

S18. Ans. (d)

S19. Ans. (d)

S20. Ans. (c)

S21. Ans. (a)

S22. Ans. (b)

S23. Ans. (c)

S24. Ans. (a)

S25. Ans. (c)

S26. Ans. (d)

S27. Ans. (c)

S28. Ans. (a)

Solutions

S1. Ans.(d)

$\vec{B}_P = \vec{B}_{upper\ wire} \oplus + \vec{B}_{semi-circle} \ominus$
$+ \vec{B}_{lower-wire} \otimes$

$B_P = -\frac{\mu_0 i}{4\pi R} + \frac{\mu_0 i}{4R} - \frac{\mu_0 i}{4\pi R}$

$= \frac{\mu_0 i}{4R}\left(1 - \frac{2}{\pi}\right)$ point away from the page

S2. Ans.(d)

$|\vec{F}| = |I(\vec{L} \times \vec{B})|$

$= |I[L\hat{\imath} \times (2\hat{\imath} + 3\hat{\jmath} - 4\hat{k})]|$

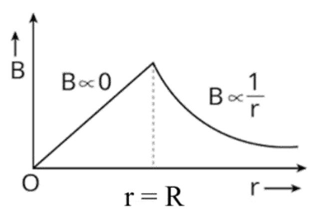
$= 5\ IL$

S3. Ans.(b)

$d\vec{B} = \frac{\mu(Id\vec{l} \times \vec{r})}{4\pi r^3}$

As per Biot Savart law, the expression for magnetic field depends on current carrying element $Id\vec{l}$, which is a vector quantity, therefore, statement-I is correct and statement-II is wrong.

S4. Ans.(b)



S5. Ans.(a)

$B = \mu_0 ni = \mu_0 \frac{N}{l} i$

$\therefore B = 4\pi \times 10^{-7} \times \frac{100}{10^{-3}} \times 1 = 12.56 \times 10^{-2} T$

S6. Ans.(c)

Polar molecules have centres of positive and negative charges separated by some distance, so they have permanent dipole moment.

S7. Ans.(c)

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

$F = BVq \sin\theta$

$\theta = 90°$

$F = BV_q$

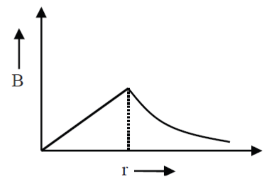
$F = \frac{\mu_0 I}{2\pi R} \times V \times e = \frac{2\times10^{-7}\times5}{20\times10^{-2}} \times 10^5 \times 1.6 \times 10^{-19}$

$F = 8 \times 10^{-20} N$

S8. Ans.(b)

$B_{in} = \frac{\mu I r}{2\pi R^2}$

$B_0 = \frac{\mu_0 I}{2\pi R}$



S9. Ans.(a)

$\vec{F} = q(\vec{V} \times \vec{B})$

$\vec{F} = (\vec{V} \times \vec{B})$

$\vec{F} = (2\hat{\imath} + 4\hat{\jmath} + 6\hat{k}) \times (B\hat{\imath} + B\hat{\jmath} + B\hat{k})$

$\vec{F} = \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ 2 & 4 & 6 \\ B & B & B_0 \end{vmatrix}$

$\vec{F} = (4B_0 - 6B)\hat{\imath} - (2B_0 - 6B)\hat{\jmath} + (2B - 4B)\hat{k}$

$4\hat{\imath} - 20\hat{\jmath} + 12\hat{k}$

$= (4B_0 - 6B)\hat{\jmath} - (2B_0 - 6B)\hat{\jmath} + (-2B)\hat{k}$

S10. Ans.(d)

$B = \mu_0 \frac{N}{l} I$

$= 4\pi \times 10^{-7} \times \frac{100}{0.5} \times 2.5$

$= 6.28 \times 10^{-4} T$

S11. Ans.(c)

Inside (d<R)

Magnetic field inside conductor

$B = \frac{\mu_0}{2\pi} \frac{i}{R^2} d$

Or $B = Kd$ ...(1)

Straight line passing through origin

At surface (d = R)

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

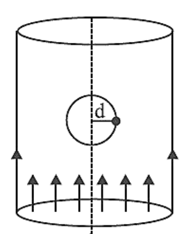
Maximum at surface

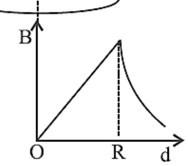
Outside (d > R)

$B = \frac{\mu_0}{2\pi} \frac{i}{d}$

Or $B \propto \frac{1}{d}$

(Hyperbolic)





S12. Ans.(a)

$r_H = \frac{mv}{eB} = \frac{p}{eB} \Rightarrow r_\alpha = \frac{p}{2eB}$

$\frac{r_H}{r_\alpha} = \frac{p/eB}{p/2eB} \Rightarrow \frac{r_H}{r_\alpha} = \frac{2}{1}$

S13. Ans.(a)

Voltage per division $= \frac{1}{20}V$

Current per division $= \frac{1}{5000}A$

$R = \frac{V}{I} = \frac{1/20}{1/5000} = 250\ \Omega$

S14. Ans.(c)

For electron

$a_e = \frac{E}{m_e} + g$

For proton

$a_p = \frac{eE}{m_p} + g \Rightarrow \because t = \sqrt{\frac{2h}{a}}$

Because $a_e > a_p$

So $t_e < t_p$

S15. Ans.(c)

Force per unit length

$F = \frac{\mu_0 I_1 I_2}{2\pi d} \Rightarrow I_1 = I_2 = i$

$F_1 = F_2 = F = \frac{\mu_0 i^2}{2\pi d}$

$F \perp F_2, \theta = 90°$

$F_{net} = \sqrt{2}F$

$= \frac{\sqrt{2}\mu_0 i^2}{2\pi d} = \frac{\mu_0 i^2}{\sqrt{2}\pi d}$

S16. Ans.(d)

Apply ampere' circuit law

$\oint B.dl = \mu_0 I_d$

$B \times 2\pi r = \mu_0 A \varepsilon_0 \frac{dE}{dt}$

$B \times 2\pi r = \mu_0 \pi r^2 \varepsilon_0 2t$

$B \propto t$

$A = \pi r_2$ as B is restricted within radius r.

S17. Ans.(c)

We know that

$f = \frac{qB}{2\pi m}$

$f = \frac{eB}{2\pi m}$

$f = \frac{1.76\times10^{11}\times3.57\times10^{-2}}{2\times3.14} Hz$

$f = 10°$ Hz or 1 GHz

S18. Ans.(d)

We know that

$\tau = M \times B \Rightarrow \tau = MB\sin\theta$

$\tau = MB\sin 60°$ ...(1)

$W = MB(1 - \cos 60°)$ ...(2)

From Eqs. (1) and (2)

$\frac{\tau}{W} = \frac{\frac{\sqrt{3}}{2}}{\frac{1}{2}} \Rightarrow \tau = W\sqrt{3}$

S19. Ans.(d)

We know that at the center of the circular loop $B = \frac{\mu_0 I}{2R}$

Since $l = 2\pi R = n(2\pi r) \Rightarrow r = \frac{R}{n}$

For one turn $B = \frac{\mu_0 i}{2R}$ and

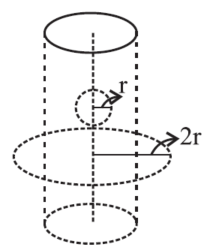
For n turn $B' = \frac{\mu_0 n i}{2r}$

$\Rightarrow B' = \frac{\mu_0 n^2 i}{2R} = n^2 B$

S20. Ans.(c)

Current density $J = \frac{I}{\pi a^2}$

From Ampere's circuital



$\oint B.dl = \mu I_{enclosed}$

For r < a

$B \times 2\pi r = \mu_0 J \pi r^2$

at $r = \frac{a}{2}, B_1 = \frac{\mu_0 I}{4\pi a}$

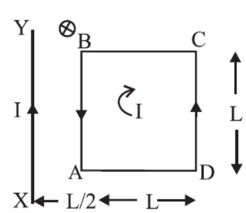
For r > a

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

At $r = 2a$

$B_2 = \frac{\mu_0 i}{4\pi a} \Rightarrow$ so, $\frac{B_1}{B_2} = 1$

S21. Ans.(a)



$F_{AB} = \frac{\mu_0 IiL}{2\pi\left[\frac{L}{2}\right]}$ towards XY

$F_{CD} = \frac{\mu_0 IiL}{2\pi\left[\frac{3L}{2}\right]}$ away from XY

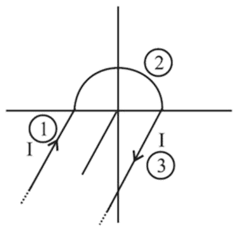
$F_{net} = F_{AB} - F_{CD}$

$= \frac{2}{3}\frac{\mu_0 Ii}{\pi}$

S22. Ans.(b)

'B' due to segment '1'

$B = \frac{\mu_0 I}{4\pi R}[\sin 90° + \sin\theta](-\hat{k})$



Due to wire

$\vec{B} = \frac{\mu_0 I}{4\pi d}[\sin\theta_1 + \sin\theta_2]$

$B_1 = B_3 \Rightarrow \theta_1 = 90° \quad \theta_2 = 0°$

$|B_1| = |B_3| = \frac{\mu_0 I}{4\pi R}[\sin 90° + \sin 0°]$

$B_1 = \frac{\mu_0 I}{4\pi R}(-\hat{k}) = \frac{-\mu_0 I}{4\pi R}(\hat{k})$

$B_2 = \frac{1}{2}\frac{\mu_0 I}{2R}(-\hat{\imath})$

$B_2 = -\frac{\mu_0 I}{4R}(\hat{\imath})$

$\vec{B} = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$

$= \frac{-\mu_0 I}{4\pi R}[\pi\hat{\imath} + 2\hat{k}]$

S23. Ans.(c)

Magnetic field due to a circular loop

$B = \frac{\mu_0 NI}{2r}$ where $N \rightarrow$ no. of loops

$I = \frac{q}{T} = \frac{e}{1/n} = ne$

$B = \frac{\mu_0 ne}{2r}$ ($\because N = 1$ as e^- makes only one loop)

S24. Ans.(a)

$m_\alpha = 4m_p$

$q_\alpha = 2e$

$q_\alpha = e$

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

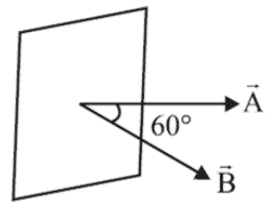
$\because R_\alpha = R_p$

$\therefore \frac{2m_\alpha k_\alpha}{q_\alpha^2 B^2} = \frac{2m_p K_p}{q_p^2 B^2}$ $(m_\alpha = 4m, q_\alpha = 2e, q_q = e)$

$\Rightarrow \frac{4m_p k_\alpha}{4e^2} = \frac{m_p(1MeV)}{e^2}$

$\Rightarrow K_\alpha = 1\ MeV$

S25. Ans.(c)



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

$|\vec{\tau}| = MB\sin\theta = NIAB\sin\theta = 0.20\ Nm$

S26. Ans.(d)

Net magnetic field, $B = \sqrt{B_1^2 + B_2^2}$

$= \sqrt{\left(\frac{\mu_0 I_1}{2\pi d}\right)^2 + \left(\frac{\mu_0 I_2}{2\pi d}\right)^2}$

$= \frac{\mu_0}{2\pi d}\sqrt{I_1^2 + I_2^2}$

S27. Ans.(c)

Acceleration of charged particle $\vec{a} = \frac{q}{m}(\vec{E} + \vec{v} \times \vec{B})$

Released from rest $\Rightarrow \vec{a} = \frac{q}{m}\vec{E} = a_0$ (west)

$\Rightarrow \vec{E} = \frac{ma_0}{e}$ (west)

When it is projected towards north, acceleration due to magnetic force $= 2a_0$

Therefore magnetic field $= \frac{2ma_0}{ev_0}$ (down)

S28. Ans.(a)

A current loop in a magnetic field can be in equilibrium in two orientations, one stable while the other is unstable