CHAPTER 18

Moving Charges and Magnetism

1. If a current is passed through a spring then the spring will **[2002]**

(a) expand (b) compress

(c) remains same (d) none of these

2. If in a circular coil A of radius R, current I is flowing and in another coil B of radius $2R$ a current $2I$ is flowing, then the ratio of the magnetic fields B_A and B_B, produced by them will be **[2002]**

(a) 1 (b) 2

(c) 1/2 (d) 4

3. If an electron and a proton having same momenta enter perpendicular to a magnetic field, then **[2002]**

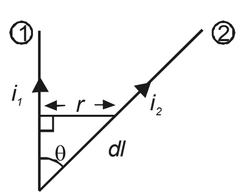
(a) curved path of electron and proton will be same (ignoring the sense of revolution)

(b) they will move undeflected

(c) curved path of electron is more curved than that of the proton

(d) path of proton is more curved.

4. Wires 1 and 2 carrying currents i_1 and i_2 respectively are inclined at an angle θ to each other. What is the force on a small element dl of wire 2 at a distance of r from wire 1 (as shown in figure) due to the magnetic field of wire 1? **[2002]**



(a) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \tan\theta$ (b) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \sin\theta$

(c) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \cos\theta$ (d) $\frac{\mu_0}{4\pi r} i_1 i_2 \, dl \sin\theta$

5. The time period of a charged particle undergoing a circular motion in a uniform magnetic field is independent of its **[2002]**

(a) speed (b) mass

(c) charge (d) magnetic induction

6. A particle of mass M and charge Q moving with velocity $\vec{v}$ describe a circular path of radius R when subjected to a uniform transverse magnetic field of induction B. The work done by the field when the particle completes one full circle is **[2003]**

(a) $\left(\frac{Mv^2}{R}\right) 2\pi R$ (b) zero

(c) $BQ2\pi R$ (d) $BQv2\pi R$

7. A particle of charge -16×10^{-18} coulomb moving with velocity 10ms^{-1} along the x-axis enters a region where a magnetic field of induction B is along the y-axis, and an electric field of magnitude 10^4V/m is along the negative z-axis. If the charged particle continues moving along the x-axis, the magnitude of B is **[2003]**

(a) 10^3Wb/m^2 (b) 10^5Wb/m^2

(c) 10^{16}Wb/m^2 (d) 10^{-3}Wb/m^2

8. A current i ampere flows along an infinitely long straight thin walled tube, then the magnetic induction at any point inside the tube is **[2004]**

(a) $\frac{\mu_0}{4\pi} \cdot \frac{2i}{r}$ tesla (b) zero

(c) infinite (d) $\frac{2i}{r}$ tesla

9. A long wire carries a steady current. It is bent into a circle of one turn and the magnetic field at the centre of the coil is B. It is then bent into a circular loop of n turns. The magnetic field at the centre of the coil will be **[2004]**

(a) $2nB$ (b) $n^2 B$
(c) nB (d) $2n^2 B$

10. The magnetic field due to a current carrying circular loop of radius 3 cm at a point on the axis at a distance of 4 cm from the centre is 54 μT. What will be its value at the centre of loop? **[2004]**

(a) 125 μT (b) 150 μT
(c) 250 μT (d) 75 μT

11. Two long conductors, separated by a distance d carry current I_1 and I_2 in the same direction. They exert a force F on each other. Now the current in one of them is increased to two times and its direction is reversed. The distance is also increased to $3d$. The new value of the force between them is **[2004]**

(a) $-\frac{2F}{3}$ (b) $\frac{F}{3}$
(c) $-2F$ (d) $-\frac{F}{3}$

12. Two concentric coils each of radius equal to 2π cm are placed at right angles to each other. 3 ampere and 4 ampere are the currents flowing in each coil respectively. The magnetic induction in Weber/m^2 at the centre of the coils will be $\left(\mu_0 = 4\pi \times 10^{-7}\,\text{Wb/A.m}\right)$ **[2005]**

(a) 10^{-5} (b) 12×10^{-5}
(c) 7×10^{-5} (d) 5×10^{-5}

13. A charged particle of mass m and charge q travels on a circular path of radius r that is perpendicular to a magnetic field B. The time taken by the particle to complete one revolution is **[2005]**

(a) $\frac{2\pi q^2 B}{m}$ (b) $\frac{2\pi mq}{B}$
(c) $\frac{2\pi m}{qB}$ (d) $\frac{2\pi qB}{m}$

14. A uniform electric field and a uniform magnetic field are acting along the same direction in a certain region. If an electron is projected along the direction of the fields with a certain velocity then **[2005]**

(a) its velocity will increase
(b) Its velocity will decrease
(c) it will turn towards left of direction of motion
(d) it will turn towards right of direction of motion

15. In a region, steady and uniform electric and magnetic fields are present. These two fields are parallel to each other. A charged particle is released from rest in this region. The path of the particle will be a **[2006]**

(a) helix (b) straight line
(c) ellipse (d) circle

16. A long solenoid has 200 turns per cm and carries a current i. The magnetic field at its centre is 6.28×10^{-2} Weber/m^2. Another long solenoid has 100 turns per cm and it carries a current $\frac{i}{3}$. The value of the magnetic field at its centre is **[2006]**

(a) 1.05×10^{-2} Weber/m^2
(b) 1.05×10^{-5} Weber/m^2
(c) 1.05×10^{-3} Weber/m^2
(d) 1.05×10^{-4} Weber/m^2

17. A long straight wire of radius a carries a steady current i. The current is uniformly distributed across its cross section. The ratio of the magnetic field at $a/2$ and $2a$ is **[2007]**

(a) 1/2 (b) 1/4
(c) 4 (d) 1

18. A current I flows along the length of an infinitely long, straight, thin walled pipe. Then **[2007]**

(a) the magnetic field at all points inside the pipe is the same, but not zero
(b) the magnetic field is zero only on the axis of the pipe
(c) the magnetic field is different at different points inside the pipe
(d) the magnetic field at any point inside the pipe is zero

19. A charged particle with charge q enters a region of constant, uniform and mutually orthogonal fields $\vec{E}$ and $\vec{B}$ with a velocity $\vec{v}$ perpendicular to both $\vec{E}$ and $\vec{B}$, and comes out without any change in magnitude or direction of $\vec{v}$. Then **[2007]**

(a) $\vec{v} = \vec{B} \times \vec{E} / E^2$ (b) $\vec{v} = \vec{E} \times \vec{B} / B^2$
(c) $\vec{v} = \vec{B} \times \vec{E} / B^2$ (d) $\vec{v} = \vec{E} \times \vec{B} / E^2$

20. A charged particle moves through a magnetic field perpendicular to its direction. Then **[2007]**

(a) kinetic energy changes but the momentum is constant

(b) the momentum changes but the kinetic energy is constant

(c) both momentum and kinetic energy of the particle are not constant

(d) both momentum and kinetic energy of the particle are constant

21. Two identical conducting wires *AOB* and *COD* are placed at right angles to each other. The wire *AOB* carries an electric current I_1 and *COD* carries a current I_2. The magnetic field on a point lying at a distance d from *O*, in a direction perpendicular to the plane of the wires *AOB* and *COD*, will be given by **[2007]**

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

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

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

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

22. A horizontal overhead powerline is at height of 4m from the ground and carries a current of 100A from east to west. The magnetic field directly below it on the ground is ($\mu_0 = 4\pi\times10^{-7}$ Tm A^{-1}) **[2008]**

(a) 2.5×10^{-7} *T* southward

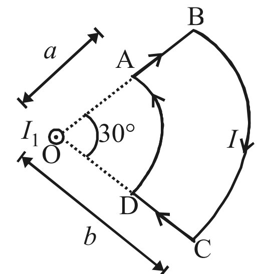
(b) 5×10^{-6} *T* northward

(c) 5×10^{-6} *T* southward

(d) 2.5×10^{-7} *T* northward

Directions : *Question numbers 23 and 24 are based on the following paragraph.*

A current loop *ABCD* is held fixed on the plane of the paper as shown in the figure. The arcs *BC* (radius = *b*) and *DA* (radius = *a*) of the loop are joined by two straight wires *AB* and *CD*. A steady current *I* is flowing in the loop. Angle made by *AB* and *CD* at the origin *O* is 30°. Another straight thin wire with steady current I_1 flowing out of the plane of the paper is kept at the origin. **[2009]**



23. The magnitude of the magnetic field (*B*) due to the loop *ABCD* at the origin (*O*) is :

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

(b) $\frac{\mu_o I}{4\pi}\left[\frac{b-a}{ab}\right]$

(c) $\frac{\mu_o I}{4\pi}[2(b-a)+\pi/3(a+b)]$

(d) zero

24. Due to the presence of the current I_1 at the origin:

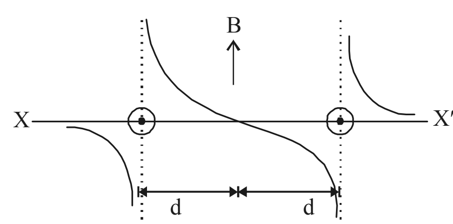
(a) The forces on *AD* and *BC* are zero.

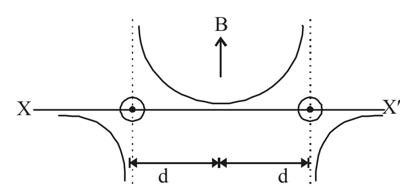
(b) The magnitude of the net force on the loop is given by $\frac{I_1 I}{4\pi}\mu_o[2(b-a)+\pi/3(a+b]$.

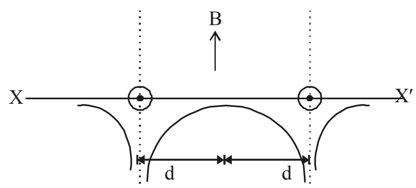
(c) The magnitude of the net force on the loop is given by $\frac{\mu_o I I_1}{24ab}(b-a)$.

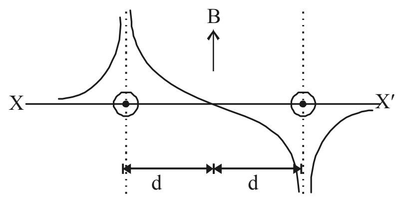
(d) The forces on *AB* and *DC* are zero.

25. Two long parallel wires are at a distance 2d apart. They carry steady equal currents flowing out of the plane of the paper as shown. The variation of the magnetic field B along the line XX' is given by **[2010]**

(a) 

(b) 

(c) 

(d) 

26. A current I flows in an infinitely long wire with cross section in the form of a semi-circular ring of radius R. The magnitude of the magnetic induction along its axis is: **[2011]**

(a) $\frac{\mu_0 I}{2\pi^2 R}$ (b) $\frac{\mu_0 I}{2\pi R}$

(c) $\frac{\mu_0 I}{4\pi R}$ (d) $\frac{\mu_0 I}{\pi^2 R}$

27. An electric charge $+q$ moves with velocity $\vec{v} = 3\hat{i} + 4\hat{j} + \hat{k}$ in an electromagnetic field given by $\vec{E} = 3\hat{i} + \hat{j} + 2\hat{k}$ and $\vec{B} = \hat{i} + \hat{j} - 3\hat{k}$ The y - component of the force experienced by $+q$ is : **[2011 RS]**

(a) $11\,q$ (b) $5\,q$

(c) $3\,q$ (d) $2\,q$

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

(a) $\pi R^4 \sigma\omega$ (b) $\frac{\pi R^4}{2}\sigma\omega$

(c) $\frac{\pi R^4}{4}\sigma\omega$ (d) $2\pi R^4 \sigma\omega$

29. Proton, deuteron and alpha particle of same kinetic energy are moving in circular trajectories in a constant magnetic field. The radii of proton, deuteron and alpha particle are respectively r_p, r_d and r_α. Which one of the following relation is correct? **[2012]**

(a) $r_\alpha = r_p = r_d$ (b) $r_\alpha = r_p < r_d$

(c) $r_\alpha > r_d > r_p$ (d) $r_\alpha = r_d > r_p$

30. A circular loop of radius 0.3 cm lies parallel to a much bigger circular loop of radius 20 cm. The centre of the small loop is on the axis of the bigger loop. The distance between their centres is 15 cm. If a current of 2.0 A flows through the smaller loop, then the flux linked with bigger loop is **[2013]**

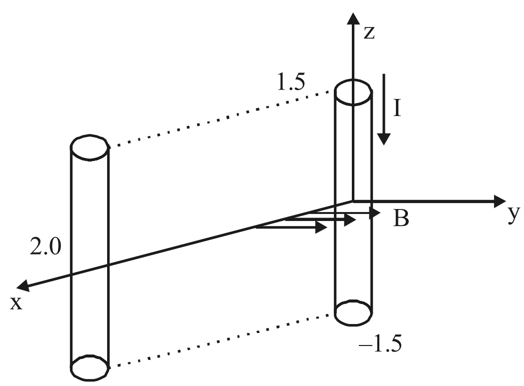
(a) 9.1×10^{-11} weber

(b) 6×10^{-11} weber

(c) 3.3×10^{-11} weber

(d) 6.6×10^{-9} weber

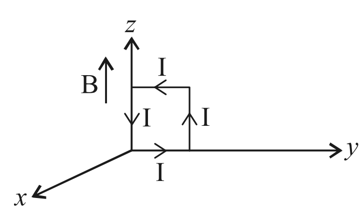
31. A conductor lies along the z-axis at $-1.5 \le z < 1.5$ m and carries a fixed current of 10.0 A in $-\hat{a}_z$ direction (see figure). For a field $\vec{B} = 3.0 \times 10^{-4} e^{-0.2x}\, \hat{a}_y$ T, find the power required to move the conductor at constant speed to x = 2.0 m, y = 0 m in 5×10^{-3} s. Assume parallel motion along the x-axis. **[2014]**



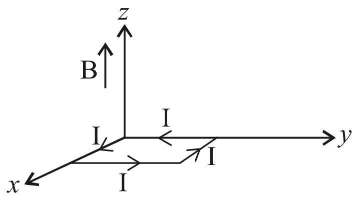
(a) 1.57 W (b) 2.97 W

(c) 14.85 W (d) 29.7 W

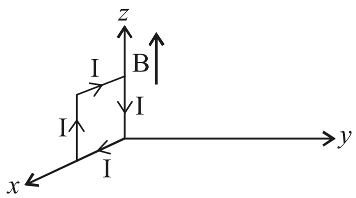
32. A rectangular loop of sides 10 cm and 5 cm carrying a current 1 of 12 A is placed in different orientations as shown in the figures below : **[2015]**

(A) 

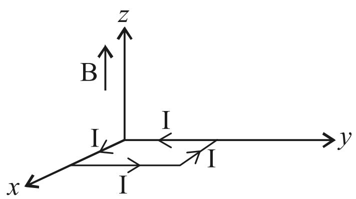
(B)



(C)



(D)



If there is a uniform magnetic field of 0.3 T in the positive z direction, in which orientations the loop would be in (i) stable equilibrium and (ii) unstable equilibrium ?

(a) (B) and (D), respectively
(b) (B) and (C), respectively
(c) (A) and (B), respectively
(d) (A) and (C), respectively

33. Two coaxial solenoids of different radius carry current I in the same direction. $\vec{F_1}$ be the magnetic force on the inner solenoid due to the outer one and $\vec{F_2}$ be the magnetic force on the outer solenoid due to the inner one. Then : **[2015]**

(a) $\vec{F_1}$ is radially inwards and $\vec{F_2} = 0$
(b) $\vec{F_1}$ is radially outwards and $\vec{F_2} = 0$
(c) $\vec{F_1} = \vec{F_2} = 0$
(d) $\vec{F_1}$ is radially inwards and $\vec{F_2}$ is radially outwards

34. Two identical wires A and B, each of length 'l', carry the same current I. Wire A is bent into a circle of radius R and wire B is bent to form a square of side 'a'. If B_A and B_B are the values of magnetic field at the centres of the circle and square respectively, then the ratio $\frac{B_A}{B_B}$ is: **[2016]**

(a) $\frac{\pi^2}{16}$ (b) $\frac{\pi^2}{8\sqrt{2}}$
(c) $\frac{\pi^2}{8}$ (d) $\frac{\pi^2}{16\sqrt{2}}$

35. A galvanometer having a coil resistance of 100 Ω gives a full scale deflection, when a currect of 1 mA is passed through it. The value of the resistance, which can convert this galvanometer into ammeter giving a full scale deflection for a current of 10 A, is : **[2016]**

(a) 0.1 Ω (b) 3Ω
(c) 0.01Ω (d) 2Ω

36. When a current of 5 mA is passed through a galvanometer having a coil of resistance 15Ω, it shows full scale deflection. The value of the resistance to be put in series with the galvanometer to convert it into to voltmeter of range 0 – 10 V is **[2017]**

(a) $2.535 \times 10^3\ \Omega$ (b) $4.005 \times 10^3\ \Omega$
(c) $1.985 \times 10^3\ \Omega$ (d) $2.045 \times 10^3\ \Omega$

Answer Key

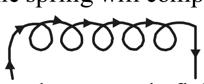
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(b)	(a)	(a)	(c)	(a)	(b)	(a)	(b)	(b)	(c)	(a)	(d)	(c)	(b)	(b)
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
(a)	(d)	(d)	(b)	(b)	(c)	(c)	(a)	(d)	(a)	(d)	(a)	(c)	(b)	(a)
31	32	33	34	35	36									
(b)	(a)	(c)	(b)	(c)	(c)									

SOLUTIONS

1. **(b)** When current is passed through a spring then current flows parallel in the adjacent turns.

NOTE When two wires are placed parallel to each other and current flows in the same direction, the wires attract each other.

Similarly, here the various turns attract each other and the spring will compress.



2. **(a)** We know that the magnetic field produced by a current carrying circular coil of radius r at its centre is $B = \frac{\mu_0}{4\pi}\frac{I}{r} \times 2\pi$

Here $B_A = \frac{\mu_0}{4\pi}\frac{I}{R} \times 2\pi$

and $B_B = \frac{\mu_0}{4\pi}\frac{2I}{2R} \times 2\pi \Rightarrow \frac{B_A}{B_B} = 1$

3. **(a)** When a charged particle enters perpendicular to a magnetic field, then it moves in a circular path of radius.

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

where q = Charge of the particle

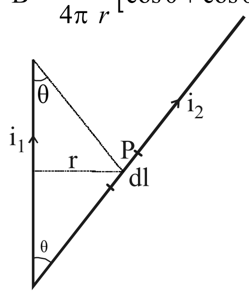
p = Momentum of the particle

B = Magnetic field

Here p, q and B are constant for electron and proton, therefore the radius will be same.

4. **(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

$dF = i_2\, dl\, B \sin 90°$

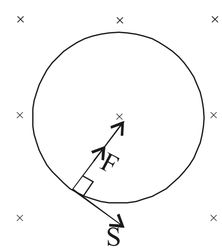
$\therefore\ dF = i_2\, dl \left[\frac{\mu_0}{2\pi}\frac{i_1\cos\theta}{r}\right] = \frac{\mu_0}{2\pi r} i_1 i_2\, dl \cos\theta$

5. **(a)** The time period of a charged particle (m, q) moving in a magnetic field (B) is $T = \frac{2\pi m}{qB}$

The time period does not depend on the speed of the particle.

6. **(b)** The workdone, $dW = Fds\cos\theta$

The angle between force and displacement is $90°$. Therefore work done is zero.



7. **(a)** The situation is shown in the figure.

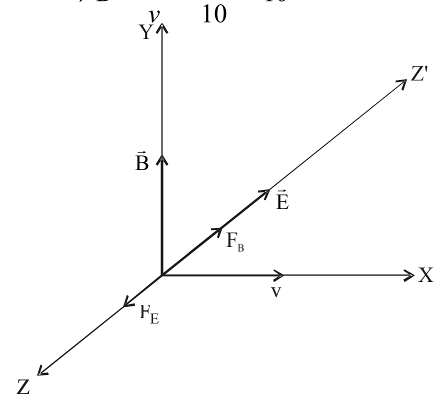
F_E = Force due to electric field

F_B = Force due to magnetic field

It is given that the charged particle remains moving along X-axis (i.e. undeviated). Therefore $F_B = F_E$

$\Rightarrow qvB = qE$

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



8. **(b)** Using Ampere's law at a distance r from axis, B is same from symmetry.

$\int \vec{B}.\vec{dl} = \mu_0 i$ i.e., $B \times 2\pi r = \mu_0 i$

Here i is zero, for $r < R$, whereas R is the radius

$\therefore\ B = 0$

9. **(b)** Magentic field at the centre of a circular coil of radius R carrying current i is

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

Given : $n \times (2\pi r') = 2\pi R$

$\Rightarrow nr' = R$ ...(1)

$B' = \dfrac{n.\mu_0 i}{2r'}$ ...(2)

From (1) and (2), $B' = \dfrac{n\mu_0 i.n}{2\pi R} = n^2 B$

10. **(c)** The magnetic field at a point on the axis of a circular loop at a distance x from centre is,

$$B = \frac{\mu_0 i\, a^2}{2(x^2 + a^2)^{3/2}}$$

$$B' = \frac{\mu_0 i}{2a}$$

$$\therefore\ B' = \frac{B.(x^2 + a^2)^{3/2}}{a^3}$$

Put $x = 4$ & $a = 3 \Rightarrow B' = \dfrac{54(5^3)}{3 \times 3 \times 3} = 250\,\mu T$

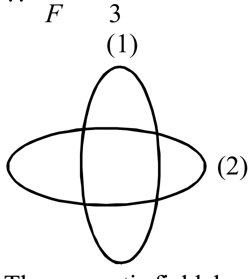
11. **(a)** Force between two long conductor carrying current,

$$F = \frac{\mu_0}{4\pi}\frac{2I_1 I_2}{d} \times \ell$$

$$F' = -\frac{\mu_0}{4\pi}\frac{2(2I_1)I_2}{3d}\ell$$

$$\therefore\ \frac{F'}{F} = \frac{-2}{3}$$

12. **(d)**



The magnetic field due to circular coil, B_1

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

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

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

$\Rightarrow B = 10^{-7} \times 5 \times 10^2$

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

13. **(c)** Equating magnetic force to centripetal force,

$$\frac{mv^2}{r} = qvB \sin 90^\circ$$

Time to complete one revolution,

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

14. **(b)** Due to electric field, it experiences force and accelerates i.e. its velocity decreases.

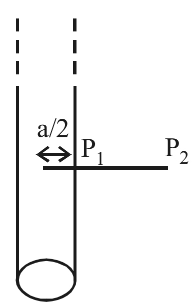
15. **(b)** The charged particle will move along the lines of electric field (and magnetic field). Magnetic field will exert no force. The force by electric field will be along the lines of uniform electric field. Hence the particle will move in a straight line.

16. **(a)** $\dfrac{B_2}{B_1} = \dfrac{\mu_0 n_2 i_2}{\mu_0 n_1 i_1}$

$$\Rightarrow \frac{B_2}{6.28 \times 10^{-2}} = \frac{100 \times \frac{i}{3}}{200 \times i}$$

$$\Rightarrow B_2 = \frac{6.28 \times 10^{-2}}{6} = 1.05 \times 10^{-2}\ \text{Wb/m}^2$$

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



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

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

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

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

18. **(d)** There is no current inside the pipe. Therefore $\oint \vec{B}.\vec{d\ell} = \mu_o I$

$I = 0 \therefore B = 0$

19. **(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,

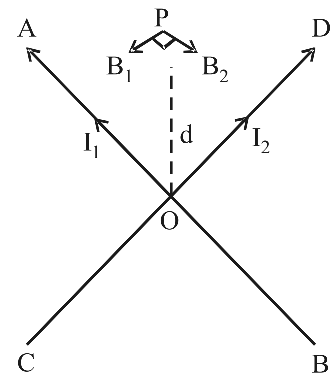
$$\left|\frac{\vec{E} \times \vec{B}}{B^2}\right| = \frac{E\ B \sin\theta}{B^2}$$

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

20. **(b)** When a charged particle enters a magnetic field at a direction perpendicular to the direction of motion, the path of the motion is circular. In circular motion the direction of velocity changes at every point (the magnitude remains constant).

Therefore, the tangential momentum will change at every point. But kinetic energy will remain constant as it is given by $\frac{1}{2}mv^2$ and v^2 is the square of the magnitude of velocity which does not change.

21. **(c)** Clearly, the magnetic fields at a point P, equidistant from AOB and COD will have directions perpendicular to each other, as they are placed normal to each other.



$\therefore$ Resultant field, $B = \sqrt{B_1^2 + B_2^2}$

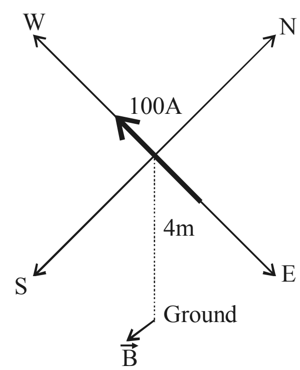
But $B_1 = \frac{\mu_0 I_1}{2\pi d}$ and $B_2 = \frac{\mu_0 I_2}{2\pi d}$

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

$$\text{or, } B = \frac{\mu_0}{2\pi d}\left(I_1^2 + I_2^2\right)^{1/2}$$

22. **(c)** The magnetic field is

$$B = \frac{\mu_0}{4\pi} \frac{2I}{r} = 10^{-7} \times \frac{2 \times 100}{4} = 5 \times 10^{-6}\ T$$



According to right hand palm rule, the magnetic field is directed towards south.

23. **(a)** The magnetic field at O due to current in DA is

$B_1 = \frac{\mu_o}{4\pi} \frac{I}{a} \times \frac{\pi}{6}$ (directed vertically upwards)

The magnetic field at O due to current in BC is

$B_2 = \frac{\mu_o}{4\pi}\frac{I}{b}\times\frac{\pi}{6}$ (directed vertically downwards)

The magnetic field due to current AB and CD at O is zero.

Therefore the net magnetic field is

$B = B_1 - B_2$ (directed vertically upwards)

$$= \frac{\mu_o}{4\pi}\frac{I}{a}\frac{\pi}{6} - \frac{\mu_o}{4\pi}\frac{I}{b}\times\frac{\pi}{6}$$

$$= \frac{\mu_o I}{24}\left(\frac{1}{a}-\frac{1}{b}\right) = \frac{\mu_o I}{24ab}(b-a)$$

24. (d) $\vec{F} = I(\vec{\ell}\times\vec{B})$

The force on AD and BC due to current I_1 is zero. This is because the directions of current element $I\,\vec{d\ell}$ and magnetic field $\vec{B}$ are parallel.

25. (a) The magnetic field varies inversely with the distance for a long conductor. That is, $B \propto \frac{1}{d}$

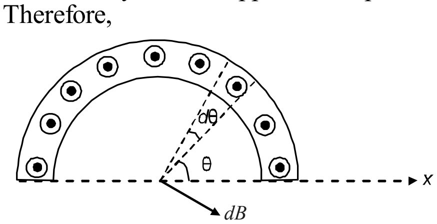
so, graph in option (a) is the correct one.

26. (d) Current in a small element, $dI = \frac{d\theta}{\pi}I$

Magnetic field due to the element

$$dB = \frac{\mu_0}{4\pi}\frac{2dI}{R}$$

The component $dB\cos\theta$, of the field is cancelled by another opposite component. Therefore,



$$B_{net} = \int dB\sin\theta = \frac{\mu_0 I}{2\pi^2 R}\int_0^{\pi}\sin\theta d\theta = \frac{\mu_0 I}{\pi^2 R}$$

27. (a) Lorentz force acting on the particle

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

$$= q\left[3\hat{i}+\hat{j}+2\hat{k}+\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 3 & 4 & 1\\ 1 & 1 & -3\end{vmatrix}\right]$$

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

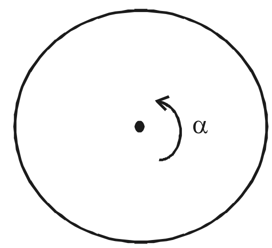
$$= q\left[3\hat{i}+\hat{j}+2\hat{k}-13\hat{i}+10\hat{j}-\hat{k}\right]$$

$$= q\left[-10\hat{i}+11\hat{j}+\hat{k}\right]$$

$F_y = 11q\hat{j}$

Thus, the y component of the force.

28. (c) $\frac{q}{2m} = \frac{\text{Magnetic dipole moment}}{\text{Angular momentum}}$



$\therefore$ Magnetic dipole moment (M)

$$M = \frac{q}{2m}.\left(\frac{mR^2}{2}\right).\omega = \frac{1}{4}\sigma.\pi R^4\omega.$$

29. (b) $\frac{mv^2}{r} = qvB \Rightarrow r = \frac{mv}{qB}$

$$\Rightarrow r_p = \frac{m_p v_p}{q_p B};$$

$$r_d = \frac{m_d v_d}{q_d B};\quad r_\alpha = \frac{m_\alpha v_\alpha}{q_\alpha B}$$

$m_\alpha = 4m_p,\ m_d = 2m_p$

$q_\alpha = 2q_p,\ q_d = q_p$

From the problem

$$E_p = E_d = E_\alpha = \frac{1}{2}m_p v_p^2$$

$$= \frac{1}{2}m_d v_d^2 = \frac{1}{2}m_\alpha v_\alpha^2$$

$$\Rightarrow v_p^2 = 2v_d^2 = 4mv_2^2$$

Thus we have, $r_\alpha = r_p < r_d$

30. (a) As we know, Magnetic flux, $\phi = B.A$

$$\frac{\mu_0(2)(20\times10^{-2})^2}{2[(0.2)^2+(0.15)^2]}\times\pi(0.3\times10^{-2})^2$$

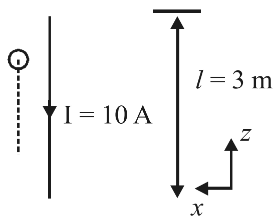
On solving

$= 9.216\times10^{-11} = 9.2\times10^{-11}$ weber

31. (b) Work done in moving the conductor is,

$$W=\int_0^2 F dx$$

$$=\int_0^2 3.0\times10^{-4}e^{-0.2x}\times10\times3dx$$



$$= 9\times10^{-3}\int_0^2 e^{-0.2x}dx$$

$$=\frac{9\times10^{-3}}{0.2}[-e^{-0.2\times2}+1]$$

$B=3.0\times10^{-4}e^{-0.2x}$ (By exponential function)

$$=\frac{9\times10^{-3}}{0.2}\times[1-e^{-0.4}]$$

$= 9\times10^{-3}\times(0.33) = 2.97\times10^{-3}$J

Power required to move the conductor is,

$$P=\frac{W}{t}$$

$$P=\frac{2.97\times10^{-3}}{(0.2)\times5\times10^{-3}}=2.97\text{ W}$$

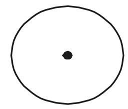
32. (a) For stable equilibrium $\vec{M}\parallel\vec{B}$

For unstable equilibrium $\vec{M}\parallel(-\vec{B})$

33. (c) $\vec{F}_1=\vec{F}_2=0$

because of action and reaction pair

34. (b) Case (a) :

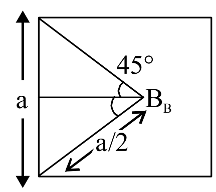


$$\beta_A=\frac{\mu_0}{4\pi}\frac{I}{R}\times2\pi=\frac{\mu_0}{4\pi}\frac{I}{\ell/2\pi}\times2\pi$$

$(2\pi R=\ell)$

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

Case (b) :



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

$$=4\times\frac{\mu_0}{4\pi}\times\frac{I}{\ell/8}\times\frac{2}{\sqrt{2}}=\frac{\mu_0}{4\pi}\frac{I}{\ell}\times\frac{64}{\sqrt{2}}=\frac{\mu_0 I}{4\pi\ell}32\sqrt{2}$$

[4a = l]

35. (c) Ig G = (I – Ig)s

$\therefore\ 10^{-3}\times100=(10-10^{-3})\times S$

$\therefore\ S\approx0.01\Omega$

36. (c) Given : Current through the galvanometer,

$i_g=5\times10^{-3}A$

Galvanometer resistance, $G=15\Omega$

Let resistance R to be put in series with the galvanometer to convert it into a voltmeter.

$V=i_g(R+G)$

$10=5\times10^{-3}(R+15)$

$\therefore\quad R=2000-15=1985=1.985\times10^3\,\Omega$