CHAPTER - 14
MOVING CHARGES AND MAGNETISM

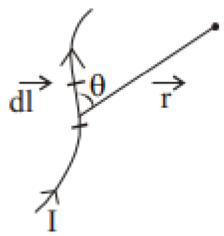
SYNOPSIS

Hans Christian Oersted observed that when a compass needle is placed near a straight wire carrying current, the compass needle aligns so that it is tangent to a circle drawn around the wire. His discovery provided the first link between electricity and magnetism.

Biot - Savart's Law

According to this law, the magnetic field due to a current element of length dl carrying a current I at a point at distance 'r' from it is given by

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,Sin\theta}{r^2}$$



In vector form $\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\left(\vec{dl}\times\hat{r}\right)}{r^2}$

Where, θ - the angle between the direction of the current and the line joining the current element to the point.

μ_0 - permeability of the free space $\left(\mu_0 = 4\pi\times10^{-7}TA^{-1}m\right)$. The direction of magnetic field is along $\vec{dl}\times\vec{r}$.

- When $\theta = 0$, dB = 0 i.e. the magnetic field along the axis of a current carrying conductor is zero
- When $\theta = 90^0$ dB = $\frac{\mu_0}{4\pi}\frac{Idl}{r^2}$ i.e. magnetic field is maximum in a plane perpendicular to the current element and passing through its axis.

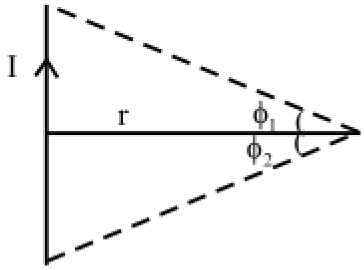
Comparison of Biot - Savart's law and Coulomb's low

- Magnetic field is produced by a vector source, the current element $I\vec{dl}$. But electrostatic field is produced by a scalar source, the electric charge.
- Both are long range, since both obey inverse square law. The principle of superposition applies to both fields.
- The electrostatic field is along the displacement vector joining the source and the field point. The magnetic field is perpendicular to the displacement vector
- There is an angle dependence in the Biot-Savart law which is not present in the coulomb's law

- Permeability μ_0 and permittivity ε_0 are related as $\mu_0\varepsilon_0 = \frac{1}{c^2}$

Magnetic field due to a current carrying conductor

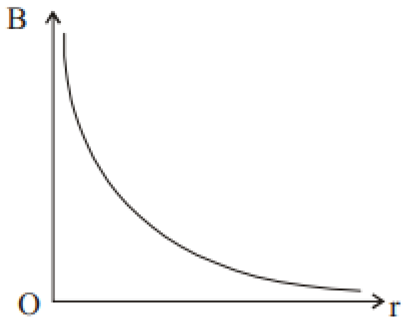
The magnetic field at a point at a perpendicular distance ‘r’ from a straight conductor carrying current I is given by.



$$B = \frac{\mu_0 I}{4\pi r}[\sin\phi_1 + \sin\phi_2]$$

In case of the straight conductor of infinite length $\left(\phi_1 = \phi_2 = \frac{\pi}{2}\right)$

$$B = \frac{\mu_0}{4\pi}\frac{2I}{r} = \frac{\mu_0 I}{2\pi r} \quad \therefore B \propto \frac{1}{r}$$



At one end of a straight infinite conductor $\left(\phi_1 = 0, \phi_2 = \frac{\pi}{2}\right)$ B = $\frac{\mu_0 I}{4\pi r}$

Right hand thumb rule : If the linear conductor is grasped in the palm of the right hand with thumb pointing along the direction of the current, then the curl fingers will point in the direction of lines of force.

- The conventional sign for a magnetic field coming out of the plane normal to it is a dot. ie. $\odot$
- The magnetic field perpendicular to the plane in the downward direction is denoted by $\otimes$
- The magnetic induction at the centre of a square loop of wire of side a carrying a current I is B = $\frac{2\sqrt{2}\mu_0 I}{\pi a}$

Magnetic field due to a current carrying circular coil

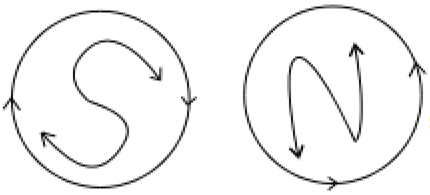
For a coil of radius a consisting of N turns and carrying current I,

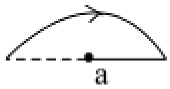
- the magnetic field at a point on the axis at a distance d from the centre is :

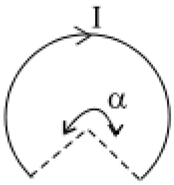
$$B=\frac{\mu_0}{4\pi}\frac{2\pi NIa^2}{(a^2+d^2)^{3/2}}=\frac{\mu_0 NIa^2}{2(a^2+d^2)^{3/2}};B=\frac{\mu_0}{4\pi}\frac{2M}{(a^2+d^2)^{3/2}}$$

Where M = NIA is the magnetic moment of the loop of wire which acts as a magnetic dipole. and $A=\pi a^2$ is the area of the coil.

- at the centre of the coil $B_0=\frac{\mu_0 NI}{2a}$
- at d = a, $B=\frac{B_0}{\sqrt{8}}$
- The current carrying loop behaves as a small magnetic dipole placed along the axis. One face of the loop acts as north pole while the other face acts as south pole.
- The face in which the current is flowing in clockwise direction behaves as south pole while the face through which the current is flowing in anticlockwise direction behaves as north pole.



- At the centre of a semi circle $B=\frac{\mu_0 I}{4a}$ 

- At the centre of the arc of a circle of angle α, $B=\frac{\mu_0 I\alpha}{4\pi a}(\alpha \text{ in radian})$ 

Right hand thumb rule : Curl the fingers of the right hand around the circular wire with the fingers pointing in the direction of the current, then the thumb gives the direction of the magnetic field.

- Ampere's circuital law states that the line integral of magnetic field around any closed path is equal to μ_0 times the current enclosed by the path.

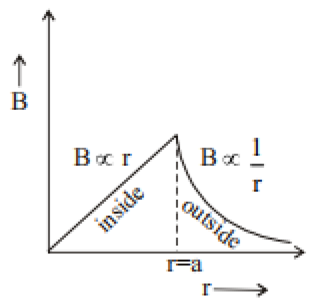
$$\oint \overline{B}.\overline{d\ell}=\mu_0 I_{enclosed}$$

This law holds for steady current which do not fluctuate with time.

Field due to a long straight wire of radius 'a' carrying steady current I.

- At a point outside the wire (r > a) $B=\frac{\mu_0 I}{2\pi r}$ or $B\propto\frac{I}{r}$

- On the surface of the wire (r = a) $B = \frac{\mu_0 I}{2\pi a}$
- At a point outside the wire (r < a) $B = \frac{\mu_0 I r}{2\pi a^2}$ or $B \propto r$



Field due to a solenoid

If a solenoid of n turns per unit length carries a current I, then field $B = \frac{\mu_0 nI}{2}[\cos\theta_1 - \cos\theta_2]$, where θ_1 and θ_2 are the angle made by the ends of the solenoid with its axis at the point.

- Magnetic field at a point well inside the solenoid, $B = \mu_0 nI$
- Field at one end of the solenoid, $B_{end} = \frac{\mu_0 nI}{2} = \frac{B}{2}$
- A solenoid acts as a magnetic dipole
- Direction of magnetic field can be found out by right hand thumb rule

Field due to a toroid

The magnetic field produced in a toroid will be same at all points and at any point it will act along the tangent to the ring. $B = \mu_0 nI$

For any point inside the empty space surrounded by the toroid and outside the toroid magnetic field is zero.

Toroid produces magnetic field without any magnetic poles

- Force on a charge 'q' in an electric field E is F = qE

The acceleration of the charge is $a = \frac{qE}{m}$

- Force on a charge 'q' in a uniform magnetic field B with velocity v is, $\vec{F} = q(\vec{v} \times \vec{B})$

or $F = qvB\sin\theta$

Then magnetic force is perpendicular to the velocity $\vec{v}$ and the work done by the magnetic force is zero. Therefore magnetic force cannot change the speed of charged particle even if the field is non-uniform.

Flemings left hand rule : If the forefinger, central finger and thumb are stretched at right angles to each other, then central finger represents the direction of current, fore finger represents field and thumb represents force.

Lorentz Force : The total force experienced by a charge moving inside the electric and magnetic field is called lorentz force. It is given by

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

Motion of a charge in a magnetic field

- The charge does not experience any force, if it is at rest or if it moves along the direction of magnetic field.
- If velocity and magnetic field are perpendicular, the force on the charge make it to move along a circular path. If r is the radius of the circular path, then

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

$$\therefore v = \frac{qBr}{m} \text{ or } r = \frac{mv}{qB} = \frac{P}{qB} = \frac{\sqrt{2mE}}{qB}$$

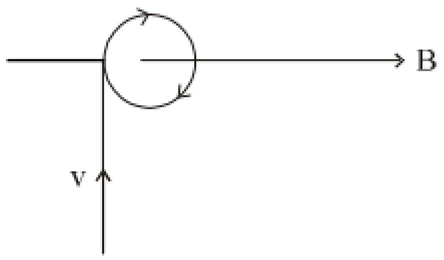
Where, P - momentum, E = kinetic energy

If the charge is accelerated through a potential difference V then E = qV

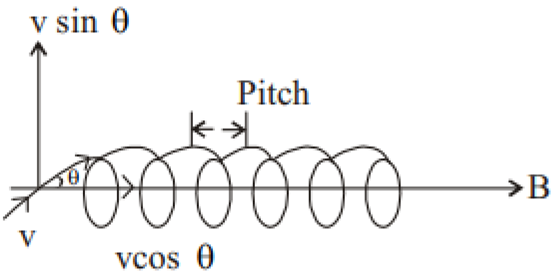
$$\therefore r = \frac{\sqrt{2mqV}}{qB}$$

Time period of revolution $T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$

Time period is independent of velocity and radius of the path



If $\vec{v}$ and $\vec{B}$ makes an angle 'θ', then due to the perpendicular component of velocity v sinθ the charge moves along a circular path of radius, r = $\frac{mv\sin\theta}{qB}$. The parallel component of velocity v cosθ makes the charge to moves along the direction of the magnetic field. Then the charge moves along a helical path. The pitch of the helix is, pitch = $\frac{2\pi mv\cos\theta}{qB}$

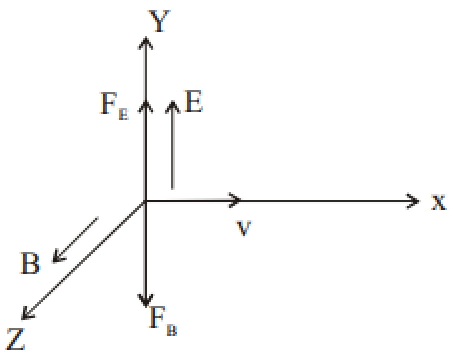


Velocity selector

If the electric field, magnetic field and velocity of the particle are mutually perpendicular as shown in figure.

$F_E = qE\hat{j},\ F_B = q\,\vec{v}\times\vec{B} = -qvB\hat{j}$

total force F = q(E - vB) $\hat{j}$



If the total force on the charge is zero then qE = qvB or v = $\frac{E}{B}$.

Therefore only particles with speed $\frac{E}{B}$ pass undeflected through the region of crossed fields. This method was used by J.J. Thomson to measure (e/m) of an electron.

Cyclotron: - It is a particle accelerator. It is based on the principle that the positive ions can be accelerated to high energies with a comparatively smaller alternating potential differences by making them to cross the electric field again and again, by making use of strong magnetic field. The frequency of the applied electric field is equal to the frequency of revolution of positive ion and this frequency is called cyclotron frequency. It is given by

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

The maximum energy attained by the particle is $E_{max} = \frac{q^2B^2R^2}{2m}$

Where R - radiuus of the dees

E_{max} = 2n (qV), where n - number of revolution completed by the ions before leaving the dees.

Frequency of revolution is independent of the energy of the charged particle

Limitations : Electrons cannot be accelerated to very high velocities - Cannot accelerate uncharged particles.

Magnetic force on a current carrying conductor

A conductor of length '*l*' carrying current I placed in a uniform magnetic field B experiences a force

$$\vec{F} = I\left(\vec{\ell}\times\vec{B}\right) \text{ or } F = I\ell B \sin\theta$$

Thus force is perpendicular to both the field and the conductor. Force is maximum, when the magnetic field acts at right angles to the length of the conductor and the force is zero, when the length of the conductor is parallel to the magnetic field.

Force between two infinitely long parallel current carrying conductors

Force per unit length of the conductor is

$F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$ where I_1 and I_2 are the currents through the conductors and r is the separation between conductors.

- The force is attractive, if currents are in the same direction and repulsive if currents are in opposite directions.
- When a coil of area A having N turns and carrying current I, is suspended in a magnetic field of strength B then the torque acts on the coil is

  τ = NIAB sin θ = MB sin θ

  Where M = NIA - magnetic moment of the coil.

  θ - angle between the direction of $\overline{B}$ and normal to the plane of the coil.

  In vector form $\vec{\tau} = \overline{M} \times \overline{B}$

  If $\overline{B}$ makes an angle α with the plane of the coil $\tau = NIAB\cos\alpha = MB\cos\alpha$

Moving coil galvanometer : It is a device used to measure small electric currents. A current carrying loop or coil experience a torque in a uniform magnetic field. This is the principle of moving coil galvanometer.

The radial field is perpendicular to the plane of the coil. Thus torque acts on the coil is τ = NIAB

If ϕ is the angle of rotation of the coil, the restoring torque $\tau = k\phi$ where k - tortional constant of the spring. In equilibrium $k\phi$ = NIAB

or $\phi = \frac{NAB}{k}I$ or $I = \frac{k}{NAB}\phi = G\phi$

Where $G = \frac{k}{NAB} =$ galvanometer constant

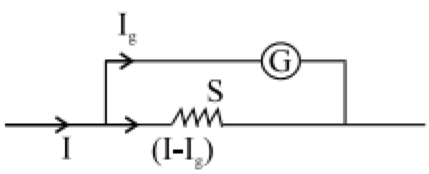
Current sensitivity : $\frac{\phi}{I} = \frac{NAB}{k}(\text{rad A}^{-1})$

Voltage sensitivity $\frac{\phi}{V} = \frac{NAB}{kR}(\text{rad V}^{-1})$, Where R - Resistance of the coil.

Ammeter :

A Galvanometer of resistance G can be converted into an ammeter of range I, by connecting a small suitable resistance S called shunt parallel to the galvanometer, which is given by

$S = \frac{I_gG}{I - I_g}$



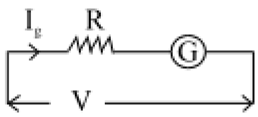
Since $I_g G = (I - I_g)S$

Where, I_g - current through galvanometer

Resistance of the ammeter is $R_A = \frac{GS}{G+S}$

Ammeter is a low resistance device and always connected in series to the circuit.

Voltmeter : A Galvanometer can be converted into a voltmeter read up to V by connecting a suitable large resistance 'R' in series to the galvanometer and $R = \frac{V}{I_g} - G$



Resistance of voltmeter $R_V = R + G$

It is a high resistance device and always connected in parallel to the circuit.

Magnetic dipole moment of a revolving electron

Let T be the time period of revolution, r be the orbital radius of the electron and v the orbital speed, then

$T = \frac{2\pi r}{v}$ and current $I = \frac{e}{T} = \frac{ev}{2\pi r}$

The orbital magnetic moment $\mu_\ell = IA = I\pi r^2 = \frac{evr}{2}$

or $\mu_\ell = IA = \frac{e}{2m}\, mvr = \frac{e}{2m} L$, L = mvr, angular momentum of the electron

$\frac{\mu_\ell}{L} = \frac{e}{2m}$ is called gyromagnetic ratio

According to Bobr hypothesis $L = \frac{nh}{2\pi},\ n = 1, 2, 3 \ldots\ldots\ldots$

$\therefore \mu_L = \frac{enh}{4\pi m}$

Its minimum value is $(\mu_\ell)_{min} = \frac{eh}{4\pi m} = 9.27\times10^{-24}\ Am^2$ and is called the Bohr magneton.

Electron has an intrinsic magnetic moment due to the spin motion of the electron and is known as spin magnetic moment $\mu_S = \frac{e}{2m}S$, Where S - spin angular momentum

PART I - (JEEMAIN)

SECTION - I - Straight objective type questions

1. A charged particle of charge 5mc and mass 5gm is moving with a constant speed 5 m/s. In a uniform magnetic field on a curve $x^2 + y^2 = 25$. Where x and y are in meter. The value of magnetic field reuired will be

   1) 0.5 Tesla
   2) 1 T along z-axis
   3) 5 kT along the x-axis
   4) 1 KJ along any line in the x-y plane

2. Two long parallel wires carry currents i_1 and i_2 such that $i_1 > i_2$. When the currents are in the same direction the magnetic field at a point midway between the wires is $6\times10^{-6}T$. If the direction of i_2 is reversed, the field becomes $3\times10^{-5}T$. The ratio i_1 / i_2 is

   1) 1/2 2) 2 3) 2/3 4) 3/2

3. A metallic wire bent to form a hexagon of side 'a' carries a current I. The magnitude of the magnetic field at the centre of the hexagon is:

   1) $\frac{\mu_0}{4\pi}\frac{\sqrt{3}I}{4a}$ 2) $\frac{\mu_0}{4\pi}\frac{4\sqrt{3}I}{a}$ 3) $\frac{\mu_0}{4\pi}\frac{\sqrt{3}I}{2a}$ 4) $\frac{\mu_0}{4\pi}\frac{2\sqrt{3}I}{a}$

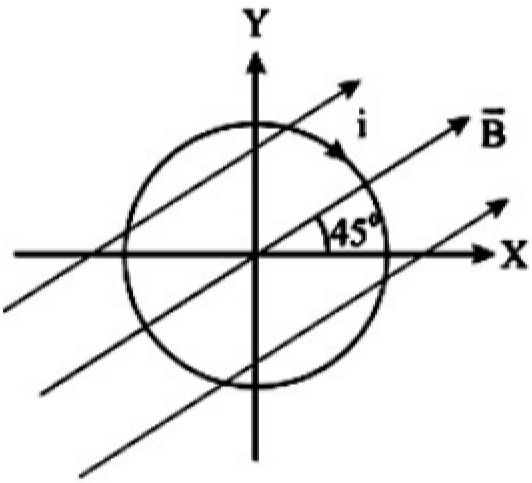
4. A long, straight wire of radius a carries a current distributed uniformly over its cross-section. The ratio of the magnetic fields due to the wire at distance $\frac{a}{2}$ and 2a, respectively from the axis of the wire is

   1) $\frac{2}{3}$ 2) 1 3) $\frac{1}{2}$ 4) 2

5. A circular coil of 100 turns and effective diameter 20 cm carries a current of 0.5A. It is to be turned in a magnetic field of B = 2.0 T from a position in which the normal to the plane of the coil makes an angle θ equals to zero to 180^0. The work required in this process is

   1) πJ 2) $2\pi J$ 3) $4\pi J$ 4) $8\pi J$

6. A circular loop of radius 20cm is placed in a uniform magnetic field $\vec{B} = 2T$ in X-Y plane, the loop carries a current 1A in the direction shown in figure. The magnitude of torque acting on the loop is nearly



1) 0.25 N-m 2) $\frac{0.25}{\sqrt{2}} N - m$ 3) 0.75 N-m 4) $\frac{0.75}{\sqrt{2}} N - m$

7. A thin wire of length L is made of an insulating material. The wire is bent to form a circular loop, and a positive charge q is distributed uniformly around the circumference of the loop. The loop is then set into rotation with angular speed ω around an axis through its centre. If the loop is in the region where there is a uniform magnetic field $\vec{B}$ directed parallel to the plane of the loop, calculate the magnitude of the magnetic torque on the loop.

1) $\frac{q\omega L^2 B}{8\pi^2}$ 2) $\frac{q\omega L^2 B}{4\pi^2}$ 3) $\frac{q\omega L^2 B}{2\pi^2}$ 4) $\frac{q\omega L^2 B}{\pi^2}$

8. A galvanometer of resistance 5Ω is connected in series with a resistance of 0.2Ω to a battery of negligible internal resistance. The deflection is noted. If the 0.2Ω resistance is replaced by 2Ω resistance, the value of shunt resistance to be connected to the galvanometer to maintain the same deflection is

1) 1Ω 2) 8.9Ω 3) 0.01Ω 4) 10Ω

9. A galvanometer 30 divisions and a sensitivity of $16\mu A$ per division. It can be converted into a voltmeter to read 3V by connecting a resistance (approximately)

1) $6k\Omega$ in series 2) $66k\Omega$ in parallel 3) $66k\Omega$ in series 4) $6k\Omega$ in parallel

10. Two similar bar magnets P and Q, each of magnetic moment M, are taken. If P is cut along its axial line and Q is cut along its equatorial line, all the four pieces obtained have

1) equal pole strength
2) magnetic moment $\frac{M}{4}$
3) magnetic moment $\frac{M}{2}$
4) magnetic moment m

11. The effective length of a magnet os 31.4 cm and its pole strength is 0.5Am. The magnetic moment, if it is bent in the form of a semi circle will be

1) 0.1 Am^2
2) 0.01 Am^2
3) 0.2 Am^2
4) 1.2 Am^2

12. A bar magnet having a magnetic moment of $2\times10^4\,Am^2$ is free to rotate in a horizontal plane. A horizontal magnetic filed is $B=6\times10^{-4}T$ exists in the space. The workdone in taking the magnet slowly from a direction parallel to the field to a direction 60^0 from the field is:

1) 2J
2) 0.6J
3) 12 J
4) 6 J

13. A short bar magnet of magnetic moment 0.32 J/T is placed in uniform field of 0.15T. If the magnetic is free to rotate in the plane of the field. The P.E. of the magnet in stable equilibrium position.

1) $-4.8\times10^{-2}J$
2) $-2.4\times10^{-2}J$
3) $4.8\times10^{-2}J$
4) $2.4\times10^{-2}J$

14. A ferromagnetic rod is subjected to cycles of magnetisation at the rate of 50Hz. The density of the rod is $7\times20^3 kg/m^3$ and specific heat is $0.5\times10^3 cal/kg/^0C$. The area enclosed by the Hysteresis loop corresponds to energy 10^{-2}J. The rise in temperature of the specimen in one minute is given by:

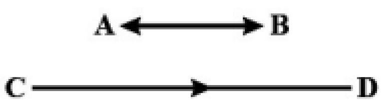
1) $10^{-6}\,^0C$
2) $2\times10^{-6}k$
3) $2\times10^{-6}\ ^0C$
4) Both 2 and 3

SECTION - II

Numerical Type Questions

15. A charged particle moves in a uniform magnetic field perpendicular to it, with a radius of curvature 4cm. On passing through a metallic sheet it loses half of its kinetic energy. Then, the radius of curvature of the particle is $2\sqrt{x}$ find x value.

16. A long horizontal wire AB, which is free to move in a vertical plane and carries a steady current of 20A, is in equilibrium at a heigh of 0.01m over another parallel long wire CD which is fixed in a horizontal plane and carries a steady current of 30A, as shown. The time period of small oscillations of the conductor AB, when it is slightly depressed and released, is $\frac{x}{10}$, then x is:



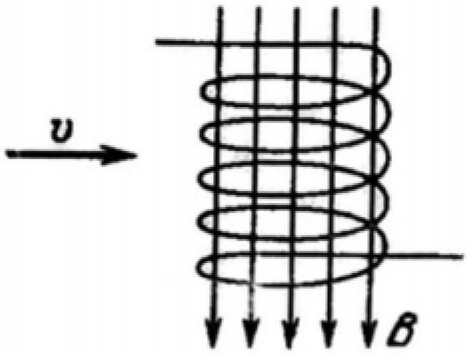
17. The susceptibility of magnesium at 27⁰C is 1.2×10^{-5}. The temperature (in K) at which susceptibility will be 1.8×10^{-5} is:

18. Two identical bar magnets with length 10cm and weight 50gm are arranged vertically and with their like poles facing. The upper magnet hangs in the air above the lower one so that the distance between nearest poles of magnet is 3mm. Moment of each magnet in Am^2 is:

PART - II (JEE ADVANCED LEVEL)

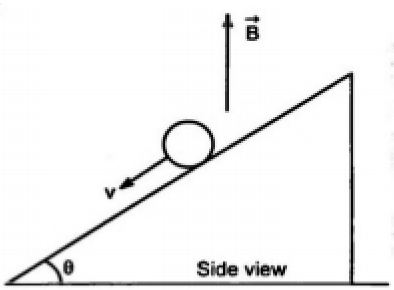
SECTION - III (One correct answer)

19. A direct current flowing through the winding of long cylindrical solenoid of radius R produces in it a uniform magnetic field of induction B. An electron flies into the solenoid along the radius between its turns (at right angles to the solenoid axis) at velocity v. After a certain time t, the electron deflected by the magnetic field leaves the solenoid. Find t



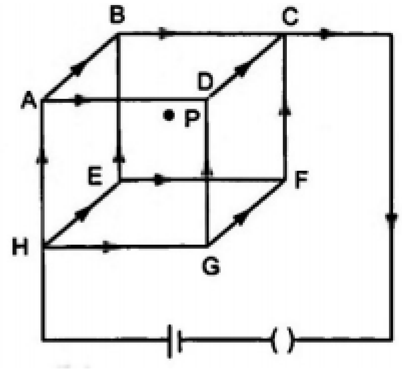
A) $\frac{2m}{eB}\tan^{-1}\left(\frac{eBR}{mv}\right)$ B) $\frac{m}{eB}\tan^{-1}\frac{eBR}{mv}$ C) $\frac{2m}{eB}\sin^{-1}\frac{eBR}{mv}$ D) $\frac{2m}{eB}\cos^{-1}\frac{eBR}{mv}$

20. A conducting rod of length ℓ and mass m is moving down a smooth inclined plane of inclination θ with constant velocity v. A current I is flowing in the conductor in a direction perpendicular to paper inward. A vertically upward magnetic field $\vec{B}$ exists in space. Then, magnitude of magnetic field $\vec{B}$ is :



A) $\frac{mg}{I\ell}\sin\theta$ B) $\frac{mg}{I\ell}\tan\theta$ C) $\frac{mg\cos\theta}{I\ell}$ D) $\frac{mg}{I\ell\sin\theta}$

21. A steady current is set up in a cubic network composed of wires of equal resistance and length d as shown in figure. What is the magnetic field at the centre P due to the cubic network?



A) $\frac{\mu_0}{4\pi}\frac{2I}{d}$ B) $\frac{\mu_0}{4\pi}\frac{3I}{\sqrt{2}d}$ C) zero   D) $\frac{\mu_0}{4\pi}\frac{\theta\pi I}{d}$

SECTION - IV (More than one correct answer)

22. A proton is fired from origin with velocity $\vec{v} = v_0\hat{j} + v_0\hat{k}$ in a uniform magnetic field $\vec{B} = B_0\hat{j}$. In the subsequent motion of the proton

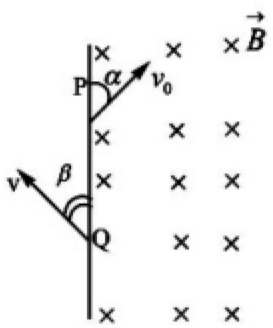
A) its z-coordinate can never be negative

B) its x-coordinate can never be positive

C) its x- and z- coordinates cannot be zero

D) its y-coordinate will be proportional to its time of flight

23. A particle of charge -q and mass m enters a uniform magnetic field $\vec{B}$ (perpendicular to paper inward) at P with a velocity v_0 at an angle α and leaves the field at Q with velocity v at angle β as shown in figure.



A) $\alpha = \beta$ B) $\upsilon = \upsilon_0$

C) $PQ = \frac{2m\upsilon_0 \sin\alpha}{Bq}$ D) The particle remains in field for time $t = \frac{2m}{2B}(\pi - \alpha)$

24. A moving coil galvanometer consists of N turns and area A suspended by a thin phosphor bronze strip in radial magnetic field B. The moment of inertia of the coil about the axis of rotationis I and C is the torsional constant of the phosphor bronze strip. When a current i is passed through the coil, it deflects through an angle θ

A) current sensitivity increased if N, A and B are increased and C is decreased

B) current sensitivity increased if N,A, B and C are increased

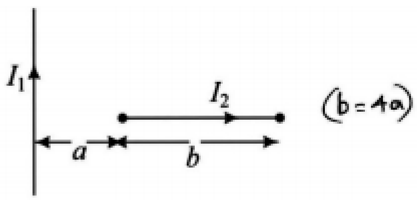
C) when a change Q is passed almost instantly through the coil, the angular speed acquired by the coil is $\frac{NABQ}{I}$

D) The maximum angular deflection of the coil is $\omega\sqrt{\frac{I}{C}}$

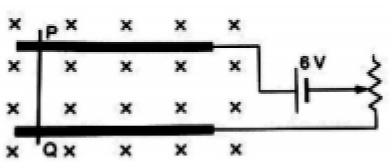
SECTION - V (Numerical Type - Upto two decimal place)

25. The magnetic field due to a current carrying circular loop of radius 3cm at a point on the axis at a distance of 4cm from the centre is $54\mu T$. If the value at the centre of the loop is ....μT

26. A short wire of length b, carrying current I_2 is placed perpendicular to another long straight wire carrying current I_1 at distance a from long wire, as shown in diagram. The total force on short wire due to long wire is $\frac{\mu_0 I_1 I_2}{2\pi}\ell n(x)$. Find x



27. A metal PQ of mass 10g lies at rest on two horizontal metal rails separated by 5cm. A vertically downward magnetic field of magnitude 0.800T exists in the space. The resistance of the circuit is slowly decreased and it is found that when the resistance goes below 20Ω, the wire PQ starts sliding on the rolls. The coefficient of friction is $\frac{x}{100}$, find x (g = 10 m)



SECTION - VI (Matrix Matching)

28. A charged particle passes through a region that could have electric field only or magnetic field only or both electric and mnagnetic fields or none of the fields. Match column I with column II

Column A	Column B
A) Kinetic energy of the particle remains constant	p) Under special conditins, this is possible when both electric and magnetic fields are present
B) Acceleration of the partilce is zero	q) The region has electric field only
C) Kinetic energy of the partilce changes and it also suffers is deflection	r) The region has magnetic field only
D) Kinetic energy of the particle changes but it suffers no deflection	s) The region contains no field

A) A-P,R,S; B-P,R,S; C-P,Q; D-P,Q

B) A-P,R,S; B-P,R,S; C-P, D-Q

C) A-P,R,S; B-P,R; C-P,Q; D-P,Q

D) A-P,R,S; B-P,R,S; C-P,Q; D-P