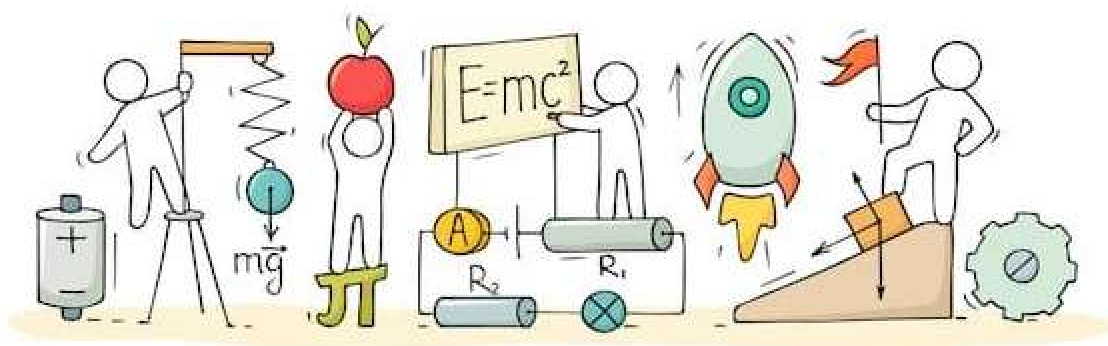
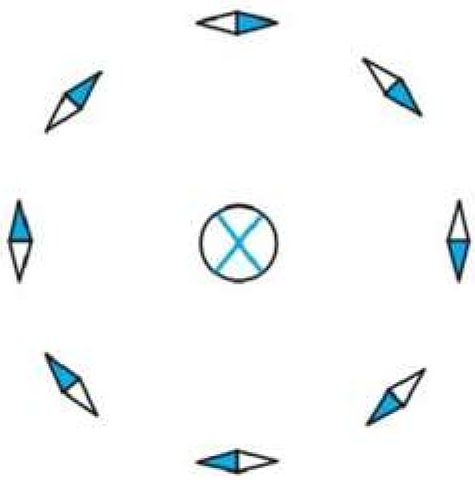
PHYSICS



MOVING CHARGES AND MAGNETISM

Magnetic Field:



We have discussed that a stationary charge creates electric field in its surrounding space, similarly a moving charge creates a field in its surrounding space which exerts a force on a moving charge this field is known as magnetic field which is a vector quantity and represented by B.

Motion of charged particle in a Magnetic Field:

When a charged particle q is thrown in magnetic field $\vec{B}$ with a velocity v then the force acting on the particle is given by F = qvB.sinθ, where θ is the angle between the velocity and the magnetic field. As the magnetic force on a charged particle is perpendicular to the velocity, it does not do any work on the particle. Hence, the kinetic energy or the speed of the particle doesn't change due to the magnetic force.

Case I: θ = 0° or 180°

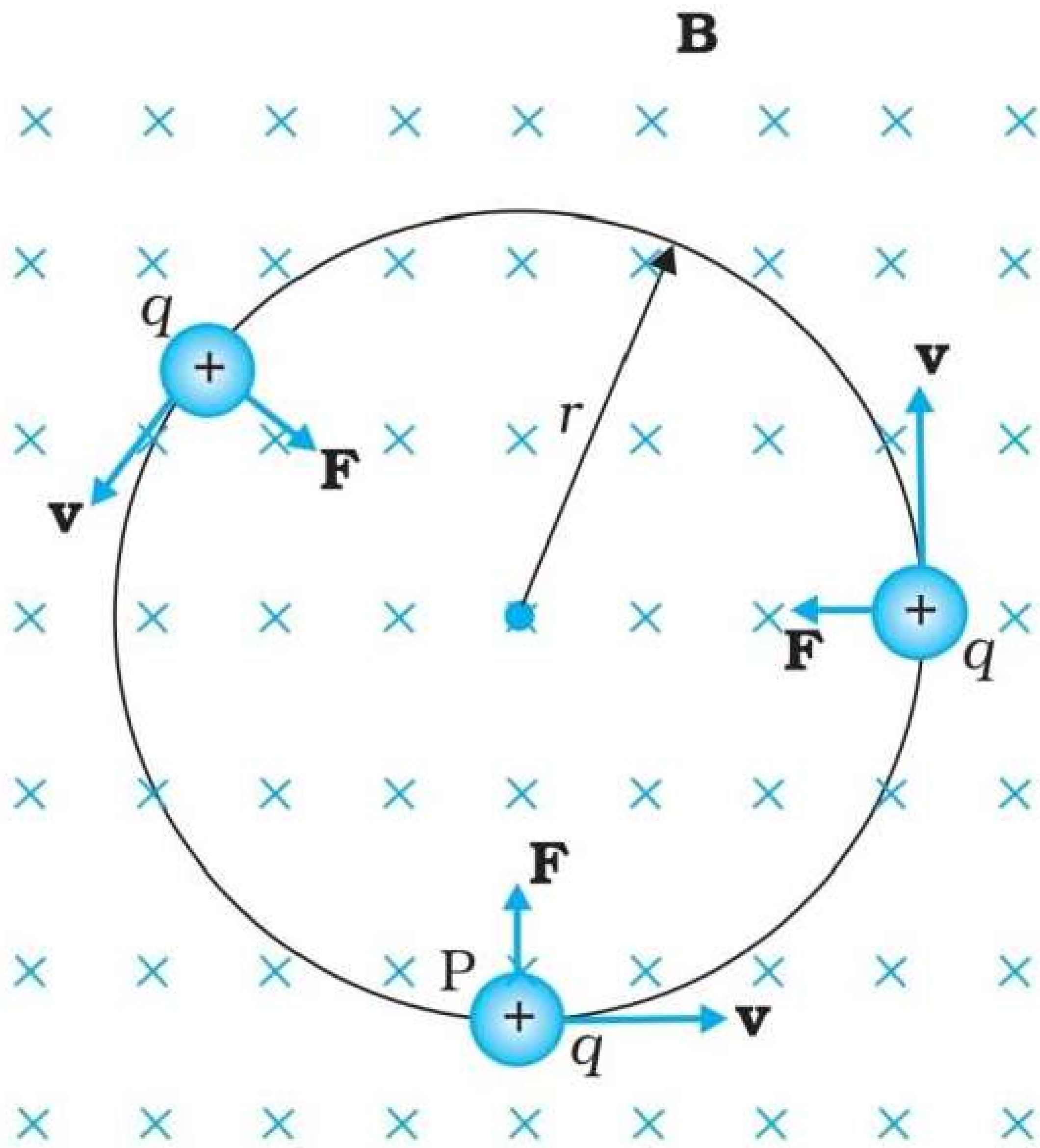
Path followed: Straight line

If a charged particle is thrown parallel or antiparallel to magnetic field it does not experience any magnetic force as the angle θ between v and B will be zero or 180°. So, it will continue to move in a straight line with constant velocity.

Case II: θ = 90°

Path followed: Circular

When a charged particle is projected perpendicular to a uniform magnetic field, its path is a circle. The magnetic Lorentz force acts as the centripetal force causing the charged particle to move in a circular path of radius R with constant speed.



$$F = qvB = \frac{mv^2}{R}$$

$$\Rightarrow R = \frac{mv}{qB}$$

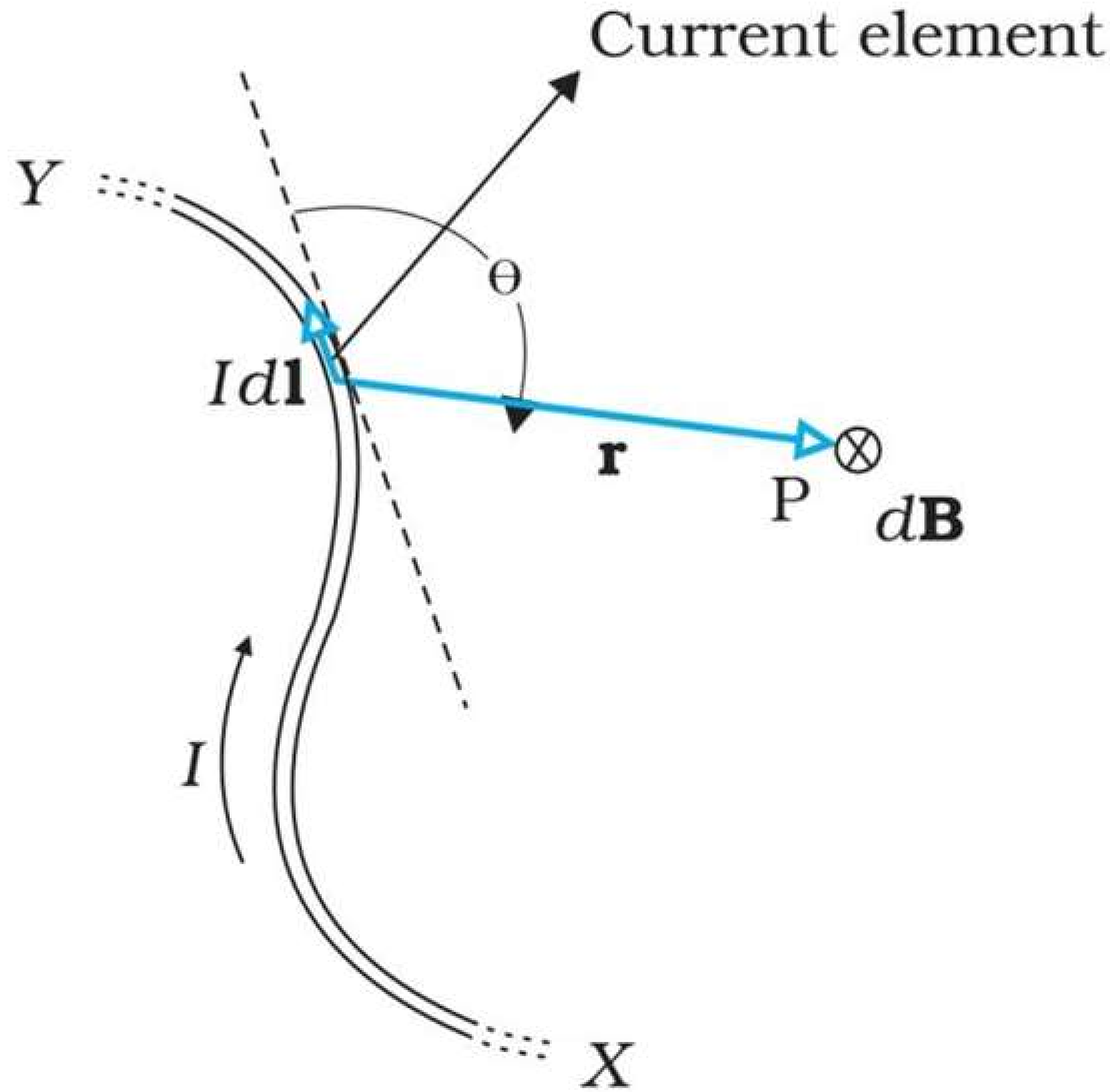
Angular velocity $(\omega) = \frac{v}{R} = \frac{qB}{m}$

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

$$\text{Frequency of revolution} = \frac{1}{T} = \frac{qB}{q2\pi m}$$

Biot-Savart Law:

Consider an infinitesimal element dl of the conductor. The magnetic field dB due to this element is to be determined at a point P which is at a distance r from it. Let θ be the angle between dl and the position vector r. The direction of dl is same as the direction of current.



According to Biot-Savart law, the magnitude of the magnetic field dB is proportional to the current I, the element length dl is inversely proportional to the square of the distance r. Its direction is perpendicular to the plane containing dl and r. Thus in vector notation,

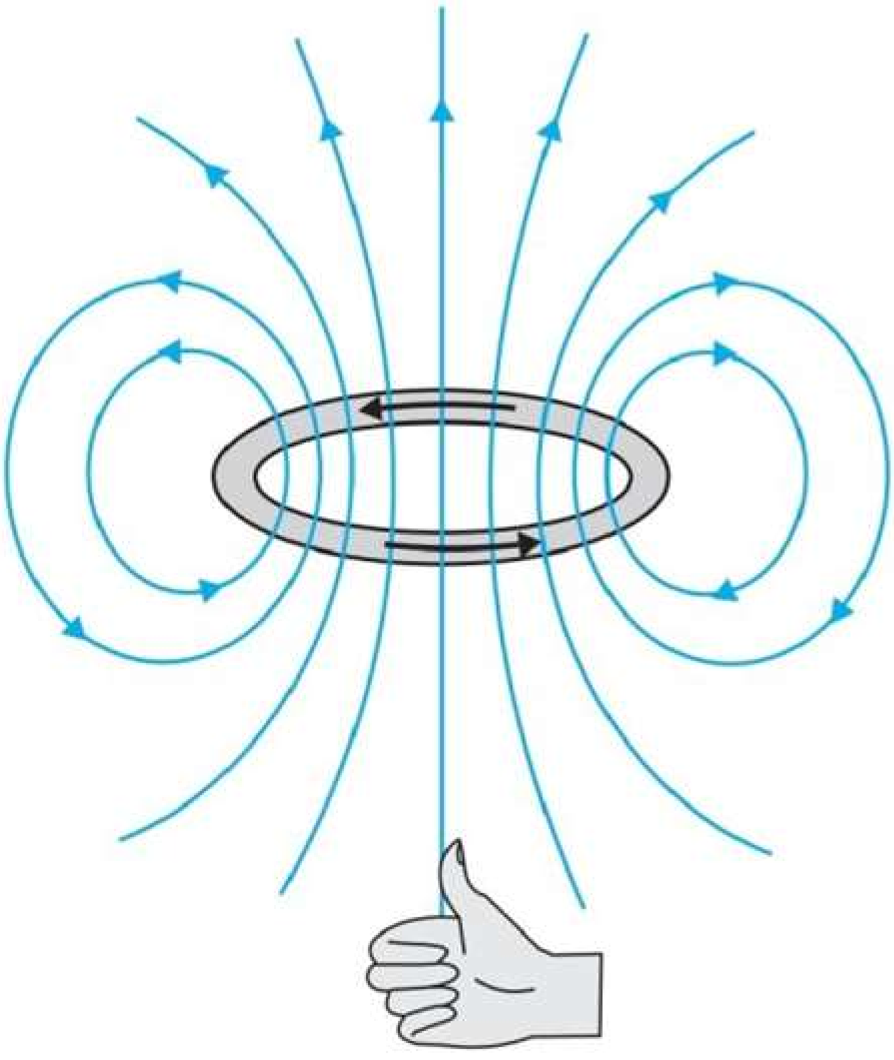
$$d\vec{B} \propto \frac{Id\vec{l}\sin\theta}{r^2}$$

$$d\vec{B} = \frac{u_0}{4\pi}\frac{Id\vec{l}\sin\theta}{r^2}$$

Where, $\frac{u_0}{4\pi}$ is a constant of proportionality. The above expression holds when the medium is vacuum. The proportionality constant in SI unit has value, $\frac{u_0}{4\pi} = 10^{-7} \mathrm{T} - \frac{\mathrm{m}}{\mathrm{A}}$. We call u_0 the permeability of free space.

Magnetic Field due to a Loop of Current:

Magnetic field lines due to a loop of wire are shown in the figure. The direction of magnetic field on the axis of current loop can be determined by right hand thumb rule. If the fingers of right hand are curled in the direction of current, the stretched thumb is in the direction of magnetic field.



Consider a current loop placed in plane carrying current i in anticlockwise sense. Due to a small current element i.dl shown in the figure, the magnetic field is given by

$$dB = \frac{\mu_0}{4\pi} \frac{idl. \sin 90}{r^2}$$

Strength of Magnetic Field at the center of loop,

$$\int dB = \int \frac{\mu_0}{4\pi} \frac{idl.\sin 90}{r^2}$$

$$B = \frac{\mu_0}{4\pi} \frac{i.\sin 90}{r^2} \int dl$$

$$B = \frac{\mu_0}{4\pi} \frac{i}{r^2} 2\pi r$$

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

If the loop has n round of wire,

$$B = \frac{\mu_0 ni}{2r}$$

Relation between μ_0 and ε_0

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \ldots (1)$$

$$\frac{\mu_0}{4\pi} = 10^{-7} \ldots (2)$$

Dividing by eq. (2) to eq. (1)

$$\frac{\frac{\mu_0}{4\pi}}{\frac{1}{4\pi\varepsilon_0}} = \frac{10^{-7}}{9 \times 10^9}$$

$$\frac{\mu_0}{4\pi} \times \frac{4\pi\varepsilon_0}{1} = \frac{1}{9 \times 10^{9+7}}$$

$$\mu_0\varepsilon_0 = \frac{1}{(3 \times 10^8)^2}$$

$$\mu_0\varepsilon_0 = \frac{1}{c^2}$$

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

Ampere's Circuital Law:

Ampere's circuital law states that line integral of steady magnetic field over a closed loop is equal to μ0 times the total current (Ie) passing through the surface bounded by the loop i.e.,

$\int B.dl = \mu_0 I_e$ where I_e is enclosed current

Magnetic Force:

It is observed that when charge is at rest it experiences almost no force. However, if the charge q is given a velocity v in the direction of current, it is deflected towards the wire. Hence, we conclude that magnetic field exerts a force on a moving charge particle. The combination of electric and magnetic force on a point charge is known as Lorentz Force.

Consider a point charge q moving with velocity v located at position vector r at a given time t. If an electric field E and a magnetic field B exist at that point, then force on the electric charge q is given by

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

This force was first given by H. A. Lorentz; hence it is called Lorentz force.

Fleming's left-hand rule:

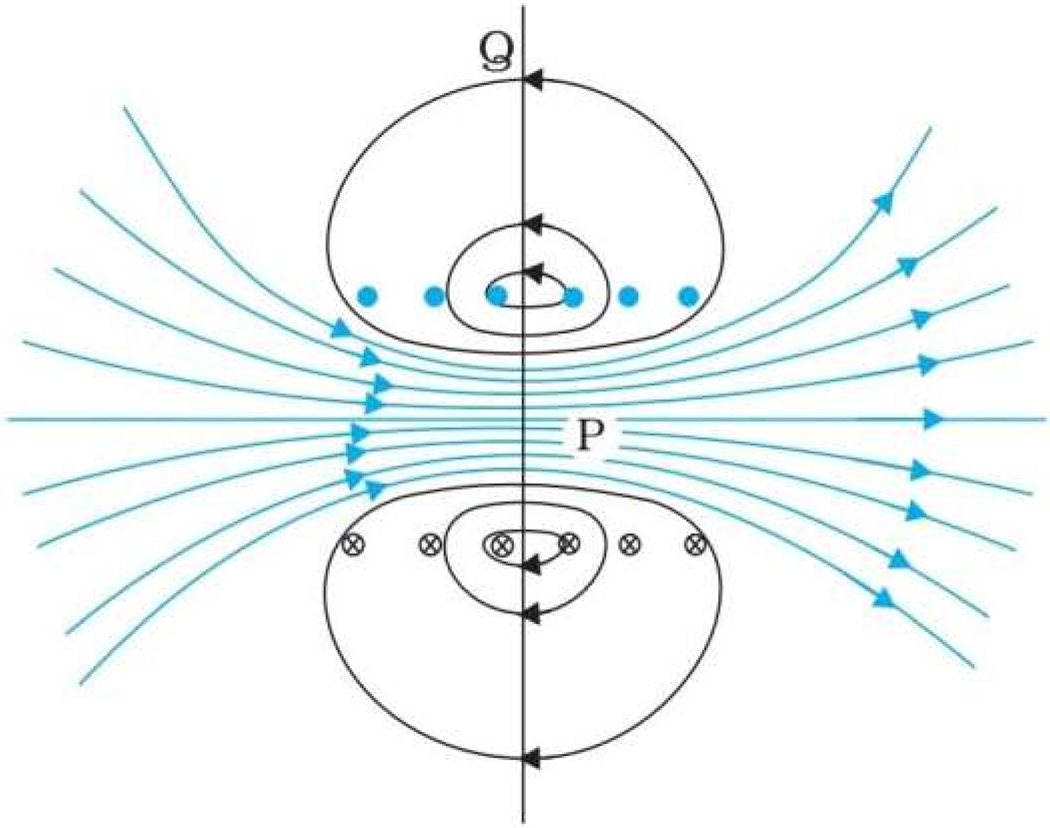
If we stretch the thumb and first two fingers of our left hand in mutually perpendicular directions such that forefinger points along B and middle finger points along v, then the thumb points along F.

Cyclone Frequency:

A charge c completes a circular orbit on a plane normal to B which is the uniform magnetic field. The uniform circular motion frequency is known as cyclone frequency. This frequency is unaffected by the radius and speed of the particle. It can be determined with the help of a machine known as cyclotron which is used to accelerate the particles which are charged.

Current Loop as a Magnetic Dipole:

A current carrying loop behaves like a magnetic dipole. It has two poles viz north and south like that of a bar magnet. Following figures show magnetic field lines due to a bar magnet and a current carrying loop.



The magnetic dipole moment vector for a current loop is given by

$$\vec{M} = Ni\vec{A},$$

where, N = number of loops or turns

i = current through each turn

A = area of each turn

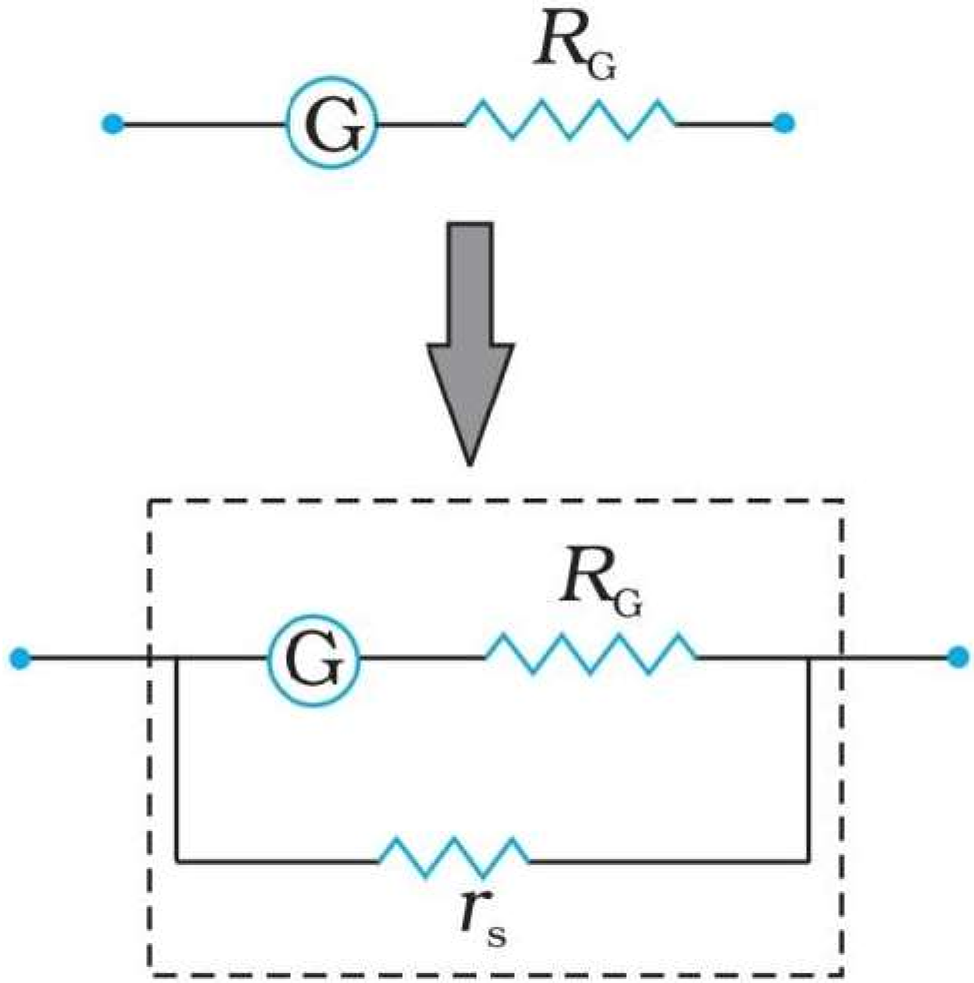
Current sensitivity: It is defined as the deflection produced per unit current passed through the galvanometer.

Voltage sensitivity: It is defined as the deflection produced per unit voltage applied across the galvanometer.

Galvanometer as Ammeter:

The galvanometer cannot as such be used as an ammeter to measure the value of the current in a given circuit. This is for two reasons.

- Galvanometer is a very sensitive device. It gives a full-scale deflection for a current of the order of µA.
- For measuring currents, the galvanometer has to be connected in series, and as it has a large resistance, this will change the value of the current in the circuit.



Ammeter

To overcome these difficulties, one attaches a small resistance r_s called shunt resistance, in parallel with the galvanometer coil, so that most of the current passes through the shunt. The resistance of this arrangement is.

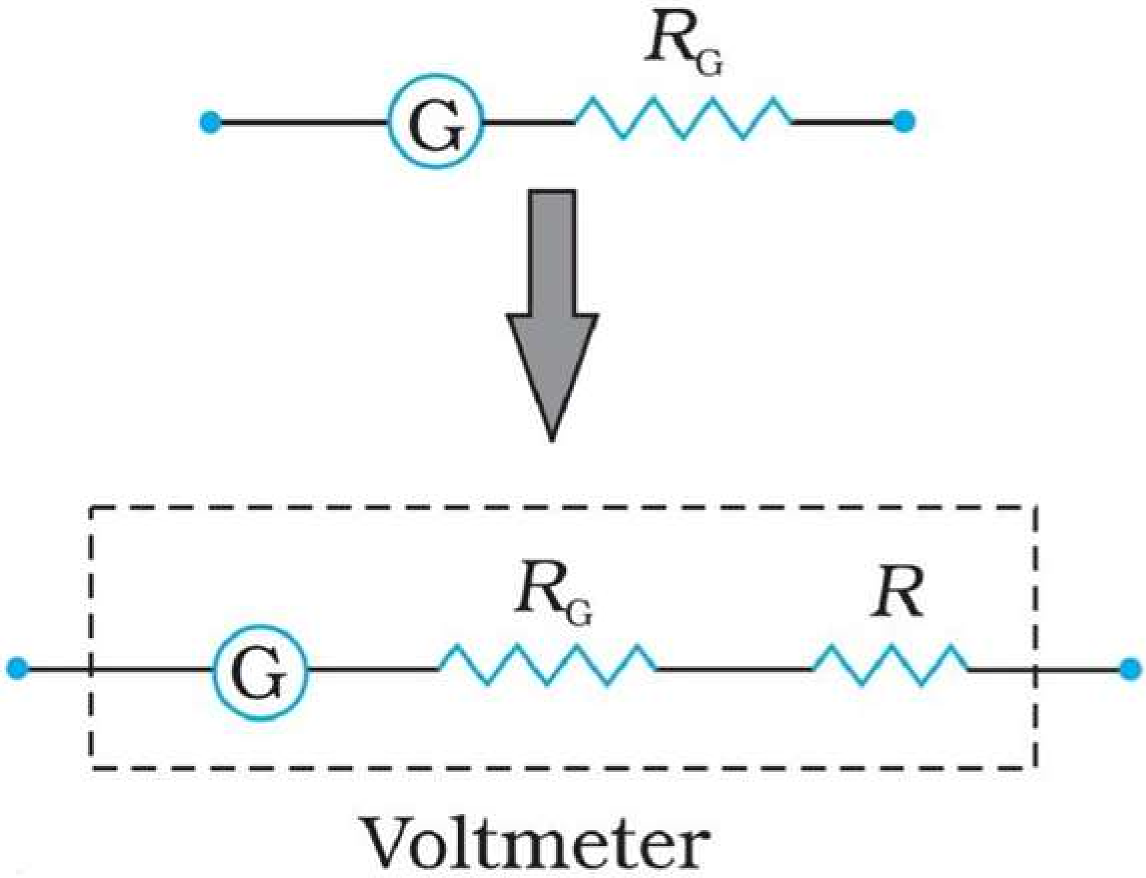
$$\frac{R_G r_s}{R_G + r_s} = r_s$$

We define the current sensitivity of the galvanometer as the deflection per unit current. Thus

$$\frac{\emptyset}{i} = \frac{NAB}{K}$$

Galvanometer as Voltmeter:

To use galvanometer to find the potential difference between a section of a circuit, it must be connected in parallel to that section of the circuit. Further, it must draw very small current, otherwise the voltage measurement will disturb the original setup by an amount which is very large. Usually, we like to keep the disturbance due to the measuring device below one percent. To ensure this, a large resistance R is connected in series with the galvanometer.



We define voltage sensitivity as the deflection per unit voltage.

$$\frac{\emptyset}{V} = \left(\frac{NAB}{K}\right)\frac{i}{v}$$

MIND MAP : LEARNING MADE SIMPLE

CHAPTER - 4

Moving Charges & Magnetism

Magnetic Field ($\vec{B}$)

- It is a region around a magnet or current carrying conductor or a moving charge in which its magnetic effect can be felt
- SI unit is Tesla(T) = weber/m^2
- 1 Gauss = 10^{-4} Tesla

Oersted Law

In April, 1820, Hans Christian Oersted discovered that flow of current in a wire could deflect a nearby magnetic compass needle

Magnetic Force on moving charge

$\vec{F} = q\vec{v} \times \vec{B}$

$= qvB \sin\theta$

- For $\theta = 0$, $\vec{F} = 0$ along the magnetic field
- For $\theta = 90°$, i.e. if charge's velocity is perpendicular to field direction, Force is perpendicular to both field & velocity

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

$r = \frac{mv}{qB}$ = radius of the circle in which charge rotates

Time period (T) = $\frac{2\pi m}{qB}$

ν(frequency) = $\frac{1}{T} = \frac{qB}{2\pi m}$

If $\theta \neq 0, 180°, 90°$

Then, $F = qvB \sin\theta$

And the charge particle will follow helix path whose

$r = \frac{m v_\perp}{q B}$ and pitch = $V_\parallel \times T = V_\parallel \times \frac{2\pi m}{qB}$

Biot-Savart Law

$\odot \quad \otimes$

$d\vec{B} = \frac{1}{4\pi\varepsilon_0 c^2} \frac{i d\vec{l} \times \vec{r}}{r^3}$

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{i d\vec{l} \times \vec{r}}{r^3}$

$dB = \frac{\mu_0}{4\pi} \frac{i dl \sin\theta}{r^2}$

where $\mu_0 = \frac{1}{\varepsilon_0 c^2}$

$= 4\pi \times 10^{-7}$ TmA^{-1}

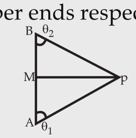
θ = angle between $d\vec{l}$ and $\vec{r}$

Direction of field will be perpendicular to plane containing current element and the point of observation.

Magnetic field due to straight wire current

$B = \frac{\mu_0 i}{4\pi d}(\cos\theta_1 - \cos\theta_2)$

where θ_1 and θ_2 are the angle corresponding to the lower and upper ends respectively



Field due to a long straight wire current

i.e $\theta_1 = 0$

$\theta_2 = \pi$

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

Field due to a circular current

Field at the centre

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

Field at an axial point

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

Field at a point far away from the centre

i.e. for d>>>a

$B = \frac{\mu_0 i a^2}{2 d^3}$

Ampere's Law

$\oint \vec{B}.d\vec{l} = \mu_0 i$

where i = total current crossing the area bounded by closed curve.

Solenoid

- Magnetic filed at a point inside due to a long solenoid $B = \mu_0 ni$
- And at point on one end $B = \frac{\mu_0 ni}{2}$

where n = no. of turns per unit length along the length of solenoid.

Magnetic field due to Toroid

$B = \frac{\mu_0 Ni}{2\pi r}$, N = total no. of turns

i = current in toroid

Force on a current carrying conductor

$d\vec{F} = i\, d\vec{l} \times \vec{B}$, F = ilB

Force between parallel currents

$F = \frac{\mu_0 i_1 i_2}{2\pi d}$

Torque experienced by a loop in uniform magnetic field

$\vec{\tau} = MB \sin\theta\, \hat{n} = \vec{M} \times \vec{B}$

Definition of Ampere

If two parallel wire kept 1 m apart, if $F = 2 \times 10^{-7}$, then current = 1A in each.

Sensitivity of moving coil galvanometer is nBA/k

Gal.to ammeter

$S = \frac{I_g}{I_T - I_g} G$

Gal.to voltameter

$R = \frac{V}{I_g} - G$

Important Questions

Multiple Choice questions-

1. A charged particle is moving in a cyclotron, what effect on the radius of path of this charged particle will occur when the frequency of the ratio frequency field is doubled?

(a) It will also be doubled.

(b) It will be halved.

(c) It will be increased by four times.

(d) It will remain unchanged.

2. Which of the following is not correct about cyclotron?

(a) It is a machine to accelerate charged particles or ions to high energies.

(b) Cyclotron uses both electric and magnetic fields in combination to increase the energy of charged particles.

(c) The operation of the cyclotron is based on the fact that the time for one revolution of an ion is independent of its speed or radius of its orbit.

(d) The charged particles and ions in cyclotron can move on any arbitrary path.

3. If an electron is moving with velocity $\vec{v}$ produces a magnetic field $\vec{B}$, then

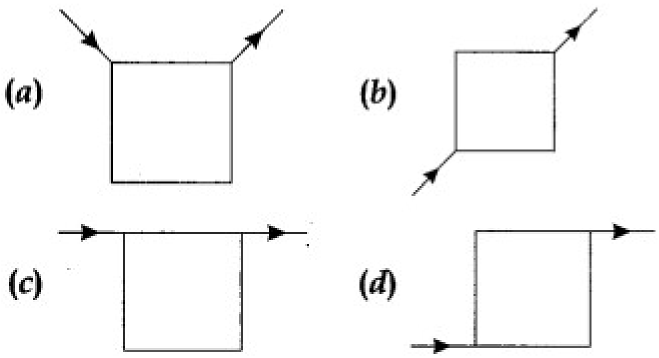
(a) the direction of field $\vec{B}$ will be same as the direction of velocity $\vec{v}$.

(b) the direction of field $\vec{B}$ will be opposite to the direction of velocity $\vec{v}$.

(c) the direction of field $\vec{B}$ will be perpendicular to the direction of velocity $\vec{v}$.

(d) the direction of field $\vec{B}$ does not depend upon the direction of velocity $\vec{v}$.

4. Current flows through uniform, square frames as shown in the figure. In which case is the magnetic field at the center of the frame not zero?



5. Ampere's circuital law is given by

(a) $\oint \vec{H}.\vec{dl} = \mu_0 I_{enc}$ (b) $\oint \vec{B}.\vec{dl} = \mu_0 I_{enc}$

(c) $\oint \vec{B}.\vec{dl} = \mu_0 J$ (d) $\oint \vec{H}.\vec{dl} = \mu_0 J$

6. Two identical current carrying coaxial loops, carry current I in opposite sense. A simple amperian loop passes through both of them once. Calling the loop as C, then which statement is correct?

(a) $\oint_c \vec{B}.\vec{dl} = \pm 2\mu_0 I$

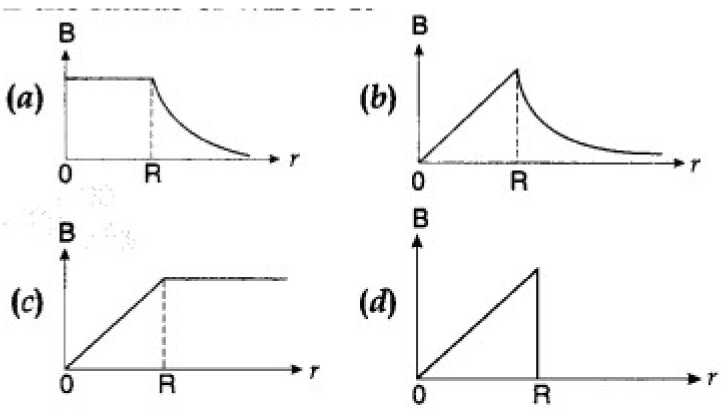
(b) the value of $\oint_c \vec{B}.\vec{dl}$ is independent of sense of C.

(c) there may be a point on C where B and dl are

parallel.

(d) none of these

7. The correct plot of the magnitude of magnetic field $\vec{B}$ vs distance r from centre of the wire is, if the radius of wire is R



8. The nature of parallel and anti-parallel currents are

(a) parallel currents repel and antiparallel currents attract.

(b) parallel currents attract and antiparallel currents repel.

(c) both currents attract.

(d) both currents repel.

9. The magnetic moment of a current I carrying circular coil of radius r and number of turns N varies as

(a) $\frac{1}{r_2}$

(b) $\frac{1}{r}$

(c) r

(d) r^2

10. A short bar magnet has a magnetic moment of 0. 65 J T^{-1}, then the magnitude and direction of the magnetic field produced by the magnet at a distance 8 cm from the center of magnet on the axis is

(a) 2.5×10^{-4} T, along NS direction

(b) 2.5×10^{-4} T along SN direction

(c) 4.5×10^{-4} T, along NS direction

(d) 4.5×10^{-4} T, along SN direction

Very Short:

1. Under what condition is the force acting on a charge moving through a uniform magnetic field minimum?

2. What Is the nature of the magnetic field in a moving coil galvanometer?

3. State two properties of the material of the wire used for suspension of the coil in a moving coil galvanometer.

4. Write one condition under which an electric charge does not experience a force in a magnetic field.

5. Mention the two characteristic properties of the material suitable for making the core of a transformer. (CBSE AI 2012)

6. Write the expression, in a vector form, for the Lorentz magnetic force due to a charge moving with velocity $\vec{V}$ in a magnetic field $\vec{B}$. What is the direction of the magnetic force? (CBSE Delhi 2014)

7. Write the condition under which an electron will move undeflected in the presence of crossed electric and magnetic fields. (CBSE AI 2014C)

8. What can be the cause of the helical motion of a charged particle? (CBSE AI 2016)

9. Write the underlying principle of a moving coil galvanometer. (CBSE Delhi 2016)

10. A proton and an electron traveling along parallel paths enter a region of the uniform magnetic field, acting perpendicular to their paths. Which of them will move in a circular path with a higher frequency? (CBSEAI and Delhi 2018)

Short Questions:

1. A charged particle having a charge q is moving with a speed of v along the X-axis. It enters a region of space where the electric field is $\vec{E}$ (E$\hat{j}$) and a magnetic field $\vec{B}$ are both present. The particle, on emerging from the region, is observed to be moving, along the X-axis only. Obtain an expression for the magnitude of $\vec{B}$ in terms of v and E. Give the direction of $\vec{B}$.

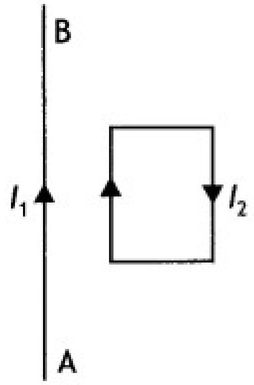
2. A stream of electrons traveling with speed v m s-1 at right angles to a uniform magnetic field 'B' is reflected in a circular path of radius 'r'.

Prove that $\frac{e}{m} = \frac{v}{rB}$

3. Which one of the two, an ammeter or a milliammeter, has a higher resistance and why?

4. A straight wire of length L carrying a current I stay suspended horizontally in mid-air in a region where there is a uniform magnetic field $\vec{B}$. The linear mass density of the wire is l. Obtain the magnitude and direction of the magnetic field.

5. In the figure below, the straight wire AB Is fixed while the loop Is free to move under the influence of the electric currents flowing in them. In which direction does the loop begin to move? Give a reason for your



6. A coil of 'N' turns, and radius 'R' carries a current 'I'. It is unwound and rewound to make a square coil of side 'a' having the same number of turns (N). Keeping the current 'I' same, find the ratio of the magnetic moments of the square coil and the circular coil. (CBSE Delhi 2013C)

7. Write the expression for Lorentz magnetic force on a particle of charge 'q' moving with velocity v in a magnetic field B. Show that no work is done by this force on the charged particle. (CBSE AI 2011)

8. (a) State Biot-Savart law in vector form expressing the magnetic field due to an element $\overrightarrow{dl}$ carrying current I at a distance $\vec{r}$ from the element.

Long Questions:

1.

(a) A particle of charge 'q' and mass 'm', moving with velocity $\vec{v}$ is subjected to a uniform magnetic field $\vec{B}$ perpendicular to its velocity. Show that the particle describes a circular path. Obtain an expression for the radius of the circular path of the particle.

(b) Explain, how its path will be affected if the velocity $\vec{v}$ makes an angle (θ ≠ 90°) with the direction of the magnetic field. (CBSE 2019C)

2.

(a) Obtain the conditions under which an electron does not suffer any deflection while passing through a magnetic field.

(b) Two protons P and Q moving with the same speed pass through the magnetic fields $\vec{B}_1$ and $\vec{B}_2$ respectively, at right angles to the field directions. If $|\vec{B}_2| > |\vec{B}_1|$, which of the two protons will describe the circular path of smaller radius? Explain. (CBSEAI 2019)

Assertion and Reason Questions-

1. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is NOT the correct explanation of A.

c) A is true but R is false.

d) A is false and R is also false.

Assertion (A): A charge, whether stationary or in motion produces a magnetic field around it.

Reason (R): Moving charges produce only electric field in the surrounding space.

2. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is NOT the correct explanation of A.

c) A is true but R is false.

d) A is false and R is also false.

Assertion (A): A charged particle moving in a uniform magnetic field penetrates a layer of lead and there by loses half of its kinetic energy. The radius of curvature of its path is now reduced to half of its initial value.

Reason (R): Kinetic energy is inversely proportional to radius of curvature.

Case Study Questions-

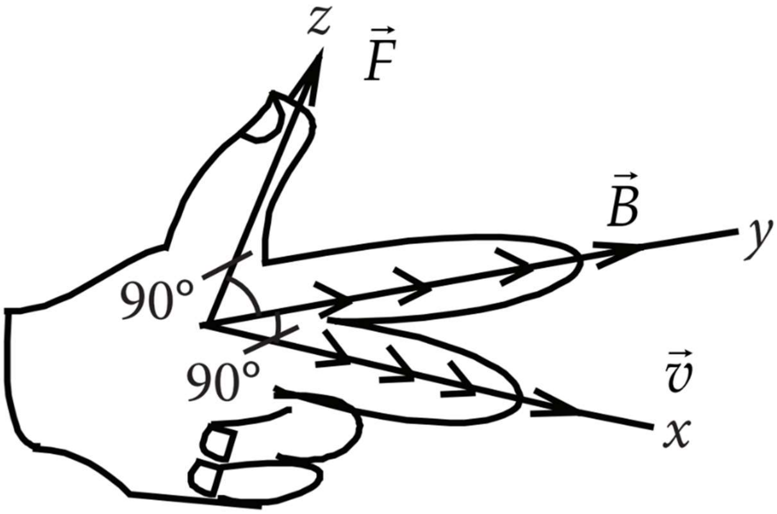
1. A charged particle moving in a magnetic field experiences a force that is proportional to the strength of the magnetic field, the component of the velocity that is perpendicular to the magnetic field and the charge of the particle.

This force is given by $\vec{F} = q(\vec{v} \times \vec{B})$ where q is the electric charge of the particle, v is the instantaneous velocity of the particle, and Bis the magnetic field (in tesla).

The direction of force is determined by the rules of cross product of two vectors.

Force is perpendicular to both velocity and magnetic field. Its direction is same as $\vec{v} \times \vec{B}$ if q is positive and opposite of $\vec{v} \times \vec{B}$ if q is negative.

The force is always perpendicular to both the velocity of the particle and the magnetic field that created it. Because the magnetic force is always perpendicular to the motion, the magnetic field can do no work on an isolated charge. It can only do work indirectly, via the electric field generated by a changing magnetic field.



(i) When a magnetic field is applied on a stationary electron, it:

a) Remains stationary.

b) Spins about its own axis.

c) Moves in the direction of the field.

d) Moves perpendicular to the direction of the field.

(ii) A proton is projected with a uniform velocity v along the axis of a current carrying solenoid, then,

a) The proton will be accelerated along the axis.

b) The proton path will be circular about the axis.

c) The proton moves along helical path.

d) The proton will continue to move with velocity v along the axis.

(iii) A charged particle experiences magnetic force in the presence of magnetic field. Which of the following statement is correct?

a) The particle is stationary and magnetic field is perpendicular.

b) The particle is moving and magnetic field is perpendicular to the velocity.

c) The particle is stationary and magnetic field is parallel.

d) The particle is moving and magnetic field is parallel to velocity.

(iv) A charge q moves with a velocity 2m s^{-1} along x-axis in a uniform magnetic field $\vec{F} = (\vec{i} + 2\vec{j} + 3\vec{k})T$, charge will experience a force.

a) In z-y plane.

b) Along -y axis.

c) Along +z axis.

d) Along -z axis.

(v) Moving charge will produce.

a) Electric field only.

b) Magnetic field only.

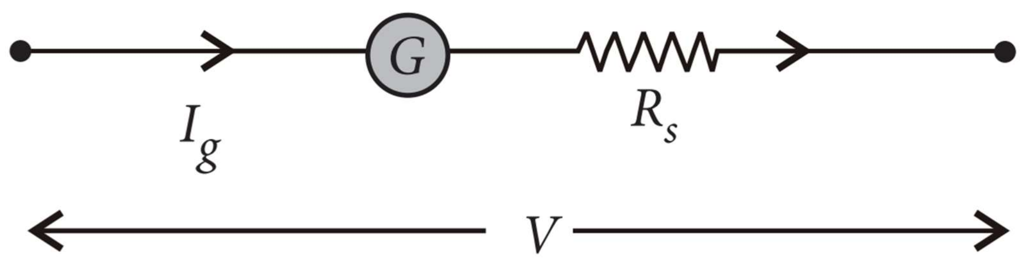
c) Both electric and magnetic field.

d) None of these.

2. A galvanometer can be converted into voltmeter of given range by connecting a suitable resistance R, in series with the galvanometer, whose value is given by,

$$R_s = \frac{V}{I_g} - G$$

where Vis the voltage to be measured, lg is the current for full scale deflection of galvanometer and G is the resistance of galvanometer.



Series resistor(R,) increases range of voltmeter and the effective resistance of galvanometer. It also protects the galvanometer from damage due to large current. Voltmeter is a high resistance instrument and it is always connected in parallel with the circuit element across which potential difference is to be measured. An ideal voltmeter has infinite resistance. In order to increase the range of voltmeter n times the value of resistance to be connected in series with galvanometer is $R_s = (n - 1)G$.

(i) 10mA current can pass through a galvanometer of resistance 25Ω What resistance in series should be connected through it, so that it is converted into a voltmeter of 100V?

a) 0.975Ω

b) 99.75Ω

c) 975Ω

d) 9975Ω

(ii) There are 3 voltmeter A, B, C having the same range but their resistance are 15000Ω,10000Ω and 5000Ωrespectively. 'Tile best voltmeter amongst them is the one whose resistance is

a) $5000\Omega5000\Omega$

b) $10000\Omega10000\Omega$

c) $15000\Omega15000\Omega$

d) all are equally good.

(iii) A milliammeter of range 0 to 25mA and resistance of 10Ω is to be converted into a voltmeter with a range of 0 to 25V. 'Tile resistance that should be connected in series will be:

a. 930Ω

b. 960Ω

c. 990Ω

d. 1010Ω

(iv) To convert a moving coil galvanometer (MCG) into a voltmeter:

a. A high resistance R is connected in parallel with MCG.
b. A low resistance R is connected in parallel with MCG.
c. A low resistance R is connected in series with MCG.
d. A high resistance R is connected in series with MCG.

(v) To increase the current sensitivity of a moving coil galvanometer, we should decrease:

a. Zero.
b. Low.
c. High.
d. Infinity.

✓ Answer Key:

Multiple Choice Answers-

1. Answer: d
2. Answer: d

3. Answer: c
4. Answer: c
5. Answer: b
6. Answer: b
7. Answer: b
8. Answer: b
9. Answer: d
10. Answer: b

Very Short Answers:

1. Answer: When the charge moves parallel to the direction of the magnetic field.
2. Answer: Radial magnetic field.
3. Answer:
   - High tensile strength.
   - Small value of torque per unit twist.
4. Answer: When it moves parallel to the direction of the magnetic field.
5. Answer:
   - Low retentivity
   - High permeability
6. Answer: The expression is $\vec{F} = q(\vec{V} \times \vec{B})$. The force is perpendicular to both the velocity and the magnetic field vector.
7. Answer: An electron moves perpendicular to both fields.
8. Answer: The charge enters the magnetic field at any angle except 0°, 180°, and 90°.
9. Answer: A current-carrying loop placed in a magnetic field experiences a torque.
10. Answer:

    The frequency of revolution is given by

    $$\nu = \frac{Bq}{2\pi m} \Rightarrow \nu \propto \frac{1}{m}$$

    As for $m_e < m_p$

    therefore $\nu_e > \nu_p$

Short Questions Answers:

1. Answer: Since the particle continues to move along the X-axis, therefore, the magnetic force acting on it should be completely balanced by the electric force. Since the electric force acts along the Y-axis, therefore, the magnetic force must be along the Z-axis.

   Thus, is equilibrium q E = B q v or v = E/B

2. Answer: Let a stream of electrons be traveling with speed v at right angles to a uniform magnetic field B then force due to magnetic field provides the required centripetal force which deflects the electron beam along a circular path of radius 'r' such that

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

   or

   $\frac{e}{m} = \frac{v}{rB}$

   where e = electronic charge and m = mass of the electron.

3. Answer:

   The shunt resistance connected to convert a galvanometer into an ammeter or a milliammeter is given by the expression $S = \frac{I_g G}{I - I_g}$ where S is shunt resistance, G galvanometer resistance, I total current through G and S, and I_g galvanometer current. In the case of milliammeter, I is small.

   Therefore $S_{milliammeter} > S_{ammeter}$. Hence the resistance of a milliammeter is greater than that of an ammeter.

4. Answer: The magnetic force acting on the straight wire balances the weight of the wire.

   Therefore, in equilibrium we have Mg = BIL, here M = L l, therefore we have L l g = BIL or B = l/ I g

   This field acts vertically upwards.

5. Answer: The loop moves towards the straight wire AB. In the loop in the side nearer to the wire AB current I_2 is in the same direction as I_1 and hence attractive force acts. However, on the side farther away from the wire AB current I_2 is in the opposite direction and the force is repulsive. But as the magnitude of attractive force is greater than the repulsive force, the net force is attractive in nature and hence, the loop moves towards the wire AB.

6. Answer:

The magnetic moment of a current loop is given by the relation M = nIA
For the circular loop $M_c = NI\pi R^2$ ...(1)

Now when the coil is unwound and rewound to make a square coil, then
$2\pi R = 4a$ or $a = \pi R/2$

Hence magnetic moment of the square coil is
$M_s = NI a^2 = NI (\pi R/2)^2 = NI \pi^2 R^2/4$ ...(2)

From (1) and (2) we have
$$\frac{M_S}{M_C} = \frac{NI\pi^2R^2/4}{NI\pi R^2} = \frac{\pi}{4}$$

7. Answer:

The expression is $\vec{F} = q(\vec{v} \times \vec{B})$. This force always acts perpendicular to the direction of motion of the charged particle. Therefore the angle between $\vec{F}$ and $\vec{r}$ is 90°. Hence work done is $W = \vec{F}.r = Fr\cos 90° = 0$

8. Answer:

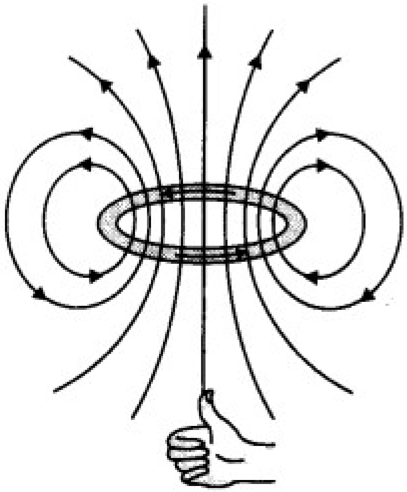
(a) It states that for a small current element dl the magnetic field at a distance r is given by

$$\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{I(\overline{dL}\times\hat{r})}{r^2}.$$

(b) The magnetic field at the centre of a circular loop is given by

$$B = \frac{\mu_0 I}{2r}$$

The field lines are as shown.



Long Questions Answers:

1. Answer:

(a) Let a charged particle of charge q and mass m be moving with velocity $\vec{v}$ right angle to the field (i.e., in the plane of the paper), then magnetic force $\vec{F}$ acting on the charge q will be

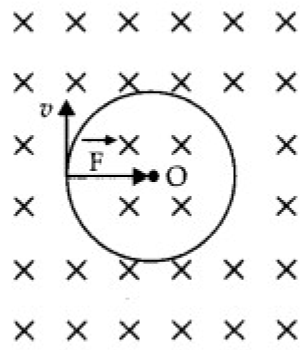
$\vec{F} = q(\vec{v} \times \vec{B})$

or

F = qvB sin 90°

or

F = qvB ... (1)



As this forces fact at a right angle to the velocity V of the charged particle, the slot is unable to change the velocity but can make the charged particle move In a circular path.

If r is the radius of the circle, then the centripetal force required by the charged particle will be

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

This centripetal force Is provided by the magnetic force acting on the charged particle.

i.e. $F_c = F$

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

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

(b) If (θ ≠ 90°), the velocity $\vec{v}$ of the moving charge can be resolved into two components v cos θ, in the direction of the magnetic field and make it v sin θ, in the direction perpendicular to the magnetic field. The charged particle under the combined effect of the two components of velocities wilt cover linear as well as a circular path, i.e., helical path whose axis is parallel to the magnetic field.

2. Answer:

(a) No deflection suffered by the electron if it moves parallel or anti-parallel to the magnetic field.

(b) The radius of the circular path travelled by a charged particle in a magnetic field is given by r = $\frac{mv}{Bq}$

Therefore, $\frac{r_1}{r_2} = \frac{B_2}{B_1}$

As $|\vec{B}_2| > |\vec{B}_1|$ therefore, $r_2 < r_1$

Assertion and Reason Answers-

1. (d) A is false and R is also false.

Explanation:

A charge, whether stationary or in motion, produces an electric field around it. If it is in motion, then in addition to the electric field, it also produces a magnetic field, because moving charges produce magnetic field in the surrounding space.

2. (b) Both A and Rare true but R is NOT the correct explanation of A.

Explanation:

The radius of curvature of a charged particle in a magnetic re rs given y,

$$r = \frac{mv}{qB} = \frac{\sqrt{2mK.E.}}{qB} \text{ i.e. } r \propto \sqrt{K.E.}$$

When kinetic energy is halved, the radius is reduced to $\left(\frac{1}{\sqrt{2}}\right)$ times its initial value.

Case Study Answers-

1. Answer :

i. (a) Remains stationary.

Explanation:

For stationary electron, $\vec{v} = 0$

$\therefore$ Force on the electron is, $\vec{F}_m = -e(\vec{v} \times \vec{B}) = 0$

ii. (d) The proton will continue to move with velocity v along the axis.

Explanation:

Force on the proton, $\vec{F}_B = e(\vec{v} \times \vec{B})$

Since, $\vec{v}$ is parallel to $\vec{B}$

$\therefore \vec{F}_B = 0$

Hence proton will continue to move with velocity v along the axis of solenoid.

iii. (b) The particle is moving and magnetic field is perpendicular to the velocity.

Explanation:

Magnetic force on the charged particle q is,

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

where θ is the angle between $\vec{v}$ and $\vec{B}$.

Out of the given cases, only in case (b) it will experience the force while in other cases it will experience no force.

iv. (a) In z-y plane.

Explanation:

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

$$= q[2\vec{i} \times (\vec{i} + 2\vec{j} + 3\vec{k})] = (4q)\vec{k} - (6q)\vec{j}$$

v. (c) Both electric and magnetic field.

Explanation:

When an electric charge is moving both electric and magnetic fields are produced, whereas a static charge produces only electric field.

2. Answer :

i. (d) 9975Ω

Explanation:

A galvanometer can be converted into a voltmeter of given range by connecting a suitable high resistance R in series of galvanometer, which is given by,

$$R = \frac{V}{I_g} - G = \frac{100}{10 \times 10^{-3}} - 25 = 10000 - 25 = 9975\Omega$$

ii. (c) 15000Ω

Explanation:

An ideal voltmeter should have a very high resistance.

iii. (c) 990Ω

Explanation:

Resistance of voltmeter $= \frac{25}{25 \times 10^{-3}} = 1000\Omega$

$\therefore X = 1000 - 10 = 990\Omega$

iv. (d) A high resistance R is connected in series with MCG.

Explanation:

To convert a moving coil galvanometer into a voltmeter,

it is connected with a high resistance in series.

The voltmeter is connected in parallel to measure the potential difference.

As the resistance is high, the voltmeter itself does not consume current.

v. (d) Infinity.

Explanation:

The resistance of an ideal voltmeter is infinity.