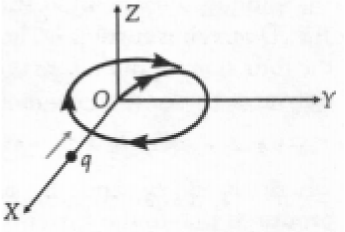
Solution

MOVING CHARGES

Class 12 - Physics

1. **(a)** $\frac{\mu_0 I^2}{2\pi r}$, attractive
   Explanation:
   $\frac{\mu_0 I^2}{2\pi r}$, attractive
2. **(a)** $\frac{1}{4}$
   Explanation:
   The energy of the electron after being accelerated by a potential V is
   $U = eV = \frac{1}{2}mv^2$
   where v is the velocity of the electron.
   $v = \sqrt{\frac{2eV}{m}}$
   The force it experiences in a magnetic field B is
   $F = Bev\sin\theta$
   When accelerated by a potential V', the velocity is
   $v' = \sqrt{\frac{2eV'}{m}}$
   and the force in the same magnetic field is
   $2F = Bev'\sin\theta$
   $2Bev\sin\theta = Bev'\sin\theta$;
   $v = \frac{v'}{2}$
   $\sqrt{\frac{2eV}{m}} = \frac{1}{2}\sqrt{\frac{2eV'}{m}}$;
   Thus, $V = \frac{V'}{4}$; $\frac{V}{V'} = \frac{1}{4}$
3. **(b)** shrink
   Explanation:
   shrink
4. **(a)** Only outside the conductor
   Explanation:
   Only outside the conductor
5. **(c)** $\frac{\mu_0}{2}$
   Explanation:
   $B = \frac{\mu_o NI}{2a} = \frac{\mu_e \times 1 \times 1}{2 \times 1} = \frac{\mu_0}{2}$
6. i. Charge q begins to move in a circular orbit in the XY-plane as shown in Fig.



   ii. As the magnetic force acts perpendicular to the velocity $\vec{v}$ of the charge q, it does no work and hence there is no gain in the kinetic energy of the charge q.
7. As the current sensitivity is 10 div per mA and there are 100 divisions on the scale, so current required for full scale deflection is
   $I_g = \frac{1}{10} \times$ 100 mA = 10 mA = 10 $\times$ 10^{-3}
   = 0.01 A

As voltage sensitivity is 2 div per mV, so voltage required for full scale deflection is

$V_g = \frac{1}{2} \times$ 100 mV = 50 mV = 50 $\times$ 10^{-3}V

Galvanometer resistance,

$R_g = \frac{V_8}{I_g} = \frac{50 \times 10^{-3}}{10 \times 10^{-3}} = 5\Omega$

i. For conversion into an ammeter. I = 5 A

   $R_s = \frac{I_g}{I - I_g} \times R_g = \frac{0.01}{5-01} \times 5 = \frac{5}{499}\Omega$

   So a shunt of 5 / 499 Ω should be connected across the galvanometer to read 5 A for full scale deflection.

ii. For conversion into voltmeter. For reading 1 div per volt, the voltage range should be 100 V because there are 100 divisions.

   $\therefore \quad R = \frac{V}{I_g} - R_g = \frac{100}{0.01} - 5 = 10000 - 5 = 9995\Omega$

   So a resistance of 9995 Ω should be connected in series with the given galvanometer to read 1 div per volt.

8. The phosphor bronze alloy is used for the suspension wire of a moving coil galvanometer because of its following properties:
   i. Small restoring torque per unit twist. This makes the galvanometer highly sensitive.
   ii. High tensile strength so that even their fibre does not break under the weight of the suspended coil.
   iii. Rust resisting.

9. Magnetic field due to inner circle at O,

   $B_1 = \frac{\mu_0 I}{2r}$

   $= \frac{2\pi \times 10^{-7} \times 1}{4 \times 10^{-2}}$

   $= \frac{\pi}{2} \times$ 10^{-5} T into the page

   Magnetic field due to semi-circle at O,

   $B_2 = \frac{\mu_0 I}{2r} \cdot \frac{1}{2}$

   $= \frac{2\pi \times 10^{-7} \times 2}{12 \times 10^{-2}}$

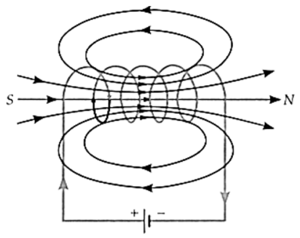
   $= \frac{\pi}{6} \times$ 10^{-5} T out of the page

   as magnetic fields are in opposite directions so

   $B_{net} = B_1 - B_2$

   $= \left(\frac{\pi}{2} \times 10^{-5} - \frac{\pi}{6} \times 10^{-5}\right) T \approx 1.0 \times 10^{-5} T$

   Direction of the net magnetic field is into the page, since $B_1 > B_2$.

10. 

   i. The magnetic lines of force of a solenoid form closed loops while the electric lines of force of an electric dipole start from the positive charge and end at the negative charge.
   ii. Such curves are called magnetic lines of force. No two such lines of force can intersect. If they do so, then there will be two tangents and hence two directions of the magnetic field at the point of intersection which is impossible.

11. i. Importance and production of the radial magnetic field: In a radial magnetic field, magnetic torque remains maximum everywhere. It is produced by cylindrical pole pieces and soft iron core.
   ii. In a moving coil galvanometer as a voltmeter, a high resistance in series is required whereas in an ammeter a shunt is used because,
      a. **Voltmeter:** A high resistance in series is required when moving a coil galvanometer is used as a voltmeter to make sure that a low current should travel through voltmeter without changing the potential difference that needs to be measured.
      b. **Ammeter:** A shunt is used when a moving coil galvanometer is used as an ammeter to make sure about not much change in the total resistance of the circuit with the actual current value of flowing current.

12. If m_p , m_d and m_a are the masses of proton, deutron and a-particle respectively, then

   $m_d = 2m_p$ and $m_a = 4m_p$

   Also $q_d = q_p$ and $q_\alpha = 2q_p$

   Kinetic energy,

$K = \frac{1}{2}mv^2$

$\therefore$ Velocity $v = \sqrt{\frac{2K}{m}}$

Radius of the circular path of a charged particle in a magnetic field is given by

$r = \frac{mv}{qB} = \frac{m}{qB} \cdot \sqrt{\frac{2K}{m}} = \frac{\sqrt{2mK}}{qB}$

$\therefore \quad r_p = \frac{\sqrt{2m_pK}}{q_pB}, r_d = \frac{\sqrt{2m_dK}}{q_dB}$ and $r_\alpha = \frac{\sqrt{2m_\alpha K}}{q_\alpha B}$

$\frac{r_p}{r_d} = \frac{q_d}{q_p}\sqrt{\frac{m_p}{m_d}} = \frac{q_p}{q_p}\sqrt{\frac{m_p}{2m_p}} = \frac{1}{\sqrt{2}}$

$\frac{r_p}{r_\alpha} = \frac{q_\alpha}{q_p}\sqrt{\frac{m_p}{m_\alpha}} = \frac{2q_p}{q_p}\sqrt{\frac{m_p}{4m_p}} = 1$

Hence $r_p : r_d : r_\alpha = 1 : \sqrt{2} : \mathbf{1}$

13. **Current loop as a magnetic dipole:** We know that the magnetic field produced at a large distance r from the centre of a circular loop (of radius a) along its axis is given by

B = $\frac{\mu_0 I a^2}{2r^3}$

or B = $\frac{\mu_0}{4\pi} \cdot \frac{2IA}{r^3}$ .....(i)

where I is the current in the loop and A = πa^2 is its area. On the other hand, the electric field of an electric dipole at an axial point lying far away from it is given by

E = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{r^3}$ ....(ii)

where p is the electric dipole moment of the electric dipole.

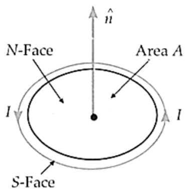
On comparing equations (i) and (ii), we note that both B and E have the same distance dependence $\left(\frac{1}{r^3}\right)$.

m = IA

In vector notation,

$\vec{m} = I\vec{A} = IA\hat{n}$

Right hand thumb rule: If we curl the fingers of the right hand in the direction of current in the loop, then the extended thumb gives the direction of the magnetic moment associated with the loop.



It follows from the above rule that the Upper face of the current loop shown in Figure. has N-polarity and the lower face has S-polarity. Thus a current loop behaves like a magnetic dipole.

If a current carrying coil consists of N turns, then

m = NIA

The factor NI is called amperes turns of current loop.

So, Magnetic dipole moment of current loop = Ampere turns $\times$ loop area

14. Apparent resistance, $R' = \frac{\text{Voltmeter reading}}{\text{Ammeter reading}} = \frac{V}{I}$

From Ohm's law, $\frac{E}{I} = R_A + \frac{1}{\frac{1}{R} + \frac{1}{R_V}}$

Also, E=I R_A + V

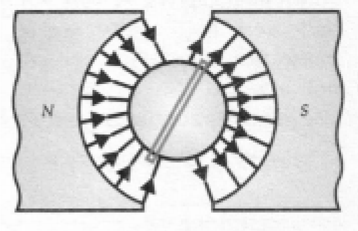
or $\frac{E}{I} = R_A + \frac{V}{I} = R_A + R'$

or $R_A + \frac{1}{\frac{1}{R} + \frac{1}{R_V}} = R_A + R'$

or $\frac{1}{R'} = \frac{1}{R} + \frac{1}{R_V}$

or $\frac{1}{R} = \frac{1}{R'} - \frac{1}{R_V}$

15. **Radial magnetic field:** By using pole pieces of a magnet and placing a soft iron cylindrical core between the concave poles, we get a magnetic field with its lines of force pointing along the radii of a circle. Such a field is called a radial field. The plane of a coil rotating in such a field is always parallel to the field, as shown in Fig.



Need of radial field: The current I through a galvanometer coil is given by $I = \frac{k}{NBA \sin\theta}\alpha$

Because of the presence of factor sin θ, the deflection a of the galvanometer coil is not quite proportional to the current I, so the instrument is not a linear one. To make its scale linear, the field is made radial. Then θ = 90°, so that

$I = \frac{k}{NBA}\alpha$ or $I \propto \alpha$

16. i. Deflection produced per unit current is called its current sensitivity.

Current sensitivity can be increased by

(a) increasing number of turns in coil

(b) increasing area of coil in magnetic field

(c) decreasing K (Torsional Constant)

(any one)

$V_s = \frac{\theta}{V} = \frac{NBA}{KR}$

If current sensitivity is increased by increasing number of turns of the coil, the resistance of the galvanometer will also increase. Thus voltage sensitivity may not increase.

ii. $V = I_G(R+G)$

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

$= \frac{100}{20\times10^{-3}} - 15$

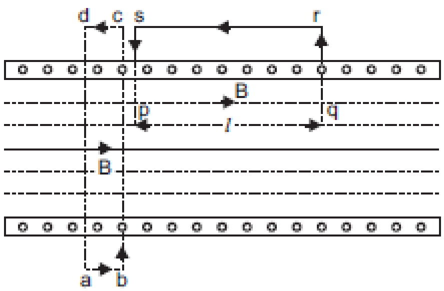
$= 5000 - 15$

$= 4985\Omega$

By connecting 4985Ω in series with galvanometer it is converted to voltmeter of range $(0 - 100\ V)$

17. a. Consider a symmetrical long solenoid having a number of turns per unit length equal to n.

Let I be the current flowing in the solenoid, then by the right-hand rule, the magnetic field is parallel to the axis of the solenoid.



Field inside the solenoid:

Consider a closed path abcd.

Now, using Ampere's circuital law to this path, we have

$\oint \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl} = \mu \times 0$

Therefore, B = 0

This implies, the magnetic field outside the solenoid is 0.

Field inside the solenoid:

Consider a closed path pqrs.

The line integral of the magnetic field is given by,

$\oint_{\mathrm{pqrs}} \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl} = \int_{pq} \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl} + \int_{qr} \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl} + \int_{rs} \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl} + \int_{sp} \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl}$ ....(i)

For path pq, $\vec{B}$ and $\overrightarrow{\mathrm{dl}}$ are along the same direction,

$\therefore \quad \int_{qr} \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl} = \int_{Sp} \overrightarrow{\mathrm{B}} \cdot \vec{dl} = \int Bdl \cos 90^\circ$ = 0

For path rs, B = 0 because outside the solenoid field is zero.

$\therefore \quad \int_{rs} \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl} = 0$

Now, using Ampere's law,

Using these equations, equation (i) gives,

$\oint_{pqrs} \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl} = \int_{pq} \overrightarrow{\mathrm{B}} \cdot \overrightarrow{dl} = Bl$

Now, using Ampere's law,

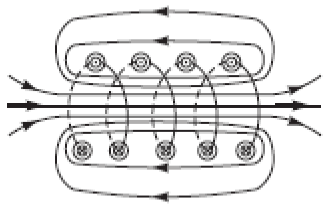
$\oint \vec{B} \cdot \vec{d} I = \mu_0 I$

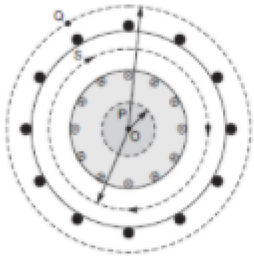
This implies,

$Bl = \mu_0 (nlI)$

$\therefore B = \mu_0 nI$

b. Magnetic lines do not exist outside the body of a toroid. Toroid is closed and the solenoid is open on both sides. The magnetic field is uniform inside a toroid whereas, for a solenoid, it is different at two ends and centre.



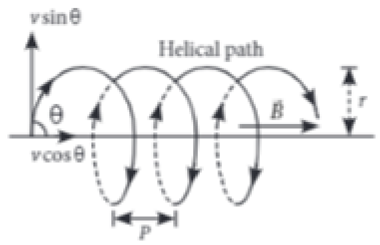


c. The magnetic field is made strong by,

i. passing large current and
ii. using a laminated coil of soft iron.

18. **Read the text carefully and answer the questions:**

The path of a charged particle in magnetic field depends upon angle between velocity and magnetic field. If velocity $\vec{v}$ is at angle θ to $\vec{B}$, component of velocity parallel to magnetic field (v cos θ) remains constant and component of velocity perpendicular to magnetic field (v sin θ) is responsible for circular motion, thus the charge particle moves in a helical path.



The plane of the circle is perpendicular to the magnetic field and the axis of the helix is parallel to the magnetic field. The charged particle moves along helical path touching the line parallel to the magnetic field passing through the starting point after each rotation.

Radius of circular path is r = $\frac{mv \sin\theta}{qB}$

Hence the resultant path of the charged particle will be a helix, with its axis along the direction of $\vec{B}$ as shown in figure.

(i) **(a)** any one of (i), (ii) and (iii)

Explanation:

any one of (i), (ii) and (iii)

(ii) **(a)** will have smaller radius of curvature than that of A

Explanation:

Using, $qvB\sin\theta = \frac{mv^2}{r}$

$r \propto \frac{1}{\sin\theta}$ for the same values of m, v, q and B

$\therefore \frac{r_A}{r_B} = \frac{\sin 90^\circ}{\sin 30^\circ}$ = 2 or $r_A = 2r_B$ or $r_B < r_A$

(iii) **(a)** 0.5 mm

Explanation:

The radius of the helical path of the electron in the uniform magnetic field is

r = $\frac{mv_\perp}{eB} = \frac{mv\sin\theta}{eB} = \frac{(2.4\times10^{-23}\ \mathrm{kg\ m/s})\times\sin 30^\circ}{(1.6\times10^{-19}\mathrm{C})\times 0.15\ \mathrm{T}}$

$= 5 \times 10^{-4}$ m $= 0.5 \times 10^{-3}$ m = 0.5 mm

(iv) **(b)** 0.157 m

Explanation:

Here, $\vec{B} = 8.35 \times 10^{-2}\hat{i}$ T

$\vec{v} = 2 \times 10^5\hat{i} + 4 \times 10^5\hat{j}$ m/s

m = 1.67 $\times$ 10^{-27} kg

Pitch of the helix (i.e., the linear distance moved along the magnetic field in one rotation) is given by Pitch of the helix = $\frac{2\pi m v_1}{qB}$

= $\frac{2\times3.14\times1.67\times10^{-27}\times2\times10^5}{1.6\times10^{-19}\times8.35\times10^{-2}}$ = 0.157 m

(v) **(b)** $\frac{qB}{2\pi m}$

Explanation:

Period of revolution

T = $\frac{2\pi R}{v\sin\theta} \Rightarrow T = \frac{2\pi\left(\frac{mv\sin\theta}{qB}\right)}{v\sin\theta} \Rightarrow T = \frac{2\pi m}{qB}$

$\therefore$ Frequency, $\text{v} = \frac{1}{T} = \frac{qB}{2\pi m}$