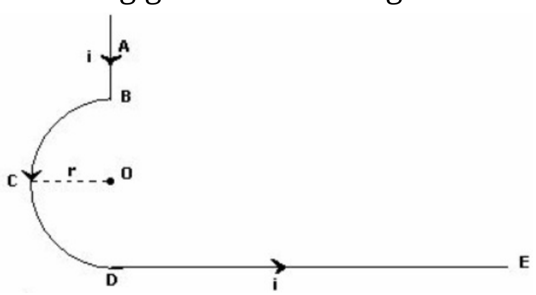
CBSE Test Paper-05

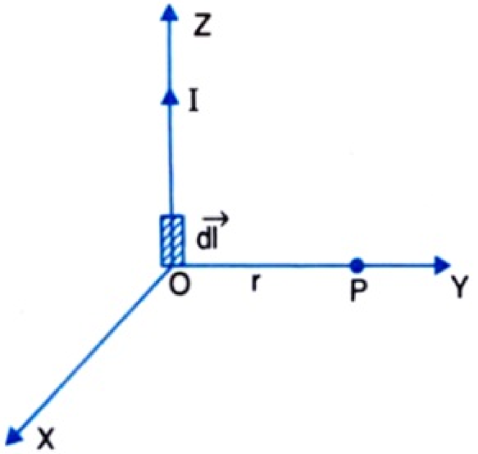
Class - 12 Physics (Moving Charges and Magnetism)

1. If electron velocity is $2\hat{i} + 3\hat{j}$ and it is subjected to magnetic field of $4\hat{k}$, then its
   a. none of these
   b. speed will change
   c. both path will change and speed will change
   d. path will change
2. Magnitude of the magnetic moment of an electron of mass m_e if e is the charge on the electron and angular momentum is l, is
   a. $\frac{e}{2m_e}l$
   b. $\frac{e}{2m_e}l^2$
   c. $\frac{e^2}{2m_e}l$
   d. $\frac{e}{4m_e}l$
3. A beam of electrons at rest is accelerated by a potential V. This beam experiences a force F in a uniform magnetic field. The accelerating potential is changed to V’ and the force experienced by the electrons in the same magnetic field is 2F. The ratio $\frac{V}{V'}$ is
   a. 2.0
   b. 1.0
   c. $\frac{1}{2}$
   d. $\frac{1}{4}$
4. For measuring μA current the galvanometer is
   a. connected in parallel series
   b. always connected in series
   c. always connected in parallel
   d. connected in series parallel
5. In the fig given below magnetic induction at the point O is

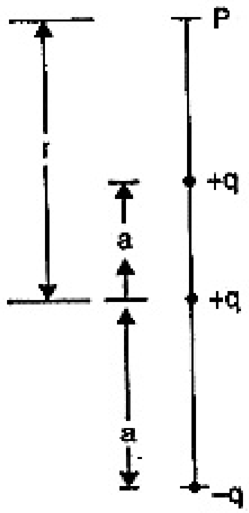


a. $\frac{\mu_o I}{4r} \cdot \frac{\mu_o I}{4\pi r}$
b. $\frac{\mu_o I}{4r} + \frac{\mu_o I}{2\pi r}$
c. $\frac{\mu_o I}{4r} + \frac{\mu_o I}{4\pi r}$
d. $\frac{\mu_o I}{4\pi r}$

6. Write one condition under which an electric charge does not experience a force in a magnetic field.
7. What is the approximate distance upto which earth's magnetic field extends?
8. A beam of protons with a velocity $4 \times 10^5 m/s$ enters a uniform magnetic field of 0.3 T at an angle 60° to the magnetic field. Find the radius of the helical path taken by the proton beam. Also find the pitch of the helix mp $= 1.67 \times 10^{-27} k$
9. Two straight wires A and B of lengths 10 m and 12 m carrying currents of 4.0 A and 6.0 A respectively in opposite directions lie parallel to each other at a distance of 0.03 m. Estimate the force on a 15 cm section of the wire B near its centre.
10. State Biot Savart law. A current I flows in a conductor placed perpendicular to the plane of the paper. Indicate the direction of the magnetic field due to a small element $\overrightarrow{dl}$ at point P situated at a distance $\overrightarrow{r}$ from the element as shown in the figure.



11. A dielectric slab of thickness 1.0 cm and dielectric constant 5 is placed between the plates of a parallel plate capacitor of plate area $0.01m^2$and separation 2.0 cm. Calculate the change in capacity on introduction of dielectric. What would be the change, if the dielectric slab were conducting?
12. Calculate the potential at P due to the charge configuration as shown in the following figure. If r >>a, then how will you modify the result?



13. A uniform magnetic field of 1.5 T exists in a cylindrical region of radius 10.0 cm, its direction parallel to the axis along east to west. A wire carrying current of 7.0 A in the north to south direction passes through this region. What is the magnitude and direction of the force on the wire if,
    a. the wire intersects the axis
    b. the wire is turned from N-S to northwest direction,
    c. the wire in the N-S direction is lowered from the axis by a distance of 6.0 cm?
14. An iron core is inserted into a solenoid 0.5 m long with 400 turns per unit length. The area of cross section of the solenoid is 0.01 m^2.
    a. Find the permeability of the core when a current of 5 A flows through the solenoid winding. Under these conditions, the magnetic flux through the cross section of the solenoid is $1.6 \times 10^{-3} Wb$.
    b. Find the inductance of the solenoid under these conditions.
15. An electron emitted by a heated cathode and accelerated through a potential difference of 2.0 kV, enters a region with uniform magnetic field of 0.15 T. Determine the trajectory of the electron if the field (a) is transverse to its initial velocity, (b) makes an angle of 30° with the initial velocity.

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Answers

1. (d) path will change

   Explanation: As magnetic force always act perpedicular to the direction of motion so path or direction will change withot any change in speed.

2. (a) $\frac{e}{2m_e}l$

   Explanation:

   The electron moving in a circular orbit of radius r with a speed v and time period T constitutes a current $i = \frac{e}{T}$.

   since $T = \frac{2\pi r}{v}$,

   therefore $i = \frac{ev}{2\pi r}$

   The orbital magnetic moment of the electron $\mu_l = iA = \frac{ev}{2\pi r} \times \pi r^2 = \frac{evr}{2}$

   The angular momentum of the electron $l = m_e vr$,

   since $vr = \frac{l}{m_e}$

   therefore, $\mu_l = \frac{e}{2m_e}l$

3. (d) $\frac{1}{4}$

   Explanation: The energy of the electron after being accelerated by a potential V is

   $U = eV = \frac{1}{2}mv^2$ 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 $2F = Bev'\sin\theta$.

   $2Bev\sin\theta = Bev'\sin\theta$;

   $v = \frac{v'}{2}; \sqrt{\frac{2eV}{m}}$

   $= \frac{1}{2}\sqrt{\frac{2eV'}{m}}$;

   $V = \frac{V'}{4}; \frac{V}{V'} = \frac{1}{4}$

4. (b) always connected in series

   Explanation: For measurement of current of any magnitude, the galvanometer is always connected in series. This is to ensure that the entire current flows through the galvanometer. If the galvanometer were connected in parallel, the current branches out and only a part of the current will flow through it.

5. (c) $\frac{\mu_o I}{4r}$ + $\frac{\mu_o I}{4\pi r}$

   Explanation: Magnetic field due to AB conductor is 0, magnetic field due to semicircular arc BCD and straight conductor DE are in the same direction so add up

   Net magnetic field = $\frac{\mu_o I}{4r}$ + $\frac{\mu_o I}{4\pi r}$

6. F = qvB sin θ

   When the electric charge is either at rest (v = 0) or parallel (θ = 0) to magnetic field, it does not experience force in magnetic field.

7. The magnetic field of earth extends to nearly five times the radius of the earth i.e.

   $5 \times (6.4 \times 10^3) km = 3.2 \times 10^4 km$

8. $\because \mathbf{r} = \frac{mv}{qB}$

   $r = \frac{1.67 \times 10^{-27} \times 4 \times 10^5 \sin 60}{1.6 \times 10^{-19} \times 0.3}$

   $= 1.2 \times 10^{-2} = 1.2 cm$

   $T = \frac{2\pi r}{v \sin \theta} = 2.175 \times 10^{-7} S$

   $\therefore P = v \cos \theta T$

   or $= 4 \times 10^5 \times \frac{1}{2} \times 2.175 \times 10^{-7} = 4.35 cm$

9. The ratio of the lengths of the wires to the separation between them is large (more than 300). So one can estimate approximately the force on a section of either of the two wires (near their centres) by using exact result for force per unit length for two infinitely long wires carrying currents I_1 and I_2.

   Force per unit length $\frac{F}{1} = \frac{\mu_0 I_1 I_2}{2\pi r} Nm^{-1}$

   $= \frac{4\pi \times 10^{-7} \times 4 \times 6}{2\pi \times 0.03} = 1.6 \times 10^{-4} Nm^{-1}$

   Force on 15 cm section of wire B (near its centre)

   $= 1.6 \times 10^{-4} \times 0.15 = 2.4 \times 10^{-5} N$ The force is repulsive as the currents are in opposite directions, the direction force is normal to the wire away from A.

10. Biot Savart law states that the magnitude of magnetic field induction at a point due to a current element of length dl, carrying I, at a point r from the element is given by

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

    Vector form: $|\overrightarrow{dB}| = \frac{\mu_0}{4\pi} \cdot \frac{|dl \times I|}{r^3}$

    The direction of magnitude field $\overrightarrow{dB}$ is perpendicular to the plane containing $\overrightarrow{dl}$ and

$\overrightarrow{r}$ and is directed inward.

11. Here, t = 1.0cm = 10^{-2}m

$\in_r = K = 5$, A = 0.01m^2 = $10^{-2}m^2$

$d = 2cm = 2 \times 10^{-2}m$

Capacity with air in between the plates

$C_0 = \frac{\in_0 A}{d} = \frac{8.85\times10^{-12}\times10^{-2}}{2\times10^{-2}}$

$C_0 = 4.425 \times 10^{-12} farad$

Capacity with dielectric slab in between the plates

$C = \frac{\in_0 A}{d-t\left(1-\frac{1}{K}\right)}$

$= \frac{8.85\times10^{-12}\times10^{-2}}{2\times10^{-2}-10^{-2}\left(1-\frac{1}{5}\right)}$

$C = 7.375 \times 10^{-12} farad$

Capacity with conducting slab in between the plates

$C' = \frac{\in_0 A}{d-t} = \frac{8.85\times10^{-12}\times10^{-2}}{2\times10^{-2}-1\times10^{-2}}$

$C' = \frac{8.85\times10^{-14}}{10^{-2}} = 8.85 \times 10^{-12} farad$

Increase in capacity on introduction of dielectric

$C - C_0 = 7.375 \times 10^{-12} - 4.425 \times 10^{-12}$

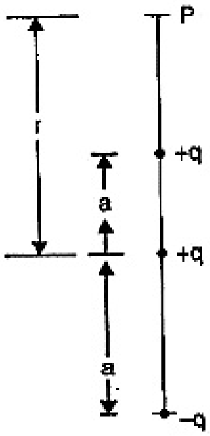
$= 2.95 \times 10^{-12} farad$

Increase in capacity on introduction of conducting slab

$C' - C_0 = 8.85 \times 10^{-12} - 4.425 \times 10^{-12}$

$= 4.425 \times 10^{-12} farad$

12. Potential at p due to the given charge configuration is the sum of the potentials due to charges -q +q and +q. These charges are at distances r +a, r and r - a respectively from the point P.



$\therefore V=\frac{1}{4\pi\varepsilon_0}\frac{-q}{(r+a)}+\frac{1}{4\pi\varepsilon_0}+\frac{1}{4\pi\varepsilon_0}\frac{q}{r-a}$

or $V=\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r}+\frac{2qa}{r^2-a^2}\right)$

if r > > a, r^2 - a^2 = r^2

$\therefore V=\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r}+\frac{2qa}{r^2}\right)$

13. a. Diameter of cylindrical region

= 20 cm = 0.20 m

Clearly, l = 0.20 m, Also $\theta=90^{\circ}$

F = B I lsin$\theta=1.5\times7\times0.20\sin 90^{\circ}N$

= 2.1 N

Using Fleming's left-hand rule, we find that the force is directed vertically downwards.

b. If I_1 is the length of the wire is the magnetic field, then

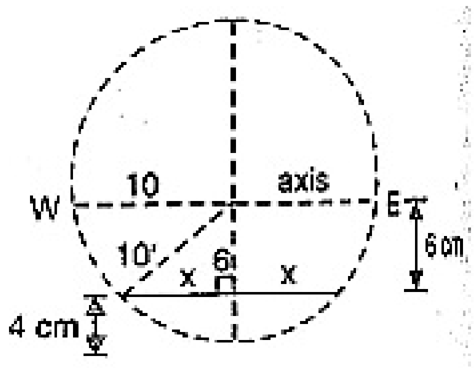
F_1 = BIl_1 sin45^{o}

But l_1 sin45^{o} = 1

$F_1=BI1=1.5\times7\times0.20N=2.1N$

The force is directed vertically downwards by Fleming's left-hand rule.

c. When the wire is lowered by 6 cm, the length of the wire in the cylindrical magnetic field is 2x.



Now x^2 = 10^2 - 6^2

$x=\sqrt{64}=8cm$

2x = 16 cm

$F_2=BIl_2=1.5\times7\times0.16N$

= 1.68 N

The force is directed vertically downwards.

14. The magnetic induction on the axis of the solenoid is given by
$B = \mu(\mu_0 nI)$
$B = \mu\left(\frac{\mu_0}{4\pi}\right)4\pi ni$
where μ is the permeability of the medium, n the number of turns per unit length and i is the current.

a. Magnetic flux $\phi = BA$, since the normal to the area is along the direction of the field,
Given, $\phi = 1.6 \times 10^{-3}Wb$, A = 0.001 = $10^{-3}m^2$
Therefore, $B = \frac{\phi}{A} = \frac{1.6\times 10^{-3}}{10^{-3}} = 1.6Wbm^{-2}$
Since n = 400, i = 5 A and $\frac{\mu_0}{4\pi} = 10^{-7}Hm^{-1}$
We have $1.6 = \mu \times 10^{-7} \times 4\pi \times 400 \times 5$
Which gives, $\mu = \frac{1.6\times 10^7}{4\pi\times 5\times 400} = 636.7 \approx 637$

b. Total number of turns in the solenoid is given by
$N = n \times 1 = 400 \times 0.5 = 200$
Total flux through the solenoid is
$N\phi = 200 \times 1.6 \times 10^{-3} = 0.32Wb$
Self inductance $L = \frac{N\phi}{i} = \frac{0.32}{5}$ = 0.064 H = 64 mH
Alternatively,
$L = \frac{\mu\mu_0 N^2 A}{1} = \mu\mu_0 n^2 1A$
$= 637 \times (4\pi \times 10^{-7}) \times 400 \times 400 \times 0.5 \times 10^{-3}$
$= 6.4 \times 10^{-2}H$ = 64 mH

15. Given, V = 2 kilo volt = 2000 volt
B = 0.15 T

a. If magnetic field is transverse to initial velocity of electron. In this particular case, the velocity vector has no component in the direction of magnetic field.
Force on electron = Bev sin 90°
= Bev
This force acts as the centripetal force
$\therefore BeV = \frac{mv^2}{r}$
or $r = \frac{mv}{eB}$ ...... (1)

But $\frac{1}{2}mv^2 = eV$ ..... (II)

or $v = \sqrt{\frac{2eV}{m}}$

$r = \frac{m}{eB}\sqrt{\frac{2eV}{m}}$ [From I, II]

or $v = \frac{1}{B}\sqrt{\frac{2mV}{e}}$

$= \frac{1}{0.15}\sqrt{\frac{2\times 9.1\times 10^{-31}\times 2000}{1.6\times 10^{-19}}}m$

= 10^{-3}m = 1.0 mm

The electron would move in a circular trajectory of radius 1.0 mm. The plane of the trajectory is normal to B.

b. If v makes an angle 30° with the direction of magnetic field, the velocity can be resolved into $v_\perp$ and $v_{||}$ i.e. v cos 30° and v sin 30° respectively.

Due to $v_\perp$ the electron will move on a circular path. The resultant path will be a combination of straight line motion and circular motion which is called helical.

Thus, $evB\ \sin\theta = \frac{m(v\sin\theta)^2}{r_n}$

For circular motion of radius r_n

$ev_\perp \times B = \frac{mv_\perp^2}{r_n}$

$v_\perp = v\sin\theta$

or $r_n = \frac{m\ v\ \sin\theta}{eB}$

$r_n = \frac{9.1\times 10^{-31}\times 2.65\times 10^{7}\times \sin 30}{1.6\times 10^{-19}\times 0.15}$

$= 0.49 \times 10^{-3}m$ = 0.49mm = 0.5 mm

The linear velocity $v\ \cos\theta$

$= 2.65 \times 10^7 \times \cos 30^\circ$

$= 2.65 \times 10^7 \times \frac{\sqrt{3}}{2}$

$= 2.3 \times 10^7 ms^{-1}$

Thus, the electron moves in a helical path of radius 0.49 mm with a velocity component of $= 2.3 \times 10^7 ms^{-1}$ in the direction of magnetic field.