Solution

Class 12 - Physics

2020-2021 - Paper-2

Section A

1. Torque experienced by the dipole is minimum when angle between $\vec{p}$and $\vec{E}$ is 0^o.

   τ = pE sin 0^o = 0
2. For the electrification of a body, only electrons are responsible. During rubbing, electrons are transferred from glass rod to silk. The glass rod acquires a positive charge and silk acquires an equal negative charge.
3. As the lines of force are pointing towards q_1 as well as q_2, so both q_1 and q_2 must be negative charges.

   OR

   Given, I = 35 A, r = 20 cm, = 0.2 m

   $B=\frac{\mu_0 I}{2\pi r}=\frac{4\pi\times10^{-7}\times35}{2\pi\times0.20}$

   $=3.5\times10^{-5}T$
4. It depends on geometry of the plates, distance between them and nature of dielectric medium separating the plates.
5. Resistivity of materials is the resistance to the flow of an electric current with some materials resisting the current flow more than others.

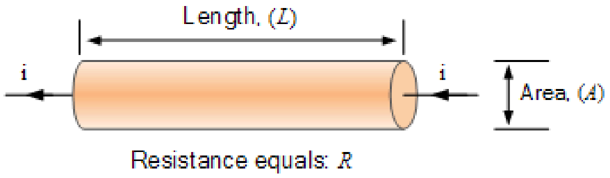
   For same length and same radius, resistance of wire

   $R\propto\rho$ [where ρ is resistivity]

   As, $\rho_{\text{nichrome}} > \rho_{\text{copper}}$

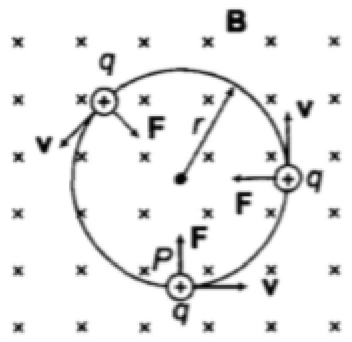
   Hence, resistance of nichrome section is more.

   In series, same current flows through both sections and heat produced = I^2Rt. So, more heat is produced in nichrome section of wire.

   OR

   Ohm's law is not applicable for non-ohmic elements. For example, vacuum tubes, semiconducting diode, liquid electrolyte etc.
6. i. As Resistance is the voltage divided by current, so region having negative slope will have negative resistance. So, DE is the region of negative resistance because the slope of curve in this part is negative.
   ii. BC is the region where Ohm's law is obeyed because in this part, the current varies linearly with the voltage.
7. Consider a charge q moving with velocity v projected perpendicular to the uniform magnetic field B. As v and B are perpendicular, so the perpendicular force, qvB, acts as a centripetal force and produces a circular motion perpendicular to the magnetic field as shown in the Figure.

   Thus,

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

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

where, r = radius of the circular path followed by charge projected perpendicular to a uniform magnetic field.

8. When a charge moves parallel or antiparallel to the direction of the magnetic field, the force acting on it is zero or minimum.
9. Given , $G=12\Omega\ I_g=3mA=3\times10^{-3}A$, V = 18 volt, R = ?

   By using formula

   V = $I_g(R + R_g)$

   or $\frac{V}{I_g}=R+R_g$

   or $R=\frac{V}{I_g}-R_g=\frac{18}{3\times10^{-3}}-12$

   $R=6\times10^3-12=5988\Omega$

OR

Here n = 300 turns/m, I = 5 A

$\therefore$ B = $\mu_0 nI=4\pi\times10^{-7}\times300\times5$

= 1.9×10^{-3} T

10. A small resistance connected in parallel with a galvanometer to convert it into ammeter is called shunt. Its SI unit is ohm.
11. **(d)** A is false and R is also false

    Explanation: If a charged particle is entering in a perpendicular electric field, then the force on charged particle,

    $qE=\frac{mv^2}{r}$ or $r=\frac{mv^2}{qE}=\frac{2\text{KE}}{qE}$

    It means, $r\propto\frac{1}{q}$

    or $\frac{n_1}{r_2}=\frac{q_2}{q_1}=\frac{e}{e}$ = 1 i.e., $r_1 = r_2$

    i. e., paths of electron and proton will be equally curved.
12. **(a)** Both A and R are true and R is the correct explanation of A

    Explanation: The magnetic field at distance from centre of loop, can be resolved into a component along x-axis and perpendicular to it. When perpendicular components are summed over the whole loop, the result is zero. That is, by symmetry any element on one side of the loop sets up a perpendicular component that cancels the component set up by an element dimetrically opposite to it.
13. **(c)** A is true but R is false

    Explanation: Assertion is false but reason is true. Consider a conductor of length l and area of cross-section A. Time taken by the free electrons to cross the conductor, t = $\frac{l}{v_d}$.

    Hence, current, $I=\frac{q}{t}=\frac{Alne}{\frac{l}{v_d}}$

    or I = $neAv_d$ or I ∞ v_d

    Thus, current is directly proportional to drift velocity.
14. **(b)** Both A and R are true but R is NOT the correct explanation of A

    Explanation: Coulomb attraction exists even when one body is charged and the other is uncharged.

Section B

15. i. (c) 10^{-6} F
    ii. (d) Larger plate area and shorter distance between plates
    iii. (c) potential energy.
    iv. (d)8μC
    v. (a)$\frac{Q^2}{2A\in_0}$
16. i. (b) Decreasing the potential gradient
    ii. (b) $\frac{\varepsilon_1}{\varepsilon_2}=\frac{l_1}{l_2}$
    iii. (c) Joystick
    iv. (a) Because there is some potential drop across the cell due to its small internal resistance
    v. (a) Small potential gradient

Section C

17. The electric field due to the charges will have a net field at point (0,0,c). We have $\vec{E}_{net} = \overrightarrow{E_1} + \overrightarrow{E_2}$

$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{r_1^3} r_1 + \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{r_2^3} \overrightarrow{r_2}$

where, $\overrightarrow{r_1} = -a\hat{i} + c\hat{k}$

and $\overrightarrow{r_2} = -b\hat{j} + c\hat{k}$

$\vec{E}_{net} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1(-a\hat{i}+c\hat{k})}{(a^2+c^2)^{3/2}} + \frac{q_2(-b\hat{j}+c\hat{k})}{(b^2+c^2)^{3/2}}\right].$

18. If n identical capacitors, each of capacitance C are connected in series combination then equivalent capacitance, $C_s = \frac{C}{n}$ and when connected in n parallel combination, then equivalent capacitance, C_p = nC

According to the problem,

$C = nC_s = 3 \times 1\mu F = 3\mu F$ i.e. the capacitance of each capacitor is $3\mu F$.

Now for the parallel combination,

$C_p = nC = 3 \times 3 = 9\mu F$

This is the net capacitance when the capacitors are connected in parallel.

Also, for same voltage, energy stored in the capacitor is given by

$U = \frac{1}{2}CV^2$ [for constant]

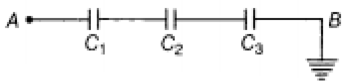
For same voltage, $U \propto C$

$\Rightarrow \quad \frac{U_s}{U_p} = \frac{C_s}{C_p} \Rightarrow \frac{U_s}{U_p} = \frac{C/n}{nC} = \frac{1}{n^2}$

$\Rightarrow \quad \frac{U_s}{U_p} = \frac{1}{(3)^2} = \frac{1}{9} \Rightarrow \quad \frac{U_s}{U_p} = \frac{1}{9}$

or $U_s : U_p = 1 : 9$

OR



For a series combination of three capacitors C_1, C_2 and C_3, the equivalent capacitance C_{eq} will be

$\frac{1}{C_{\text{ca}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \Rightarrow \frac{1}{C_{eq}} = \frac{1}{20} + \frac{1}{30} + \frac{1}{15}$

$\Rightarrow \frac{1}{C_{\text{eq}}} = \frac{3+2+4}{60} \Rightarrow C_{\text{eq}} = \frac{60}{9}\mu\text{F} = \frac{20}{3}\mu\text{F}$

Total charge of the system of three capacitors,

$Q = C_{\text{eq}}V = \frac{20}{3} \times 10^{-6} \times 90$

$\Rightarrow Q = 600\mu C$

Charge on each capacitor will remain same as they are in series with the battery. Now, potential drop across the capacitor C_2,

$V_2 = \frac{Q}{C_2} = \frac{600\times10^{-6}}{30\times10^{-6}} = 20\text{V}$

Hence stored electrical potential energy of capacitor C_2 is $U_2 = \frac{1}{2}C_2V_2^2$

$U_2 = \frac{1}{2} \times 30 \times 10^{-6} \times (20)^2 = 6 \times 10^{-3}\text{J}$

19. R = 290 ohm

The current through the potentiometer wire

$= \frac{3\text{V}}{(290+10)\Omega}$ = 10^{-2} A

$\therefore$ Potential drop per unit length of the potentiometer wire,

$\phi = \frac{10^{-2}\times10}{400}$

$= \frac{1}{4} \times 10^{-3}$ V/cm

$V = \phi l = \frac{1}{4} \times 10^{-3} \times 240$ volt

= 6V $\times 10^{-2}$ V

= 60 millivolt

= 60 mV

20. The resistance of a platinum wire at ice point R_0 = 5 Ω,

The resistance of a platinum wire at steam point R_{100} = 5.23 Ω and

When the thermometer is inserted in a hot bath the resistance of the platinum wire is R_t = 5.795 Ω

Now, $t = \frac{R_t - R_0}{R_{100} - R_0} \times 100$, $R_t = R_0(1 + \alpha t)$

$= \frac{5.795-5}{5.23-5} \times 100$

$= \frac{0.795}{0.23} \times 100 = 345.65^{\circ}\mathrm{C}$

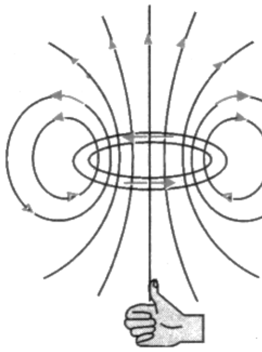
21. i. According to Biot-Sarvart's law, the magnetic field due to a current element vector (dl) carrying current I at a distance of r is given by:

$\overrightarrow{dB} = \frac{\mu_0}{4\pi} \frac{I(\overrightarrow{dl} \times \vec{r})}{r^3}$

ii. 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:



22. Derivation of ratio of the radii of the circular paths $r = \frac{mv}{qB}$

But $\frac{p^2}{2m} = k \Rightarrow p = \sqrt{2mk}$ = mv

$\Rightarrow \quad \frac{r_\alpha}{r_p} = \frac{\sqrt{2m_\alpha k_\alpha}/q_a B}{\sqrt{2m_p k_p}/q_p B}$

But $k_\alpha = k_p$

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

Since, charge of alpha particle $q_\alpha = 2q_p$

mass of alpha particle $m_\alpha = 4m_p$

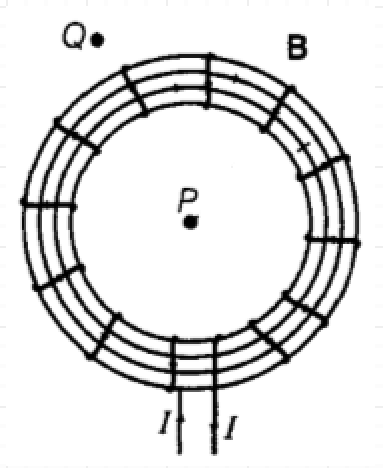
$\Rightarrow \quad \frac{r_\alpha}{r_p} = \frac{q_p}{2q_p}\sqrt{\frac{4m_p}{m_p}}$ = 1:1

23. The velocity v of the particle is along the x-axis, while B, the magnetic field is along the y-axis, so $v \times B$ is along the z-axis (screw rule or right-hand thumb rule). So, depending upon the charge force is given by:
   a. for electron it will be along –z axis.
   b. for a positive charge (proton) the force is along +z axis.

OR

Figure shows the toroid, which can be viewed as an endless solenoid in the form of ring.
Magnetic Field at point P and Q is zero. To calculate the magnetic field in the interior of it, Ampere's circuital law can be used. Let I be the current, r be the mean radius, N number of turns in toroid and B be the magnetic field inside the toroid.
Then, the line integral of the magnetic field around the closed path of the circle of radius r is

$\oint B.dl = B.\ 2\pi r$



Now, from Ampere's circuital law,
$B.\ 2\pi r$ = $\mu_o NI$
Thus, $B\ =\ \frac{\mu_o NI}{2\pi r}$
Comparing with solenoid, if n be the number of turns/unit length, the total number of turns,
N = 2πr n
Thus, $B = \mu_0 nI$

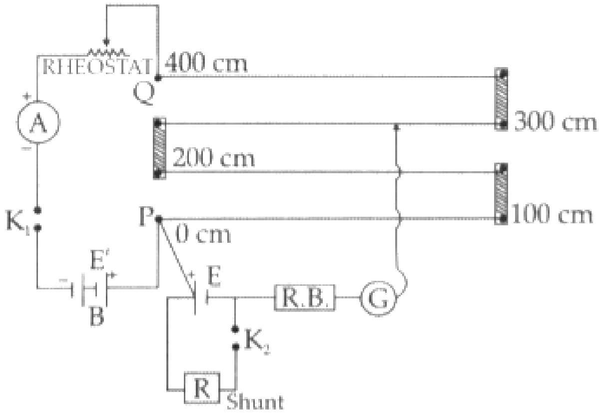
24. The required expression is $\vec{F} = q(\vec{v} \times \vec{B})$
The magnetic force, at all instants, is, therefore, perpendicular to the instantaneous direction of $\vec{v}$, which is also the instantaneous direction of displacement ($\overrightarrow{ds}$).
Since F is perpendicular to ($\overrightarrow{ds}$), at all instants, work done =($\vec{F}.\overrightarrow{ds}$) as cos$90^0$ is zero.
There being no work done, there can be no change in the magnitude of $\vec{v}$.
From $\vec{F} = q(\vec{v} \times \vec{B})$ we get
$|\vec{F}|$ = qvB sin θ
$\therefore$ F = B if q = 1, v = 1 and θ = $\frac{\pi}{2}$
Hence, the magnetic field, $\vec{B}$ at a point equals one tesla if a charge of one coulomb, moving with a velocity of 1 m/s, along a direction perpendicular to the direction of $\vec{B}$, experiences a force of one newton.

OR

Condition under which, the particle will continue moving along the x-axis,electric force is equal to magnetic force:-
qE = qvB
v = $\frac{E}{B}$
Trajectory becomes helical about the direction of the magnetic field.

25. i. The expression for the magnetic field at the centre of a circular current-carrying coil,
$B = \mu_0 NI/2r$
where N is the number of turns of coil, I is current flowing in the coil, r is the radius of circular coil and μ_o is permeability of free space.
ii. Magnetic moment is given by,
$M = NIA = NI\left(\pi r^2\right)$
$M = \pi NIr^2$

Section D

26. 

If key K_2 is open and key K_1 is closed and the null point is obtained at a distance l_1 from Q,

$E = Kl_1$ ...(i)

If key K_2 is closed and key K_1 is the open and null point is obtained at a distance l_2 from Q,

$V = Kl_2$ ...(ii)

On dividing equation (i) by (ii)

$\frac{E}{V} = \frac{l_1}{l_2}$, E = I(R+r) and V = IR

$\frac{R+r}{R} = \frac{l_1}{l_2}$

Hence, $r = \left(\frac{l_1 - l_2}{l_2}\right) R$

where,

R = shunt resistance in parallel with the cell,

l_1 and l_2 = balancing length without and with shunt

r = internal resistance of the cell.

27. Each branch of the network is assigned an unknown current to be determined by the application of Kirchhoff's rules. To reduce the number of unknowns at the outset, the first rule of Kirchhoff is used at every junction to assign the unknown current in each branch. (current entering into the junction is equal to current leaving the junction) We then have three unknowns I_1, I_2 and I_3 which can be found by applying the second rule of Kirchhoff to three different closed loops. Kirchhoff's second rule for the closed-loop ADCA gives,

$10 - 4(I_1 - I_2) + 2(I_2 + I_3 - I_1) - I_1 = 0$ ...(i)

that is, $7I_1 - 6I_2 - 2I_3 = 10$

For the closed-loop ABCA, we get

$10 - 4I_2 - 2(I_2 + I_3) - I_1 = 0$

that is, $I_1 + 6I_2 + 2I_3 = 10$ ...(ii)

For the closed-loop BCDEB, we get

$5 - 2(I_2 + I_3) - 2(I_2 + I_3 - I_1) = 0$

that is, $2I_1 - 4I_2 - 4I_3 = -5$ ...(iii)

Equations (i, ii, iii) are three simultaneous equations in three unknowns. These can be solved by the usual method to give

$I_1 = 2.5A$, $I_2 = \frac{5}{8}$ A, $I_3 = 1\frac{7}{8}$ A

The currents in the various branches of the network are

AB : $\frac{5}{8}$A, CA : $2\frac{1}{2}$ A, DEB : $1\frac{7}{8}$ A

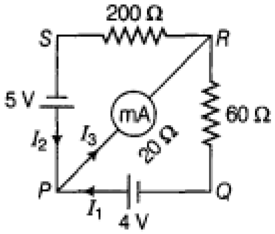
AD : $1\frac{7}{8}$A, CD : 0 A, BC : $2\frac{1}{2}$ A

It is easily verified that Kirchhoff's second rule applied to the remaining closed loops does not provide any additional independent equation, that is, the above values of currents satisfy the second rule for every closed loop of the network. For example, the total voltage drop over the closed-loop BADEB

$5\mathrm{V} + \left(\frac{5}{8} \times 4\right)\mathrm{V} - \left(\frac{15}{8} \times 4\right)\mathrm{V}$ equal to zero, as required by Kirchhoff's second rule.

OR

The given diagram is shown below



Applying Kirchhoff's second law i.e. KVL to the loop PRSP,

$-I_3 \times 20 - I_2 \times 200 + 5 = 0$

$\Rightarrow$ $4I_3 + 40I_2 = 1$ ...(i)

For loop PRQP,

$-20I_3 - 60I_1 + 4 = 0$

$\Rightarrow$ $5I_3 + 15I_1 = 1$ ....(ii)

Applying Kirchhoff's first law i.e. KCL we get,

$I_3 = I_1 + I_2$ ....(iii)

From Eqs. (i) and (iii), we have

$4I_1 + 44I_2 = 1$....(iv)

Also from eqs. (ii) and (iii) , we have

$20I_1 + 5I_2 = 1$....(v)

On solving eqs (iii), (iv) and (v) we get

$I_3 = \frac{11}{172}A = \frac{11000}{172}\text{mA}$

$I_2 = \frac{4000}{215}\text{mA}, I_1 = \frac{39000}{860}\text{mA}$

$\therefore$ The reading in the millimeter will be $\frac{11000}{172}\text{mA}$

28. i. The force experienced, $\vec{F} = q(\vec{v} \times \vec{B})$

The charge will go undeflected when $\vec{v}$ is parallel or antiparallel to $\vec{B}$

$\because \vec{F} = 0$

[Alternatively, If v makes an angle of 0° or 180° with $\vec{B}$]

ii. The KE of electron

KE = $\frac{e^2r^2B^2}{2m}$ = eV ,V is equal to 10^4 V.

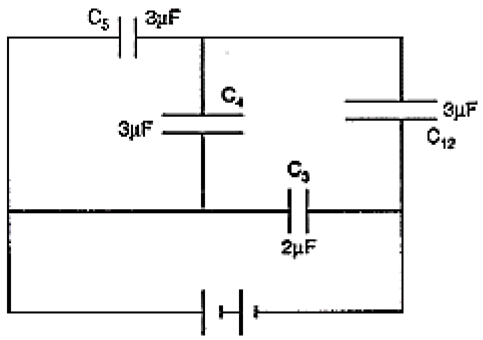
$\therefore r = \frac{1}{B}\sqrt{\frac{2mV}{e}}$ = $\left[\sqrt{\frac{2\times 9.1\times 10^{-31}\times 10^4}{1.6\times 10^{-19}}} \times \frac{1}{0.04}\right]$

$= 8.4 \times 10^{-3}$ m

29. In the given figure the capacitors C_1 and C_2 are in parallel combination.

$C_{12} = 1 + 2 = 3\mu F$

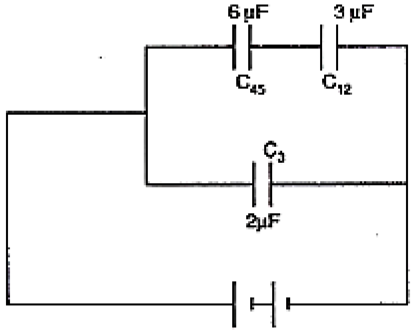
The circuit reduces to



Capacitors C_4 and C_5 are in parallel combinations

$\therefore C_{45} = 3 + 3 = 6\mu F$

Now, the circuit reduces to



Capacitors C_{12} and C_{45} are in series combinations.

$\frac{1}{C_{1245}} = \frac{1}{6} + \frac{1}{3}$

$\therefore C_{1245} = \frac{3\times6}{3+6} = \frac{18}{9}2\mu F \left[\because C_S = \frac{C_1\cdot C_2}{C_1+C_2}\right]$

Now, C_{1245} and C_3 are in parallel combinations, thus equivalent capacitance is

$\therefore C = C_{1245} + C_3 = 2 + 2 = 4\mu F$

Total charge q = CV

$= 4\times10^{-6}\times100 = 4\times10^{-4}C$

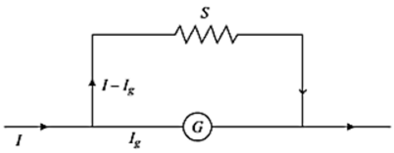
Energy stored $= \frac{1}{2}CV^2$

$= \frac{1}{2}\times4\times10^{-6}\times(100)^2$

$= 2\times10^{-6}\times10^4 = 2\times10^{-2}J$

OR

i. **Current sensitivity:** It is defined as the deflection produced in the galvanometer when a unit current flows through it.
 I = k n A B θ, Where N = no. of turns in the coil, B = magnetic field, A = area of the coil of galvanometer
 Or The sensitivity (i.e. current sensitivity) of a galvanometer is defined as the angle of deflection per unit current flowing through it.

ii. a. 

Galvanometer can be converted into an ammeter by connecting a shunt (small resistance) S with parallel to the galvanometer.

As galvanometer and shunt are connected in parallel, so,

Potential across G = Potential across S

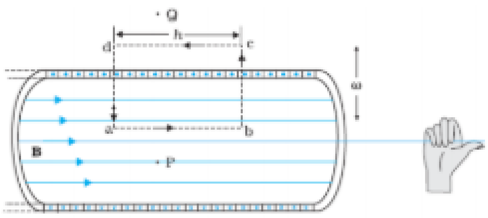
I_g G = (I - I_g)S

$\therefore$ S = $\frac{I_g}{I-I_g}G$

b. Effective resistance of this ammeter will be

$\frac{1}{R_s} = \frac{1}{G} + \frac{1}{S}$

R_A = $\frac{GS}{G+S}$

30. i. 

Consider the loop abcd. Along cd, the magnetic field is zero. Along bc and ad, the field component is zero, hence makes no contribution. Let field along ab be B. Let n be the number of turns per unit length. Thus, the total number of turns is nh.

The enclosed current is I_e = I(nh)

From Ampere's circuital law,

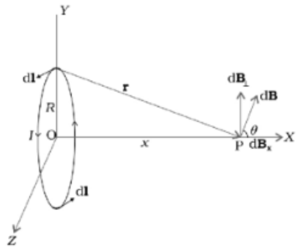
BL = μ_o I_e

Bh = μ_o I (nh) [here L = h]
Therefore, magnetic field B = μ_o n I
Its direction is given by right hand thumb rule.

ii. The toroid is a hollow circular ring having large number of turns closely wound. It is viewed as solenoid bent into circular shape.
The magnetic field, B of toroid having N turns is,
$B=\frac{\mu_o\ N\ I}{2\pi\ r}$
where N = $2\pi r\ n$
Also, Solenoid behaves like a bar magnet whereas Toroid does not.

Section E

31. i. Consider a circular loop having current I of radius R in y-z plane. Let O be the origin. Let P be the point on x-axis at the distance x from the origin O where the magnetic field is to be calculated. Consider dl element of the loop.



According to Biot Savart Law, the magnitude dB of the magnetic field due to dl is given by,
$|\overrightarrow{\mathrm{dB}}| = \frac{\mu_0}{4\pi}\frac{I\ dl\ \sin 90^\circ}{r^2}$
Where r = $\sqrt{x^2+R^2}$
$|\overrightarrow{dB}| = \frac{\mu_0}{4\pi}\frac{I\ dl}{(x^2+R^2)}$
The direction of $\overrightarrow{dB}$ is perpendicular to $\overrightarrow{dl}$ and $\overrightarrow{r}$.
It has components dB_x and $\mathrm{dB}_\perp$. The components $\mathrm{dB}_\perp$ due to the whole coil cancel out in pairs.
Net field B = $\int \mathrm{dB_X} = \int \mathrm{dB}\cos\theta$
Now, cos $\theta=\frac{R}{(x^2+R^2)^{1/2}}$
Therefore, $\mathrm{dB_X} = \frac{\mu_0\ I\ dl}{4\pi}\frac{R}{(x^2+R^2)^{3/2}}$
The summation of elements dl over the circular loop yields the circumference, $2\pi R$
Thus, net magnetic field (in vector form),
$\vec{B} = \frac{\mu_0 IR^2}{2(x^2+R^2)^{\frac{3}{2}}}\hat{i}$
At, x = 0,
$B=\frac{\mu_o\ I}{2R}\ \hat{i}$

ii. From above, for circular loop, the magnitude of magnetic field B is
$B=\frac{\mu_o\ I}{2R}$
For the semi-circular loop, the magnitude of the net magnetic field, B = $\frac{\mu_0 \mathrm{I}}{4\mathrm{R}}$ i.e. half of the circular loop
= $\frac{4\pi\times10^{-7}\times5}{4\times2\times10^{-2}}$
= 7.85 $\times$ 10^{-5} T
And the field is directed inwards perpendicular to the plane of the page.

OR

Here it is given that V = 2.0 kV = 2.0 $\times$ 10^3 volt; B = 0.15 T
Suppose e and m are the charge and mass of electron respectively. When the electron is accelerated through a potential difference of V, velocity v acquired by the electron is found as under:
$eV=\frac{1}{2}mv^2$ or $v=\left(\frac{2eV}{m}\right)^{1/2}=\left(\frac{2\times1.6\times10^{-19}\times2.0\times10^3}{9.1\times10^{-31}}\right)^{1/2}$ = 2.65 $\times$ 10^7 ms^{-1}

a. Force on the electron due to transverse magnetic field F_m = evB sin 90° = evB. This force is perpendicular to $\vec{v}$ as well as $\vec{B}$. Therefore the force will change the direction of $\vec{v}$ but not the magnitude (speed) of $\vec{v}$. Obviously, it is the centripetal force and will cause the electron to move in a circle i.e. the trajectory of the electron will be **circular**. The radius of the circular path is given by;

$evB = \frac{mv^2}{r}$ or $r = \frac{mv}{eB} = \frac{9.1\times10^{-31}\times2.65\times10^{7}}{1.6\times10^{-19}\times0.15}$ = 10^{-3} m = 1 mm

b. When the initial electron velocity v makes an angle θ with the direction of magnetic field, then it can be resolved into two rectangular components viz.

(i) v_1 = v sinθ perpendicular to the magnetic field

(ii) v_2 = v cosθ along the direction of magnetic field

Due to the perpendicular component v sinθ, the magnetic force acting on the electron moves it in a circular path. However, no magnetic force acts on the electron due to the component v cosθ so that electron moves in a straight line due to component v cosθ. Therefore, the electron will cover circular path as well as linear path. The result is that trajectory (path) of the electron will be **helical**.

The radius of the helical path is given by:

$$\frac{m(v\sin\theta)^2}{r} = e(v\sin\theta)B$$

or $r = \frac{mv\sin\theta}{eB} = \frac{9.1\times10^{-31}\times2.65\times10^{7}\sin30^\circ}{1.6\times10^{-19}\times0.15}$ = 0.5 × 10^{-3}m = 0.5 mm

32. a. Given, that $B = \frac{\mu_0 I R^2 N}{2(x^2+R^2)^{3/2}}$ (Axial line)

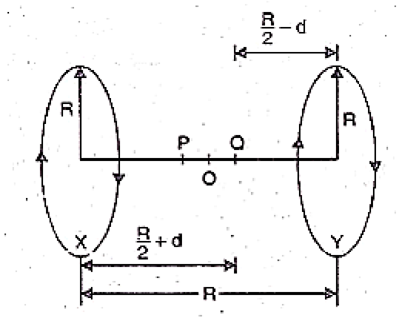
Putting x = 0 (centre of coil),

$$B = \frac{\mu_0 I R^2 N}{2R^3}$$

or $B = \frac{\mu_0 I N}{2R}$

which is same as the standard result

b. In figure, O is a point which is midway between the two coils X and Y. Let OQ = d.



Let B_X be the magnetic field at Q due to coil X. Then,

$$B_x = \frac{\mu_0 N I R^2}{2\left[\left(\frac{R}{2}+d\right)^2+R^2\right]^{3/2}}$$

If B_y is the magnetic field at P due to coil Y, then,

$$B_y = \frac{\mu_0 N I R^2}{2\left[\left(\frac{R}{2}-d\right)^2+R^2\right]^{3/2}}$$

The currents in both the coils X and Y are flowing in the same direction. So, the resultant field is given by $B = B_X + B_y$

$$B = \frac{\mu_0 N I R^2}{2\left[\left(\frac{R}{2}+d\right)^2+R^2\right]} + \frac{\mu_0 N I R^2}{2\left[\left(\frac{R}{2}-d\right)^2+R^2\right]^{3/2}}$$

$$B = \frac{\mu_0 N I R^2}{2}\left[\frac{1}{\left[\left(\frac{R}{2}+d\right)^2+R^2\right]^{3/2}} + \frac{1}{\left[\left(\frac{R}{2}-d\right)^2+R^2\right]^{3/2}}\right]$$

$$B = \frac{\mu_0 N I R^2}{2}\left[\frac{1}{\left[\frac{R^2}{4}+d^2+Rd+R^2\right]^{3/2}} + \frac{1}{\left[\frac{R^2}{4}+d^2-Rd+R^2\right]^{3/2}}\right]$$

$B=\frac{\mu_0 NIR^2}{2}\left[\frac{1}{\left[\frac{5R^2}{4}+Rd\right]^{3/2}}+\frac{1}{\left[\frac{5R^2}{4}-Rd\right]^{3/2}}\right]\because d^2<<R^2$

$B=\frac{\mu_0 NIR^2}{2\left(\frac{5}{4}R^2\right)^{3/2}}\left[\frac{1}{\left[1+\frac{4}{5}\frac{d}{R}\right]^{3/2}}+\frac{1}{\left[1-\frac{4}{5}\frac{d}{R}\right]^{3/2}}\right]$

$=\frac{\mu_0 NIR^2}{2\left(\frac{5}{4}\right)^{3/2}R^3}\left[\left(1-\frac{3}{2}\times\frac{4}{5}\times\frac{d}{R}\right)+\left(1+\frac{3}{2}\times\frac{4}{5}\times\frac{d}{R}\right)\right]$

$=\frac{\mu_0 NI}{R\left(\frac{5}{4}\right)^{3/2}}$

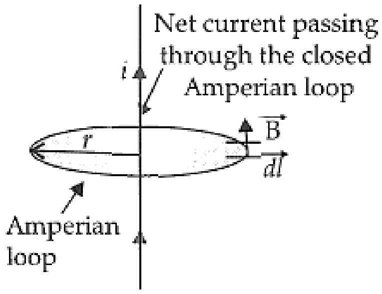
$=0.72\frac{\mu_0 NI}{R}$(approx)

Hence proved.

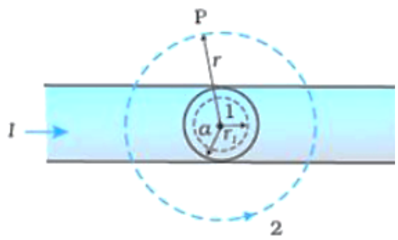
OR

i. Ampere's circuital law states that the line integral of the magnetic field around a closed path is $\mu_0$times of total current enclosed by the path, $\oint\vec{B}\cdot\overrightarrow{dl}=\mu_0 I$ Or
Ampere's circuital law can be written as the line integral of the magnetic field surrounding closed-loop equals to the number of times the algebraic sum of currents passing through the loop.

where,
B = magnetic field
dl = infinitesimal segment of the path
μ_0 = permeability of free space.
I = enclosed electric current by the path Magnetic field at a point will not depend on the shape of the Amperian loop and will remain the same at every point on the loop.



ii. Consider the case r < a. The Amperian loop is a circle labelled 1 (fig.)



For this loop, taking the radius of the circle to be r
Let this loop contains charge I_e. This current enclosed I_e is not I, but is less than this value.
Since the current distribution is uniform, the current enclosed is
$I_e=I\left(\frac{\pi r^2}{\pi a^2}\right)=I\left(\frac{r^2}{a^2}\right)$
Using Ampere's law,
$B.2\pi r=\mu_0 I\left(\frac{r^2}{a^2}\right)$
$B=\frac{\mu_0 I}{2\pi}\left(\frac{r}{a^2}\right)$
So, $B\propto r\quad for\ r<a$
Consider the case r > a. The Amperian loop, labelled 2, is a circle concentric with the cross-section. For this loop,
$L=2\pi r$

I_e = Current enclosed by the loop = I

The result is the familiar expression for a long straight wire

$B.2\pi r = \mu_0 I$

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

$B \propto \frac{1}{r}$ when $r > a$

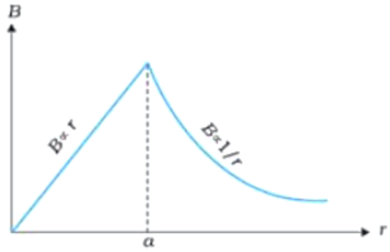


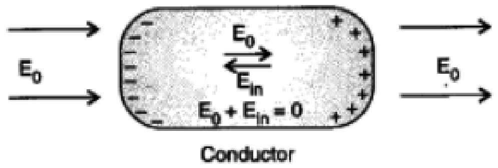
Fig. shows a plot of the magnitude of B with distance r from the centre of the wire. The direction of the field is tangential to the respective circular loop (1 or 2) and given by the right-hand rule.

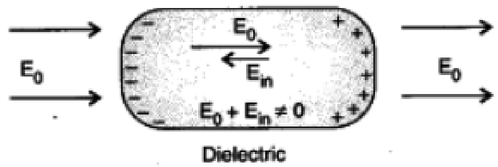
33. i. a. In the presence of electric field, the free charge carriers, in a conductor, move the charge distribution in the conductor re-adjusting itself so that the net electric field within the conductor becomes zero.

b. In a dielectric, the external electric field induces a net dipole moment, by stretching/reorienting the molecules. The electric field, due to this induced dipole moment, opposes, but does not exactly cancel, the external electric field.

Polarisation: Induced dipole moment, per unit volume, is called the polarization. For linear isotropic dielectrics having a susceptibility χ_c, we have

P = χ_c E





ii. a. Net force on the charge $\frac{Q}{2}$, placed at the centre of the shell is zero.

Force on charge 2Q kept at point A

F = E $\times$ 2Q

$= \frac{1\left(\frac{3Q}{2}\right)2Q}{4\pi\varepsilon_0 r^2} = \frac{3Q^2}{4\pi r^2 \varepsilon_0}$

b. Electric flux through the shell,

$\phi = \frac{Q}{2\varepsilon_0}$ (because charge enclosed is Q/2)

OR

Let R' be the resistance of potentiometer wire.In an experiment with a potentiometer, V_B=10V. R is adjusted to the 50Ω

$\therefore$ Variable resistance, R=50 Ω

I is the current in primary circuit which is at E_B = 10V so that effective resistance is =50+R'

$\therefore I = \frac{V_B}{R+R'} \Rightarrow \frac{10}{50+R'} = \mathrm{I}$ (in primary circuit) ...I

Potential difference across the wire of potentiometer

V' = IR'

From I $V' = \frac{10R'}{50+R'}$ II

As with R' = 50Ω resistance, null point cannot be obtained by 8 Volt.

So, V < 8 Volt.

$\frac{10R'}{50+R'}$ (No. balance point)
As 50 + R’ is positive so we can multiply above equation by positive number and we get 10R’<400+8R’
2R’ < 400
R’ < 200 ...III
Similarly, null point obtained by R = 10Ω. Then V” > 8 at balance point. So it is possible when $\frac{10R'}{10+R'} > 8$ (as from I, R = 10)
Similarly, multiply above equation by positive number 10 + R’ to both sides
10R’ > 80 + 8R
2R’ > 80
R’ > 40 ...IV
As the null point is obtained on 4th segment or at $\frac{3}{4}$ of total length So at $\frac{3}{4}$ R’ (No. balance point)
OR $\frac{10\times\frac{3}{4}R'}{10+R'} < 8$ (At balance point)
So, 7.5R’ < 80 + 8R'
-0.5R’ < 80
-R' < 160
R' > -160
R’ can never be negative so, -160Ω is considered 160Ω
So 160 < R' < 200 ...V
Any R' between 160Ω and 200Ω will achieve null point.
Since the null point is on last 4th segment of potentiometer wire, so the potential drop across 400cm wire > 8 Volt. so that potential gradient
So, K*400cm > 8V (At balance point)
$K > \frac{8}{400} Volt/cm$
$K > \frac{8}{4} Volt/m$
K > 2 Volt/m
As balance point is at 4^{th} wire, so no balance point at 300cm= 3m,
K.3 < 8 (No. balance point)
$K < \frac{8}{3} Volt/m$
$K < 2\frac{2}{3} Volt/m$
So, $2\frac{2}{3} V/m > K > 2 Volt/m$