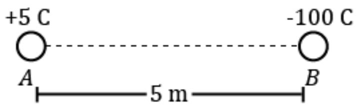
JEE Main Part Test 3

Subject: Physics | Class: Stand

1. Find the distance of the point from A where the net electric field will be zero for the given configuration.



A. $0.4 \mathrm{~m}$ towards left

B. $1.4 \mathrm{~m}$ towards left

C. $2.4 \mathrm{~m}$ towards left

D. $3.4 \mathrm{~m}$ towards left

For the unlike charges, the net electric field is zero near smaller charge.
Let us say that the electric field is zero at a distance x from A to the left.

The electric field due to $5 \mathrm{~C}$ charge is $\frac{5k}{x^2}$ towards left.

The electric field due to $-100 \mathrm{~C}$ charge is $\frac{100k}{(x+5)^2}$ towards right.

For the net electric field to be zero these two terms must be equal.

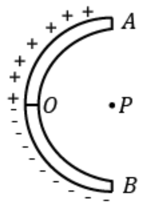
$$\frac{5k}{x^2} = \frac{100k}{(x+5)^2}$$

Simplifying this we get,

$$\Rightarrow x = \frac{5}{\sqrt{\frac{100}{5}} - 1}$$

$\Rightarrow x = 1.4 \mathrm{~m}$ [from A towards left]

2. A thin Non-conducting rod is bent into a semicircle of radius r. A charge $+Q$ is uniformly distributed along the upper half and a charge $-Q$ is uniformly distributed along the lower half, as shown in figure. Find the electric field E at P.



A. $\frac{Q}{\pi^2\epsilon_0 r^2}$

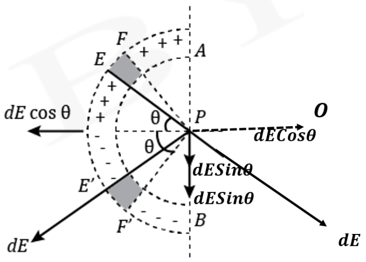
B. $\frac{2Q}{\pi^2\epsilon_0 r^2}$

C. $\frac{4Q}{\pi^2\epsilon_0 r^2}$

D. $\frac{Q}{4\pi^2\epsilon_0 r^2}$

Take PO as the x-axis and PA as the y-axis.

Consider two small elements EF and E'F' of width $d\theta$ at angular distance θ above and below PO, as shown in figure.



The magnitude of the field at P due to either elements is

$$dE = \frac{1}{4\pi\epsilon_0}\frac{r d\theta \times \left(\frac{Q}{\frac{\pi r}{2}}\right)}{r^2}$$

$$\Rightarrow dE = \frac{Q}{2\pi^2\epsilon_0 r^2} d\theta$$

Resolving the fields, we find that the components along PO sum up to zero, and hence the resultant field is along PB.

Therefore, field at P due to pair of elements is $2dE\sin\theta$

Therefore, the total electric field at P due the semicircular arc is,

$$E = \int_0^{\frac{\pi}{2}} 2dE\sin\theta$$

Substituting the value of dE, we get

$$E = \int_0^{\frac{\pi}{2}} \frac{Q}{\pi^2\epsilon_0 r^2}\sin\theta\, d\theta$$

$$\therefore E = \frac{Q}{\pi^2\epsilon_0 r^2}$$

Hence, option (a) is the correct answer.

Alternate solution:

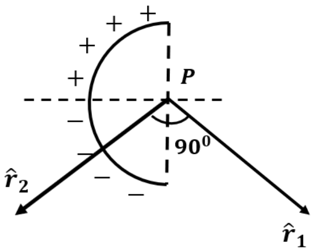
Electric field due to a quarter ring carrying charge $+Q$ is given by

$$\overrightarrow{E}_1 = \frac{\sqrt{2}k\lambda}{r}\hat{r}_1$$

Electric field due to a quarter ring carrying charge $-Q$ is given by

$$\overrightarrow{E}_2 = \frac{\sqrt{2}k\lambda}{r}\hat{r}_2$$

Since, $\hat{r}_1$ is perpendicular to $\hat{r}_2$



The net electric field at point P is given by

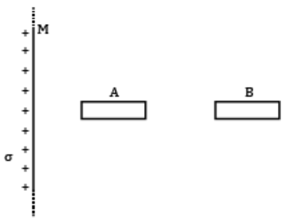
$$|E| = \sqrt{(E_1)^2 + (E_2)^2}$$

$\Rightarrow |E| = \frac{2k\lambda}{r}$

Since, $\lambda = \frac{Q}{\left(\frac{\pi r}{2}\right)}$, we can rewrite the above equation as,

$E = 2 \times 2 \times \frac{Q}{4\pi\varepsilon_0 \times \pi r \times r} = \frac{Q}{\pi^2\epsilon_0 r^2}$

3. A large non-conducting sheet M is given a uniform charge density. Two uncharged small metal rods A and B are placed near the sheet as shown in f
Which of the following options is incorrect?



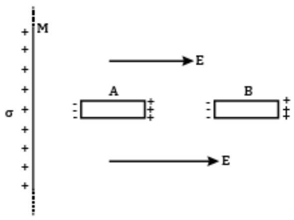
A. M attracts A

B. M attracts B

C. A attracts B

D. B repels A ✔

Charges will be induced in the small metal rods A and B due to the large non-conducting sheet M. The charge distribution is as shown in figure.



From the figure, we can conclude that
(1) M attracts A
(2) M attracts B
(3) A attracts B

Hence, statement in option (d) is incorrect.

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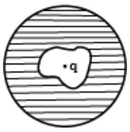
4. A charge $+q$ is kept inside the cavity present in a solid conducting sphere, as shown in figure.

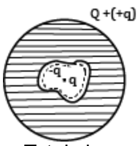


If the sphere is given a charge Q, then total charge appearing on outer surface of sphere will be:

- **A.** $Q-q$
- **B.** Q
- **C.** $-(q+Q)$
- **D.** $Q+q$

Let us consider a spherical Gaussian surface passing through region of conductor outside cavity.

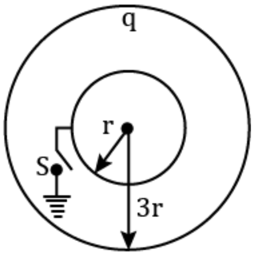
Electric field inside metal is always zero i.e $E=0$
On applying Gauss law,
$\oint \vec{E}.d\vec{A}=\frac{q_{en}}{\epsilon_0}$
Where, $q_{en}=$ charge enclosed by the Gaussian surface.
$dA=$ Elemental Gaussian surface area
Thus, $q_{en}=0$
This is only possible when a charge $-q$ is induced at the inner surface of the cavity.
The charge Q given to sphere will remain at its outermost surface and as per law of conservation of charge, +q will also appear on the outer surface o
sphere. The $+q$ charge will quickly redistribute uniformly on the surface.



$\therefore$ Total charge appearing at outer surface $=Q+q$
Hence, option (d) is correct.

Why this question?
Note: The electric field exists inside a cavity present in conductor if a charge is placed there. It is in accordance of Gauss's law$(q_{en}\neq 0, E\neq 0)$

5. Figure shows two conducting thin concentric shells of radii r and $3r$. The outer shell carries q while inner shell is neutral and is connected to earth by S. Find the charge that will flow from earth to inner shell after the switch S is closed.



A. $-\frac{q}{3}$

B. $-\frac{q}{2}$

C. $\frac{q}{3}$

D. $\frac{2q}{3}$

Let q' be the charge on the inner shell when it is earthed (switch S is closed).

Since the shell is grounded , potential of inner shell, $V_{inner} = 0$

$V_{inner} = V_1 + V_2$

Where, $V_1 \rightarrow$ Potential due to outer shell on the inner shell.

$V_2 \rightarrow$ Potential due to charge present on the inner shell.

$$V_{inner} = \frac{1}{4\pi\varepsilon_o}\left[\frac{q'}{r} + \frac{q}{3r}\right] = 0$$

$$\Rightarrow q' = -\frac{q}{3}$$

Hence, option (a) is the correct answer.

Why this question: This question will check the basic understanding on application of concept of earthing.

6. What is the capacitance of a parallel plate capacitor having $40 \text{ cm} \times 40 \text{ cm}$ square plates separated by the distance 10 cm?
(Take $\epsilon_o = 8.85 \times 10^{-12} \text{ F/m}$)

A. $2.8 \times 10^{-12} \text{ F}$

B. $1.4 \times 10^{-11} \text{ F}$

C. $2.8 \times 10^{-11} \text{ F}$

D. $1.4 \times 10^{-12} \text{ F}$

Area of each plate will be

$A = 40 \times 40 \text{ cm}^2 = 1600 \text{ cm}^2$

$\Rightarrow A = 0.16 \text{ m}^2$

Distance between the plates

$d = 10 \text{ cm} = 0.1 \text{ m}$

When no medium is mentioned explicitly, assume air as the medium.

Now using formula of capacitance of parallel plate capacitor

$$C = \frac{A\epsilon_0}{d}$$

$$\Rightarrow C = \frac{0.16 \times 8.85 \times 10^{-12}}{0.1}$$

$$\Rightarrow C = 1.4 \times 10^{-11} \text{ F}$$

Hence, option (b) is correct.

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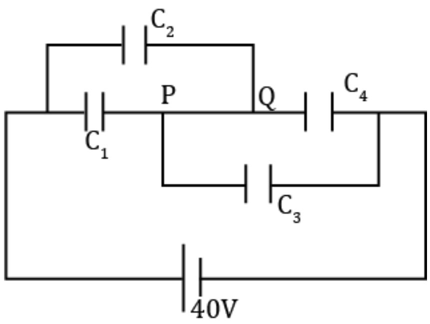
7. The figure shows a circuit where $C_1 = C_2 = C_3 = C_4 = 4\ \mu\text{F}$. What is the extra charge flown through the battery when a $12\ \mu\text{F}$ capacitor is introduced between P and Q?

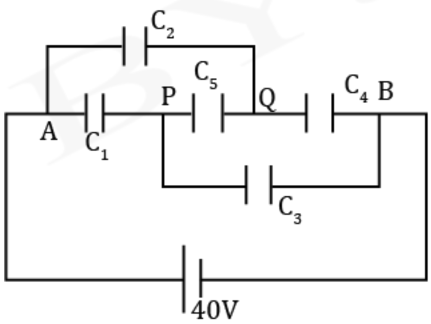


A. 0

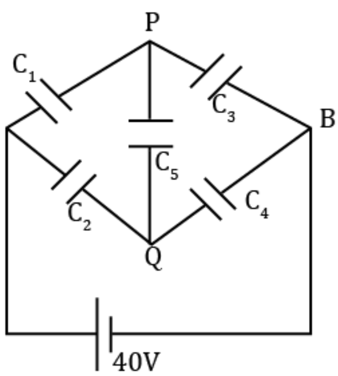
B. $100\ \mu\text{C}$

C. $200\ \mu\text{C}$

D. $80\ \mu\text{C}$



Let's redraw the circuit



$C_1 = C_2 = C_3 = C_4$

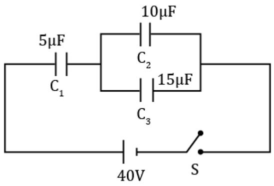
$\Rightarrow \frac{C_1}{C_2} = \frac{C_3}{C_4}$

The given circuit is a balanced Wheatsone Bridge.

Thus, $V_P = V_Q$ and there will be no flow of current through C_5.

So, no extra charge will be flown with the addition of fifth capacitor between P and Q.

8. If at $t=0$ switch S is closed, then at steady state find charge (in$\mu\mathrm{C}$) across each capacitor as shown in figure.



A. $\frac{400}{3}, \frac{200}{3}, 150$

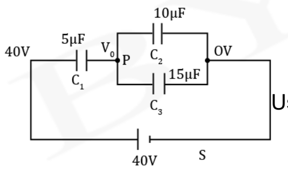
B. $\frac{100}{3}, \frac{200}{3}, 50$

C. $\frac{500}{3}, \frac{400}{3}, 200$

D. $\frac{500}{3}, \frac{200}{3}, 100$

We can solve this problem by using potential method, by assigning potential to known points as shown in figure.

When switch is closed:



Using Kirchoff`s junction law at junction P, we can write

$(V_o-40)5+10(V_0-0)+15(V_0-0)=0$

$\Rightarrow 5V_0-200+10V_0+15V_0=0$

$\Rightarrow 200=30V_0$

$\therefore V_0=\frac{20}{3}V$

Using V_0 we can find charge on each capacitor,

Charge on C_1 is:

$\Rightarrow Q_1=C_1\left(40-\frac{20}{3}\right)=5\left(\frac{100}{3}\right)=\frac{500}{3}\mu\mathrm{C}$

Similarly, for Q_2 and Q_3 as follows,

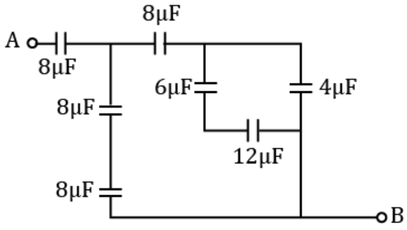
$Q_2=C_2\left(\frac{20}{3}-0\right)=10\left(\frac{20}{3}\right)=\frac{200}{3}\mu\mathrm{C}$

$Q_3=C_3\left(\frac{20}{3}-0\right)=15\left(\frac{20}{3}\right)=100\ \mu\mathrm{C}$

Hence, option (d) is the correct answer.

Why this question: To understand the application of Kirchhoff's law.

9. The equivalent capacitance across AB is



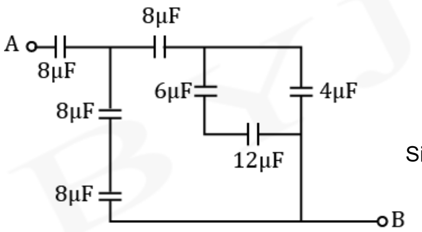
A. $8\ \mu\text{F}$

B. $12\ \mu\text{F}$

C. $4\ \mu\text{F}$

D. $24\ \mu\text{F}$

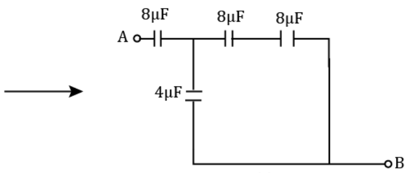
Given circuit:



(a)

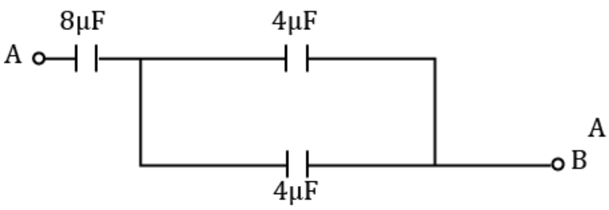
Since, capacitors $6\ \mu\text{F}$ and $12\ \mu\text{F}$ are in series and thies equivalent capacitance $\frac{6\times 12}{6+12} = 4\ \mu\text{F}$ is in paralle

$4\ \mu\text{F}$ capacitor. Redrawing the circuit,



(c)

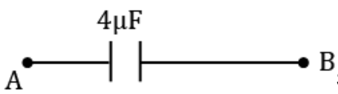
Since, both the $8\ \mu\text{F}$ capacitors are in series so, their equivalent capacitance, $\frac{8\times 8}{8+8} = 4\ \mu\text{F}$.



(d)

(e)

Finally,



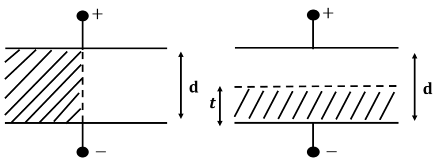
So, the equivalent capacitance, $(C_{eq})_{AB} = 4\mu F$

Hence, option (c) is correct answer.

Why this question :
This question is aimed at recalling the approch of succesive reduction of the electrical circuits.

Note : This method will be very helpful in current electricity as well.

10. A capacitor is half filled with a dielectric of dielectric constant $K = 2$ as shown in figure -A. If the same capacitor has to be filled with same dielectric a in figure B, What would be the thickness of dielectric such that capacitor still has the same value of capacitance.



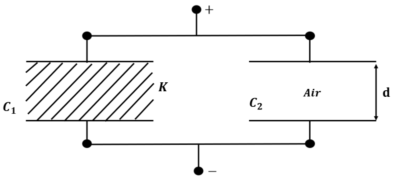
A. $\frac{2d}{3}$

B. $\frac{3d}{2}$

C. $\frac{3d}{4}$

D. $\frac{4d}{3}$

The figure A in the given question can be visualised as combination of two capacitors in parallel with each having area of plate $\frac{A}{2}$ and separation bet
plates being $'d'$.



Thus , equivalent capacitance, $C_{eq} = C_1 + C_2$

$$\Rightarrow C_{eq} = \frac{K\left(\frac{A}{2}\varepsilon_0\right)}{d} + \frac{\left(\frac{A}{2}\right)\varepsilon_0}{d}$$

$$\Rightarrow C_{eq} = \frac{(K+1)A\varepsilon_0}{2d}$$

$$\Rightarrow C_{eq} = \frac{3A\varepsilon_0}{2d} \;\ldots\ldots(1) \quad [\because K = 2]$$

The arrangement shown in figure B, represents a capacitor with area A and separation d which is partially filled with dielectric K.

Thus, capacitance of the given arrangement is given by

$$C'_{eq} = \frac{A\varepsilon_0}{(d-t) + \frac{t}{K}}$$

$$\Rightarrow C'eq = \frac{A\varepsilon_0}{(d-t) + \frac{t}{2}}$$

$$\Rightarrow C'_{eq} = \frac{A\varepsilon_0}{d - \frac{t}{2}} \quad \ldots\ldots\ldots(2)$$

From (1) and (2) we get,

$$\frac{A\varepsilon_0}{d - \frac{t}{2}} = \frac{3A\varepsilon_0}{2d}$$

$$\Rightarrow 2d = 3\left(d - \frac{t}{2}\right)$$

or, $2d = 3d - \frac{3t}{2}$

or , $\frac{3t}{2} = d \quad \therefore t = \frac{2d}{3}$

Thus, required thickness is $\frac{2d}{3}$

Hence, option (a) is the correct answer.

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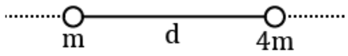
11. Two point masses m and $4m$ are separated by a distance d on a straight line as shown in figure. A third point mass m_o is to be placed at a point on th such that the net gravitational force on it is zero.



The distance of the m_0 from the m is

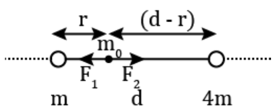
A. $\frac{d}{2}$

B. $\frac{d}{4}$

C. $\frac{d}{3}$

D. $\frac{d}{5}$

Let, the mass m_0 be placed at distance r from mass m.



Force of gravitation on m_o due to m is

$$F_1 = \frac{Gmm_0}{r^2}$$

Force of gravitation on m_o due to $4m$ is

$$F_2 = \frac{G(4m)m_0}{(d-r)^2}$$

Since, the net force acting on m_0 is to be zero, we have

$$F_1 = F_2$$

$$\Rightarrow \frac{Gmm_0}{r^2} = \frac{G(4m)m_0}{(d-r)^2}$$

$$\Rightarrow (d-r)^2 = 4r^2$$

$$\Rightarrow (d-r)^2 = (2r)^2$$

$$\Rightarrow d - r = \pm 2r$$

$$\Rightarrow d = +3r \text{ or } -r$$

The null point must lie in between the two stationary masses,

$$\therefore r = \frac{d}{3}$$

Hence, option (c) is the correct answer.

Why this question: To make students familiar with the concept of equilibrium of masses under action of gravitational force.

12. If V is the gravitational potential on the surface of the earth, then what will be its value at the centre of the earth?

A. $2V$

B. $3V$

C. $\frac{3V}{2}$ ✔

D. $\frac{2V}{3}$

The gravitational potential due to a solid sphere (like earth) of radius R at a distance r from its centre is given by

$$V = -\frac{GM}{2R^3}\left(3R^2 - r^2\right) \quad ; \quad (r \le R)$$

Let V_S be the potential at the surface.

At the surface of earth, $r = R$,

$\therefore V_S = -\frac{GM}{R} = V(\text{say}) \ldots\ldots (1)$

Let V_C be the potential at center.

At the centre, $r = 0$,

$\therefore V_C = -\frac{3}{2}\frac{GM}{R}$

$\Rightarrow V_C = \frac{3V}{2}$ [from 1]

Hence, option (c) is the correct answer.

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13. If a tunnel is cut at any orientation through earth, then find the time taken by a ball released from one end to reach the other end. (neglect earth rotati take radius of earth as $R = 64 \times 10^5$ m and $g = 10 \text{ m/sec}^2$)

A. 84.6 minutes

B. 41.9 minutes

C. 8 minutes

D. depend on orientation

As we know that when the particle of mass m is at a distance x $(x < R)$ from the center inside the earth, the gravitational force on it be equal to

$$F = -\frac{GMmx}{R^3}$$

Now, the acceleration of the particle at this, point is,

$$\Rightarrow a = \frac{F}{m} = -\frac{GM}{R^3}x$$

Thus, $a \propto (-x)$, this is the case of SHM.

So, comparing with the standard equation of SHM, $a = -\omega^2 x$ we have, angular frequency of oscillation,

$$\Rightarrow \omega = \sqrt{\frac{GM}{R^3}}$$

As, $g = \frac{GM}{R^2}$,

$$\therefore \omega = \sqrt{\frac{g}{R}}$$

Time period is given by,

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{R}{g}}$$

Substituting, $R = 64 \times 10^5$ m and $g = 10 \text{ m/s}^2$, we get

$$\Rightarrow T = 2\pi\sqrt{\frac{64 \times 10^5}{10}}$$

$$\Rightarrow T = 1600\pi \text{ sec}$$

$$\Rightarrow T = \frac{1600\pi}{60} = 83.8 \text{ min}$$

So, time taken by ball from one end to other end is $\left(\frac{T}{2}\right) = 41.9$ min.

Hence, option (b) is the correct answer.

14. A space station is set up in space at a distance equal to earth's radius from the surface of earth. Suppose a satellite can be launched from the space also. Let v_1 and v_2 be the escape velocities of the satellite on the earth's surface and space station respectively, then

A. $v_2 = v_1$

B. $v_2 < v_1$

C. $v_2 > v_1$

D. $1,\ 2$ and 3 are valid depending on the mass of satellite.

The escape velocity for an object at a distance r from the center of a planet having mass M is given by

$$v_e = \sqrt{\frac{2GM}{r}}$$

If R is the radius of the earth, then the escape velocity at earth's surface $(r = R)$ is given by,

$v_1 = \sqrt{\frac{2GM}{R}} \quad \ldots.(1)$

Escape velocity from orbit at distance $(r = R + R = 2R)$,

$v_2 = \sqrt{\frac{2GM}{2R}} \quad \ldots.(2)$

So, from equation (1) and (2), we can conclude that

$v_2 < v_1$

Hence, option (b) is the correct answer.

15. In a wire of cross-section radius r, free electrons travel with drift velocity v when a current I flows through the wire. What is the current in another wire the radius and of the same material when the drift velocity is $2v$?

A. $2I$

B. I

C. $I/2$

D. $I/4$

From current and drift velocity relation, we know that

$I = neAv_d$

For first wire:
$A = \pi r^2;\ \ v_d = v$

$\therefore I = ne(\pi r^2)v \quad \ldots\ldots\ldots..(1)$

For second wire:
$A = \pi (r/2)^2;\ \ v_d = 2v$

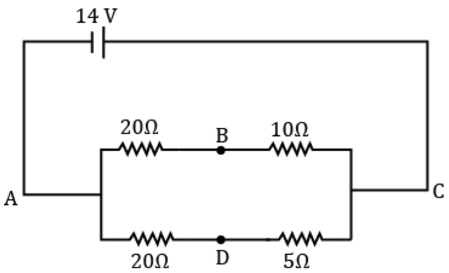
$\therefore I' = ne\left[\pi\left(\frac{r}{2}\right)^2\right]2v \quad \ldots\ldots.(2)$

From eq. (1) & (2)

$I' = I/2$

Hence, option (c) is correct.

16. What resistor should be connected in parallel with the $20\ \Omega$ resistor in branch ADC in the circuit shown in figure, so that potential difference between
may be zero ?

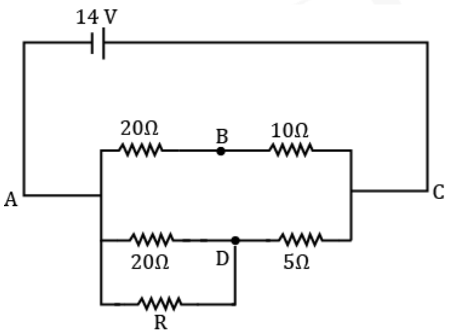


A. $20\ \Omega$ (correct)

B. $10\ \Omega$

C. $5\ \Omega$

D. $15\ \Omega$



Since, R resistor is connected in parallel with the $20\ \Omega$ resistor, so effective resistance will be

$$R_{eq}=\frac{20R}{20+R}=x\ (\text{let})$$

The potential difference between B and B will be zero only when bridge is balanced.

So, let's balance Wheatstone bridge,

$$\frac{20}{x}=\frac{10}{5}$$

$$\Rightarrow x=10\ \Omega$$

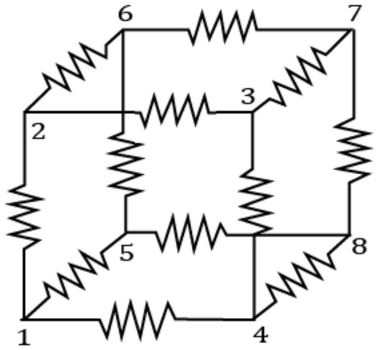
$$\Rightarrow \frac{20R}{20+R}=10 \Rightarrow 10R=200$$

$$\therefore R=20\ \Omega$$

Hence, option (a) is correct.

JEE Main Part Test 3

17. Twelve resistors each of resistance r are connected together so that each lies along the edge of the cube as shown in the figure. The equivalent resis
between points 1 and 4 is

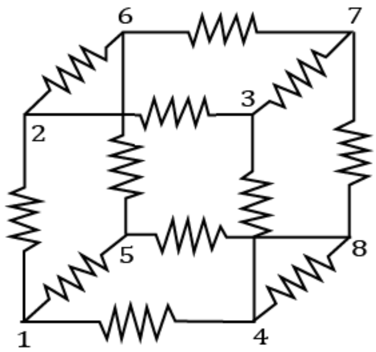


A. $\frac{5r}{12}$

B. $\frac{7r}{12}$

C. $\frac{11r}{12}$

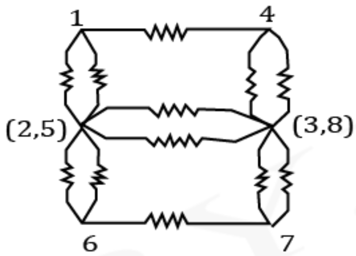
D. $\frac{13r}{12}$



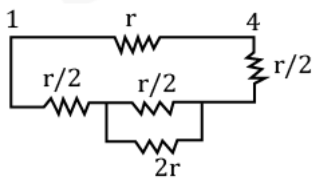
From the diagram, we can see that points $(2, 5)$ are symmetrically located with respect to points 1 and 4. So they are at same potentials.

Similarly, points $(3, 8)$ are also symmetrically located with respect to points 1 and 4. So they are again at same potentials.

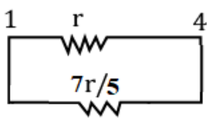
On this basis redrawing the circuit,



Simplifying above circuit by using concept of series and parallel combination,



On successive reduction in circuit, we get,



Since, both are in parallel combination, so equivalent resistance will be

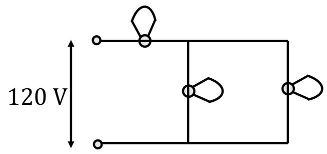
$$R_{eq} = \frac{(7r/5) \times r}{(7r/5) + r} = \frac{7}{12}r$$

The equivalent resistance between points 1 and 4 is $7r/12$.

Hence, option (b) is correct.

Why this question?
Key Idea-This question gives you a hint that how symmetry can simplify complex resistors network.

18. Three light bulbs $(60\ \mathrm{W}, 120\ \mathrm{V})$ are connected across a $120\ \mathrm{V}$ power source. If the resistance of each bulb does not change with current, then find ou
power delivered to the three bulbs.



A. $80\ \mathrm{W}$

B. $60\ \mathrm{W}$

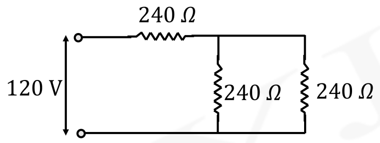
C. $40\ \mathrm{W}$

D. $20\ \mathrm{W}$

Resistance of each bulb,

$$R = \frac{V^2}{P} = \frac{120^2}{60} = 240\ \Omega$$

On assuming each bulb as a resistor of $240\ \Omega$ and redrawing the circuit, we get,



Equivalent resistance,

$$R_{\text{eq}} = \frac{240 \times 240}{240 + 240} + 240 = 360\ \Omega$$

So, total power delivered,

$$P = \frac{V^2}{R_{\text{eq}}} = \frac{120^2}{360} = 40\ \mathrm{W}$$

19. If an ammeter is to be converted into a voltmeter, then we must connect with the ammeter a

A. Low resistance in parallel

B. High resistance in parallel

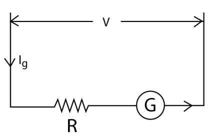
C. High resistance in series

D. Low resistance in series

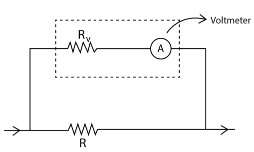
We know that, a galvanometer behaves as an ammeter if a low resistance is connected to it in parallel.

To convert a galvanometer into a voltmeter of certain range say V, a high resistance R is connected in series with the galvanometer so that current p
through the galvanometer of resistance G becomes equal to its full scale deflection value (I_g). This is possible only if

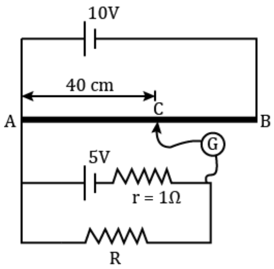
$$V = I_g(G + R)\ i.e.\ R = \frac{V}{I_g} - G$$



Hence, if a high resistance is connected in series to an ammeter, it behaves as an voltmeter.



20. A potentiometer wire AB is $100 \mathrm{~cm}$ long and has a total resistance of 10Ω. if the galvanometer shows zero deflection at the position C, then find the v unknown resistance R.



A. 4Ω

B. 6Ω

C. 5Ω

D. 2.5Ω

The potential difference across AB is
$V_{AB}=10$ volt

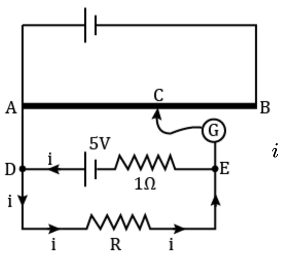
Potential gradient of wire AB,

$$\frac{dV}{dl}=\frac{10}{100}=\frac{1}{10} \mathrm{V/cm}$$

$$\therefore V_{AC}=L_{AC} \times \frac{dV}{dl}$$

$$V_{AC}=40 \mathrm{~cm} \times \frac{1}{10} \mathrm{V/cm}=4 \mathrm{~V}$$

Redrawing the circuit at balanced state,



$$i=\frac{5}{1+R}$$

Also equating the potential difference,

$$V_{DE}=V_{AC}$$

$$V_D-5+1\left(\frac{5}{1+R}\right)=V_E$$

$$\Rightarrow V_D-V_E=5-\frac{5}{1+R}$$

$$V_A-V_C=5-\frac{5}{1+R}$$

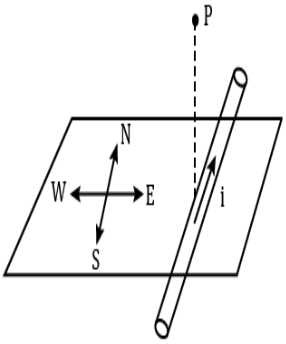
$$4=5-\frac{5}{1+R} \Rightarrow 1=\frac{5}{1+R}$$

$$\Rightarrow 1+R=5$$

$$\therefore R=4 \Omega$$

Hence, option (a) is the correct answer.

21. Current flows due north in a horizontal transmission line as shown in the figure. Magnetic field at a point P vertically above it is directed



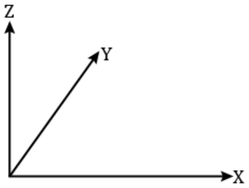
A. northwards

B. southwards

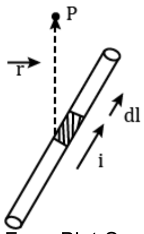
C. towards east ✔

D. towards west

Taking the reference axis x, y, z as shown below.



The current element vector $(\overrightarrow{dl})$ for the transmission line is along y-axis.
The direction of $\overrightarrow{dl}$ is along $\hat{j}$
The direction of position vector for point P is along $\hat{k}$.



From Biot-Savart's law at point P,

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

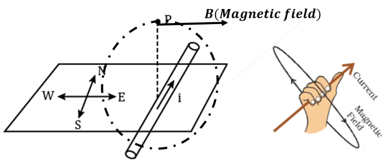
The direction of magnetic field at B is given by,

$\overrightarrow{dl} \times \overrightarrow{r}$
or, direction of $\overrightarrow{dB} \Rightarrow \hat{j} \times \hat{k} = \hat{i}$

$\therefore$ Direction of field at point P is towards east.

Alternate method :

The direction of magnetic can also be determined using "Fleming's right-hand thumb rule".



In the question, current is from south to north, and hence the direction of the magnetic field would be in the direction of the curl of the fingers. This is represented in the diagram shown.

Thus, the direction of the magnetic field point P is towards east.

Why this question?

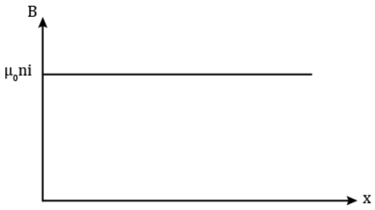
Tip: The direction of $\overrightarrow{B}$ at any point can be obtained by applying biot savart law and assigning the current element vector $\overrightarrow{(dl)}$ in the direction of curren

Concept: The direction of magnetic field will be given by direction of $\overrightarrow{dl} \times \overrightarrow{r}$

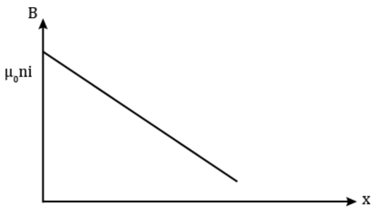
JEE Main Part Test 3

22. Which of the following graphs correctly represent the variation of magnetic field (B) inside a finite length solenoid with respect to distance x from its c
The current in solenoid having n turns per unit length is i.

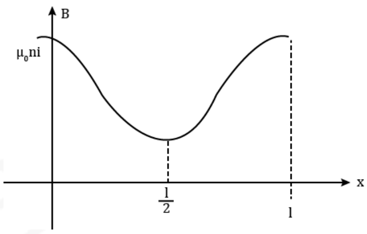
A.



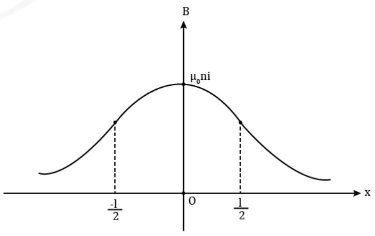
B.



C.



D.



The magnetic filed at a point inside the finite length solenoid is given by,

$$B = \frac{\mu_0 ni}{2}[\cos\theta_1 - \cos\theta_2]$$

For a point at the center of solenoid

$\theta_1 = 0^\circ$ and $\theta_2 = 180^\circ$

$$B = \frac{\mu_0 ni}{2}[\cos\ 0^\circ - \cos\ 180^\circ] = \frac{\mu_0 ni}{2}[1 - (-1)]$$

$\therefore B = \mu_0 ni$

Thus, the magnetic field is maximum at center, and it will decrease symmetrically on both side of center.

The value of magnetic field drops significantly as the point moves further apart the half-length distance.

Hence, option (d) gives correct representation.

23. A toroid has a core of inner radius $20\ \mathrm{cm}$ and outer radius $22\ \mathrm{cm}$ around which 4200 turns of a wire are wound. If the current in the wire is $10\ \mathrm{A}$, what is magnetic field inside the core ?

A. $3 \times 10^{-2}\ \mathrm{T}$

B. $1 \times 10^{-2}\ \mathrm{T}$

C. $4 \times 10^{-2}\ \mathrm{T}$

D. $2 \times 10^{-2}\ \mathrm{T}$

Given:
$N = 4200; \ \ i = 10\ \mathrm{A}$
inner radius, $r_1 = 20\ \mathrm{cm}$
outer radius, $r_2 = 22\ \mathrm{cm}$

$\therefore$ mean radius, $r = \dfrac{r_1 + r_2}{2}$

$$r = \frac{20 + 22}{2} = 21\mathrm{cm} = 0.21\ \mathrm{m}$$

Magnetic field inside the core of toroid is given by

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

$$B = \frac{4\pi \times 10^{-7} \times 4200 \times 10}{2\pi \times 0.21}$$

$$\therefore B = 4 \times 10^{-2}\ \mathrm{T}$$

Therefore, option (c) is the right choice.

24. An electron is travelling along the x-direction. It encounters a magnetic field in the y-direction. Its subsequant motion will be

A. Straight line along the x-direction

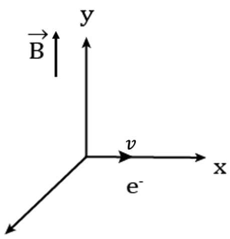
B. A circle in the x-z plane

C. A circle in the y-z plane

D. A circle in the x-y plane

Given, $\vec{v} = v\,\hat{i}$

$\vec{B} = B\,\hat{j}$



Magnetic force on the charge particle is,

$$\vec{F} = q\,(\vec{v} \times \vec{B}) = -e\,[v\hat{i} \times B\hat{j}]$$

$$\vec{F} = evB\,(-\hat{k})$$

Since force is in $-z$ axis, It will force e^- to move in circle in x-z plane.

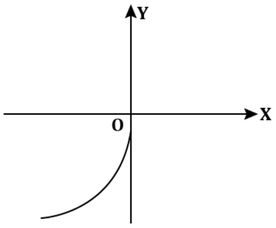
Hence, option (b) is correct answer.

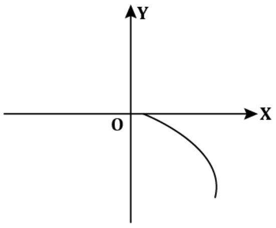
Why this question ?

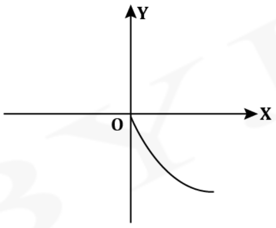
To know the quantities on which magnetic force experienced by charge moving in the magnetic field depends and its relation with them along with us
Right-hand thumb rule.

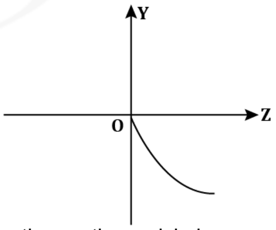
Note: The plane of the circle will be perpendicular to the magnetic field.

25. In a region , uniform electric field is present as $\vec{E} = E_0\hat{j}$ and a uniform magnetic field is present as $\vec{B} = -B_0\hat{k}$. An electron is released from rest at or
Which of the following best represents the path followed by electron after release.

A.


B.


C.


D.


Total force acting on the paricle is

$$\vec{F}_T = \vec{F}_B + \vec{F}_E = q(\vec{V} \times \vec{B}) + q\vec{E}$$

Given,
$\vec{E} = E_0\hat{j}$ and $\vec{B} = -B_0\hat{k}$

Since, initially the electron e is at rest $\therefore \vec{V} = 0$

$\therefore \vec{F}_B = q(\vec{V} \times \vec{B}) = 0$

So, only $\vec{F}_E = q\vec{E} = -eE_0\hat{j}$ exists

$\therefore e$ starts moving along $-y$ axis (initially)

$\therefore$ Now it has velocity along $-y$ axis

$\therefore \vec{F}_B = q(\vec{V} \times \vec{B}) = qVB_0[(-\hat{j}) \times (-\hat{k})]$

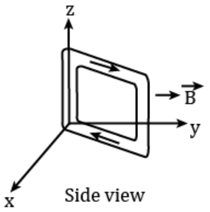
$\Rightarrow \vec{F}_B = -eVB_0\hat{i} = eVB_0(-\hat{i})$

Thus, $\vec{F}_B$ will be acting along $-ve\ x-$ axis.

$\therefore e$ initially moving in $-y$ axis but then move in 3^{rd} quadrant because of both forces.

Hence, option (A) is the correct answer.

26. The square loop in the figure has sides of length 20 cm. It has 5 turns and carries a current of 2 A. The normal to the loop is at 37° to a uniform field, $B = 0.5\hat{j} \text{ T}$. Find the work needed to rotate the loop from its position of minimum energy to the given orientation.

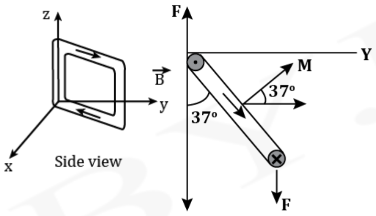


A. -0.04 J

B. $+0.04 \text{ J}$

C. -0.02 J

D. $+0.02 \text{ J}$



The potential energy of the loop is,

$U = -\mu B \cos\theta$

Where,

$\mu = NIA = 5 \times 2 \times (0.2)^2 = 0.4 \text{ Am}^2$

And the position of minimum energy is $\theta = 0^\circ$.

Thus, the external work, W_{ext} needed to rotate it to the given orientation, is given by

$W_{ext} = U_f - U_i$

$= (-\mu B \cos 37^\circ) - (-\mu B \cos 0^\circ)$

$= (0.4)(0.5)(1 - 0.8)$

$= 0.04 \text{ J}$

The external work is positive since the dipole is rotated away from alignment with the field.

Hence, option (b) is the correct answer.

27. Two long current carrying wires. separated by a distance d carry currents I_1 and I_2 in the same direction They exert a force F on each other. Now the in one of them is increased to two times and its direction is reversed. The distance is also Increased to $3d$ The new value of the force between them i

A. $\frac{-F}{3}$

B. $\frac{F}{3}$

C. $\frac{2F}{3}$

D. $\frac{-2F}{3}$

Force per unit length between two long current carrying wires is given by,

$$F_1 = \frac{\mu_0 I_1 I_2}{2\pi d}$$

When I_1 is changed to $2I_1$ and d is changed to $3d$

$$\therefore \quad F_2 = \frac{\mu_0 (2I_1)(I_2)}{2\pi(3d)}$$

$$= \frac{\mu_0 I_1 I_2}{2\pi d} \times \frac{2}{3} = \frac{2F}{3}$$

As direction of current is reversed, the direction of the force will also get reversed.

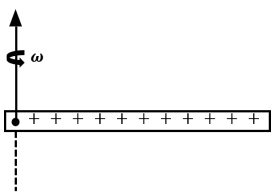
$$\therefore \quad F_2 = \frac{-2F}{3}$$

Here, negative sign indicates that the force is now repulsive in nature.

Why this Question?
Note: Force per unit length between two long current carrying wires is given by,

$$F_1 = \frac{\mu_0 I_1 I_2}{2\pi d}$$

28. A non conducting rod of length $l = 20$ cm carries a charge $q = 3$ C uniformly distributed on it. The rod is pivoted at one of its ends as shown in the figu is rotated at an angular frequency $\omega = 10$ rad/s about a fixed axis perpendicular to rod and passing through pivot. The magnetic moment of the rod sy



A. 500 A cm^2

B. 1000 A cm^2

C. 2000 A cm^2

D. Zero

Magnetic moment of rotating rod pivoted at one of its ends is given by

$$\mu = \frac{q\omega l^2}{6}$$

From the data given in the question,

$$\mu = \frac{3 \times 10 \times (0.2)^2}{6}$$

$$\Rightarrow \mu = \frac{30 \times 0.04}{6} = 0.2 \text{ Am}^2 \text{ or } 2000 \text{ A cm}^2$$

Hence, option (c) is the correct answer.

29. A moving coil galvanometer has following characteristics,
Number of turns = 80, Area of coil =$50\ \text{mm}^2$, Resistance of coil = $20\ \Omega$, magnetic field = $0.2\ \text{T}$, torsional constant of the suspension wire = 5×10^{-9} N-m
Which of the following statements are correct.

A. The angular deflection produced due to a potential difference of $0.01\ \text{mV}$ is $0.08\ \text{div}$

B. Current sensitivity of the device is $160\ \text{div/mA}$

C. Voltage sensitivity of the device is $8\ \text{div/mV}$

D. All of the above.

We know that current sensitivity is given by,

$$I_s = \frac{\theta}{i} = \frac{NAB}{C}$$

$$I_s = \frac{80 \times 50 \times 10^{-6} \times 0.2}{5 \times 10^{-9}}$$

$$I_s = 160 \times 10^3\ \text{div/A} = 160\ \text{div/mA}$$

Now, voltage sensitivity is given by,

$$V_s = \frac{\theta}{V} = \frac{I_s}{R} = \frac{NAB}{CR}$$

$$V_s = \frac{160}{20} = 8\ \text{div/mV}$$

If $V = 0.01\ \text{mV}$,

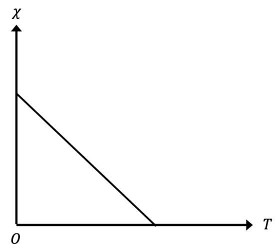
$$\theta = 8 \times 0.01 = 0.08\ \text{div}$$

Hence, option (D) is the correct answer.

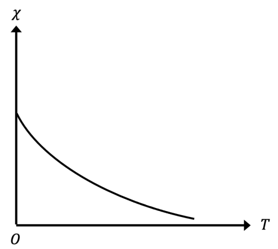
JEE Main Part Test 3

30. The variation of magnetic susceptibility χ with absolute temperature T, for a ferromagnetic material, is best shown by which of the following graphs?

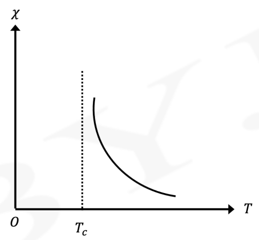
A.



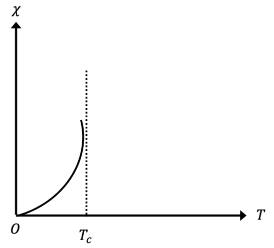
B.



C. ✔



D.



The dependence of magnetic susceptibility with temperature for a ferromagnetic substance is given by,

$$\chi = \frac{C}{T - T_c}$$

Where,

$C =$ material-specific Curie constant

From the above equation, we can infer that χ is inversely proportional to the absolute temperature.

So, as temperature increases, magnetic susceptibility decreases.

The relation is not linear, rather it is rectrangular hyperbola-like relation.

Moreover, the law also predicts a singularity in the susceptibility at $T = T_c$

Hence, option (C) is the correct answer.

Why this Question?
Key point: The dependence of magnetic susceptibility with temperature for a ferromagnetic substance is given by,

$$\chi = \frac{C}{T - T_c}$$

Where,
$C =$ material specific Curie constant
$\chi =$ magnetic susceptibility of the material
$T_c =$ Curie's temperature(in Kelvin)