Electrostatics

Question1

An electric dipole with dipole moment $2 \times 10^{-10}\mathrm{Cm}$ is aligned at an angle 30° with the direction of uniform electric field of $10^{4}\mathrm{NC}^{-1}$. The magnitude of the torque acting on the dipole is

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Options:

A.

$10^{-6}\mathrm{Nm}$

B.

$10^{-4}\mathrm{Nm}$

C.

$10^{-5}\mathrm{Nm}$

D.

$10^{-3}\mathrm{Nm}$

Answer: A

Solution:

Given data:

- Dipole moment, $p = 2 \times 10^{-10}\ \mathrm{C\,m}$
- Electric field, $E = 10^{4}\ \mathrm{N\,C^{-1}}$
- Angle between $\vec{p}$ and $\vec{E}$, $\theta = 30^{\circ}$

Formula for torque:

$\tau = pE \sin\theta$

Substitute values:

$\tau = (2 \times 10^{-10})(10^4) \sin 30^\circ$

$= 2 \times 10^{-6} \times \frac{1}{2}$

$= 1 \times 10^{-6}\ \mathrm{N\,m}$

✅ **Final Answer:**

$\boxed{10^{-6}\ \mathrm{N\,m}}$

Correct option: A

Question2

An electric charge $10^{-3}\mu\mathrm{C}$ is placed at the origin of xy-plane. The potential difference between point A and B located at $(\sqrt{2}\ \mathrm{m}, \sqrt{2}\ \mathrm{m})$ and $(2\ \mathrm{m}, 0\ \mathrm{m})$ respectively is

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Options:

A.

4.5 V

B.

9 V

C.

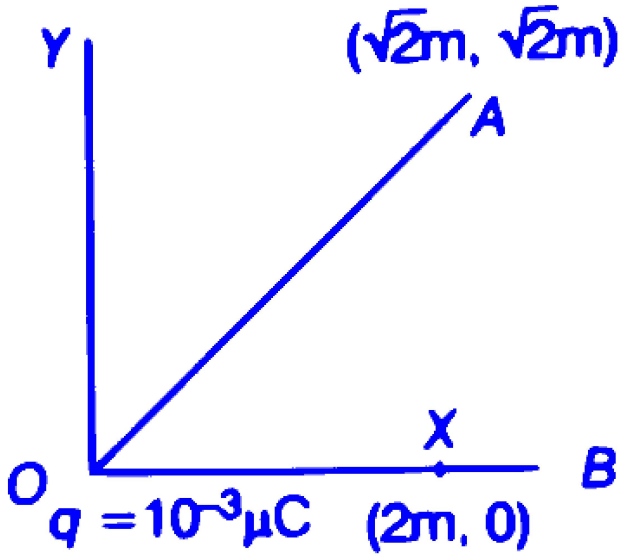
0 V

D.

2 V

Answer: C

Solution:



$$OA = \sqrt{(\sqrt{2})^2 + (\sqrt{2})^2} = 2$$
$$OB = 2 \text{ m}$$
$$\therefore \quad V_A = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{OA}$$
$$= 9 \times 10^9 \times \frac{10^{-3} \times 10^{-6}}{2} = 4.5 \text{ V}$$
Similarly, $V_B = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{OB}$
$$= 9 \times 10^9 \times \frac{10^{-3} \times 10^{-6}}{2}$$
$$= 4.5 \text{ V}$$
$$\therefore \quad V_A - V_B = 4.5 - 4.5 = 0 \text{ V}$$

Question3

The force between two conducting spheres of same radius having charges $+8\mu$C and -4μC separated by some distance in air is F. If the spheres are connected by a conducting wire and after some time the wire is removed, then the magnitude of the force between the two conducting spheres is

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Options:

A.

F

B.

$\frac{F}{2}$

C.

$\frac{F}{8}$

D.

$\frac{F}{4}$

Answer: C

Solution:

Initially,

$$F=\frac{k\left|q_1 q_2\right|}{r^2}$$

$$=\frac{k \times 8 \times 10^{-6} \times 4 \times 10^{-6}}{r^2}$$

$$=\frac{32 \times 10^{-12} k}{r^2}$$

After connecting by conducting wires,

$q=q_1+q_2=8 \mu C+(-4 \mu C)=4 \mu C$

$\therefore$ Charge on each sphere

$$q^{\prime}=\frac{q}{2}=2 \mu \mathrm{C}=2 \times 10^{-6} \mathrm{C}$$

$$\therefore \quad F^{\prime}=k \cdot \frac{q^2}{r^2}=\frac{k \times\left(2 \times 10^{-6}\right)^2}{r^2}$$

$$=\frac{4 \times 10^{-12} k}{r^2}=\frac{1}{8} \times \frac{32 \times 10^{-12} k}{r^2}$$

$$=\frac{F}{8}$$

Question4

In space the electric potential varies as $V = 20|\mathbf{r}|$ volt. where $\mathbf{r} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$ is the position vector. Then, electric field in $\left(\mathrm{NC}^{-1}\right)$ at the point $(4\ \mathrm{m}, 3\ \mathrm{m}, -5\ \mathrm{m})$ is

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Options:

A.

$-\sqrt{2}(4\hat{\mathbf{i}} + 3\hat{\mathbf{j}} - 10\hat{\mathbf{k}})$

B.

$-\sqrt{2}(8\hat{\mathbf{i}} + 6\hat{\mathbf{j}} - 10\hat{\mathbf{k}})$

C.

$-(8\hat{\mathbf{i}} + 6\hat{\mathbf{j}} - 10\hat{\mathbf{k}})$

D.

$4\hat{i} + 3\hat{j} - 5\hat{k}$

Answer: B

Solution:

$$V = 20|r| = 20\sqrt{x^2 + y^2 + z^2}$$

$$\therefore E = -\left(\frac{\partial v}{\partial x}\hat{\mathbf{i}} + \frac{\partial v}{\partial y}\hat{\mathbf{j}} + \frac{\partial v}{\partial z}\hat{\mathbf{k}}\right)$$

$$= -\left[\frac{20x}{\sqrt{x^2 + y^2 + z^2}}\hat{\mathbf{i}} + \frac{20y}{\sqrt{x^2 + y^2 + z^2}}\hat{\mathbf{j}} + \frac{20z}{\sqrt{x^2 + y^2 + z^2}}\hat{\mathbf{k}}\right]$$

$$= \frac{-20(x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}})}{\sqrt{x^2 + y^2 + z^2}}$$

At point $(4m, 3m, -5m)$

$$E = \frac{-20(4\hat{\mathbf{i}} + 3\hat{\mathbf{j}} - 5\hat{\mathbf{k}})}{\sqrt{4^2 + 3^2 + (-5)^2}}$$

$$= \frac{-20}{5\sqrt{2}}(4\hat{\mathbf{i}} + 3\hat{\mathbf{j}} - 5\hat{\mathbf{k}})$$

$$= -\sqrt{2}(8\hat{\mathbf{i}} + 6\hat{\mathbf{j}} - 10\hat{\mathbf{k}})$$

Question5

The sum of two point positive charges separated by a distance of 1.5 m in air is $25\mu\mathrm{C}$. If the electrostatic force between the two charges is 0.6 N , then the difference between the two charges is

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Options:

A.

$5\mu\mathrm{C}$

B.

$8\mu\mathrm{C}$

C.

$3\mu\mathrm{C}$

D.

$6\mu\mathrm{C}$

Answer: A

Solution:

Given, $q_1 + q_2 = 25\mu\mathrm{C}$

Also, $F = \frac{kq_1q_2}{r^2}$

$$\Rightarrow \quad 0.6 = \frac{9 \times 10^9 (q_1q_2)}{(1.5)^2}$$

$$\Rightarrow \quad q_1q_2 = \frac{0.6 \times (1.5)^2}{9 \times 10^9}$$

$\Rightarrow q_1q_2 = 1.5 \times 10^{-10}$

Using $(q_1 - q_2)^2 = (q_1 + q_2)^2 - 4q_1q_2$

we get

$$(q_1 - q_2)^2 = \left(25 \times 10^{-6}\right)^2 - 4 \times 1.5 \times 10^{-10}$$
$$\Rightarrow (q_1 - q_2)^2 = 625 \times 10^{-12} - 6 \times 10^{-10}$$
$$= (625 - 600) \times 10^{-12}$$
$$= 25 \times 10^{-12}$$

or $\quad q_1 - q_2 = 5 \times 10^{-6}\text{C} = 5\mu\text{C}$

Question6

A solid of mass 1 kg has 6×10^{24} atoms. If one electron is removed from every one atom of 0.005% of the atoms, then the charge gained by the solid is

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Options:

A.

+24 C

B.

+48 C

C.

+96 C

D.

+60 C

Answer: B

Solution:

Given:

- Total atoms in the solid = 6×10^{24}
- 0.005% of atoms lose **one electron each**.

Step 1: Find how many atoms lose an electron

Number of affected atoms $= (0.005\%) \times (6 \times 10^{24})$

$0.005\% = \frac{0.005}{100} = 5 \times 10^{-5}$

$\Rightarrow$ Number of atoms losing electrons $= 6 \times 10^{24} \times 5 \times 10^{-5} = 3 \times 10^{20}$

Step 2: Each atom loses one electron

Each lost electron corresponds to a **positive charge** gained by the solid equal to the charge of that electron ($e = 1.6 \times 10^{-19}$ C).

Step 3: Total charge gained

$Q = (3 \times 10^{20}) \times (1.6 \times 10^{-19})$

$Q = 4.8 \times 10^{1} = 48$ C

✅ **Final Answer:**

$\boxed{+48 \text{ C}}$

Correct Option: B (+48 C)

Question7

If the energy stored in a spherical conductor having a charge of 12μC is 6 J , then the radius of the spherical conductor is

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Options:

A.

10.8 cm

B.

0.108 cm

C.

1.08 cm

D.

108 cm

Answer: A

Solution:

Step 1: Write the Formula for Energy Stored

The energy stored in a capacitor is given by the formula: $U=\frac{q^2}{2C}$ where U is energy, q is charge, and C is capacitance.

Step 2: Rearranging to Find Capacitance

We can solve for C as follows: $C=\frac{q^2}{2U}$

Here, $q=12\times10^{-6}$ C and $U=6$ J. Substitute these values into the formula:

$C=\frac{(12\times10^{-6})^2}{2\times6}$

Step 3: Calculate Capacitance

Simplify the above equation: $C=12\times10^{-12}$ F

Step 4: Capacitance of a Spherical Conductor

The capacitance of a spherical conductor is given by: $C=4\pi\varepsilon_0 r$

Step 5: Find the Radius

Rearrange to find the radius r: $r=\frac{C}{4\pi\varepsilon_0}$

We can also use $\frac{1}{4\pi\varepsilon_0}=9\times10^9\ \mathrm{N\ m^2/C^2}$ so:

$r=9\times10^9\times12\times10^{-12}$

Step 6: Solve for the Radius

Multiply the values: $r=108\times10^{-3}=0.108\ \mathrm{m}=10.8\ \mathrm{cm}$

Question8

A particle of mass 0.2 g and charge 2 C is released from rest in a uniform electric field of $20\mathrm{NC}^{-1}$. The kinetic energy of the particle after moving a distance of 20 cm is

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Options:

A.

10 J

B.

8 J

C.

18 J

D.

12 J

Answer: B

Solution:

Force on charge particle in electric field,

$F = qE = 2 \times 20 = 40$ N

According to work energy theorem, Kinetic energy $= W$

$= F \cdot s = 40 \times 0.2 = 8$ J

Question9

Two charged conducting spheres of radii 5 cm and 10 cm have equal surface charge densities. If the electric field on the surface of the smaller sphere is E, then the electric field on the surface of the larger sphere is

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Options:

A.

$2E$

B.

$4E$

C.

$0.5E$

D.

E

Answer: D

Solution:

$\sigma_1 = \sigma_2 = \sigma$

Since, $E = \frac{\sigma}{\varepsilon_0}$

$\therefore$ For the smaller sphere,

$E_1 = \frac{\sigma_1}{\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$

For the larger sphere,

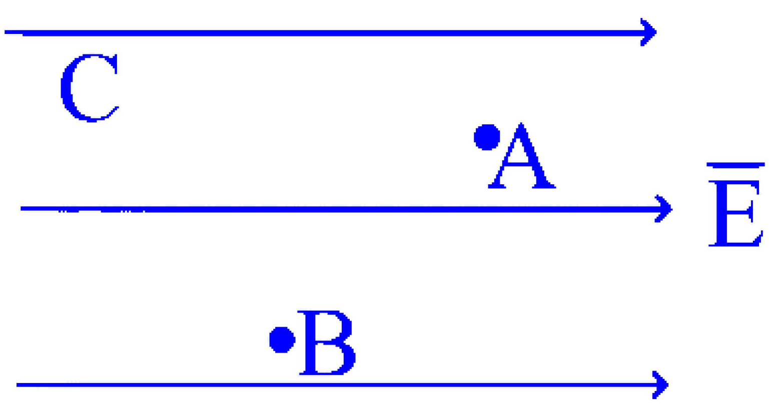
$E_2 = \frac{\sigma_2}{\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$

Since, $\sigma_1 = \sigma_2 = \sigma$

Thus, $E_1 = E_2 = E$

Question10

As shown in the figure, if the values of the electric potential at three points A, B and C in a uniform electric field (E) are V_A, V_B and V_C respectively, then



Options:

A.

$V_A > V_B > V_C$

B.

$V_A > V_C > V_B$

C.

$V_C > V_B > V_A$

D.

$V_C > V_A > V_B$

Answer: C

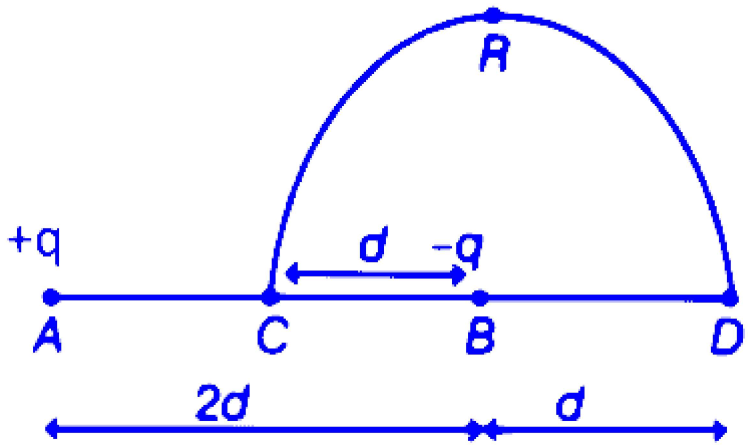
Solution:

As we move along a field line we are moving in direction of reducing potential.

So, $V_C > V_B > V_A$

Question11

As shown in the figure, the work done to move the charge ' Q ' from point C to point D along the semicircle CRD is



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Options:

A.

$\frac{qQ}{4\pi\varepsilon_0 d}$

B.

$\frac{qQ}{2\pi\varepsilon_0 d}$

C.

$\frac{-qQ}{6\pi\varepsilon_0 d}$

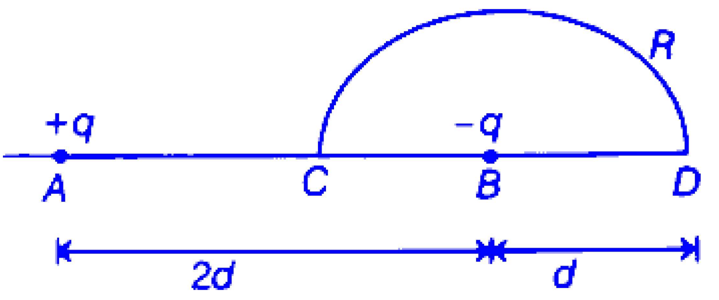
D.

$\frac{-qQ}{4\pi\varepsilon_0 d}$

Answer: C

Solution:

Potential at point C, due to charges $+q$ and $-q$.



$V_C = -\frac{kq}{d} + \frac{kq}{d} = 0$

and potential of point D

$V_0 = \frac{-kq}{d} + \frac{kq}{3d} = \frac{-2kq}{3d}$

So, potential difference between C and D

$V_D - V_C = \frac{-2kq}{3d}$

So, work done in moving charge Q from C to D

$$W = Q\left(V_D - V_C\right)$$
$$W = \frac{-2kQq}{3d}$$

$$Now,\ K = \frac{1}{4\pi\varepsilon_0} \Rightarrow W = \frac{-2Qq}{3\left(4\pi\varepsilon_0\right)d}$$
$$W = \frac{-Qq}{6\pi\varepsilon_0 d}$$

Question12

In a region, the electric field is given by $\mathbf{E} = (3\hat{\mathbf{i}} + 5\hat{\mathbf{j}} + 7\hat{\mathbf{k}})\mathrm{NC}^{-1}$. The electric flux through a surface of area $3\ \mathrm{m}^2$ in yz-plane is (in SI units)

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Options:

A.

21

B.

15

C.

12

D.

9

Answer: D

Solution:

Electric flux

$$\phi = \mathbf{E} \cdot \mathbf{A} = (3\hat{\mathbf{i}} + 5\hat{\mathbf{j}} + 7\hat{\mathbf{k}}) \cdot (3\hat{\mathbf{i}})$$
$$= 9\left(\mathrm{Nm}^2/\mathrm{C}\right)$$

Question13

The velocity acquired by an electron at rest when subjected to a uniform electric field of potential difference 180 V is

(Mass of electron $= 9 \times 10^{-31}$ kg and charge of electron $= 1.6 \times 10^{-19}$C)

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Options:

A.

$400 \mathrm{~km} \mathrm{~s}^{-1}$

B.

$4000 \mathrm{~km} \mathrm{~s}^{-1}$

C.

$800 \mathrm{~km} \mathrm{~s}^{-1}$

D.

$8000 \mathrm{~km} \mathrm{~s}^{-1}$

Answer: D

Solution:

$$\begin{aligned} & \frac{1}{2} m v^2=q V \\ \Rightarrow \quad & v=\sqrt{\frac{2 q V}{m}}=\sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 180}{9 \times 10^{-31}}} \\ & =8 \times 10^6 \mathrm{~m} / \mathrm{s}=8000 \times 10^3 \mathrm{~m} / \mathrm{s} \\ & =8000 \mathrm{~km} / \mathrm{s} \end{aligned}$$

Question14

Three particles of each charge q are placed at the vertices of an equilateral triangle of side L. The work to be done to decrease the side of the triangle to $\frac{L}{2}$ is

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Options:

A.

$\frac{1}{4 \pi \varepsilon_0} \frac{q^2}{L}$

B.

$\frac{1}{4 \pi \varepsilon_0} \frac{2 q^2}{L}$

C.

$\frac{1}{4 \pi \varepsilon_0} \frac{3 q^2}{L}$

D.

$\frac{1}{4 \pi \varepsilon_0} \frac{3 q^2}{2 L}$

Answer: C

Solution:

Initial potential energy of the system of

$U_i = 3 \times \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{L}$

Final potential energy of the system

$U_f = 3 \times \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{\frac{L}{2}} = 6 \times \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{L}$

$\therefore$ Required work done

$$\begin{aligned} W &= U_f - U_i \\ &= 6 \times \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{L} - 3 \times \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{L} \\ &= \frac{1}{4\pi\varepsilon_0} \frac{3q^2}{L} \end{aligned}$$

Question15

If 27 charged water droplets, each of radius 10^{-3} m and charge 10^{-12}C coalesce to form a single big spherical drop, then the potential of the big drop is

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Options:

A.

9 V

B.

27 V

C.

39 V

D.

81 V

Answer: D

Solution:

$27 \times \frac{4}{3} \pi r^3 = \frac{4}{3} \pi R^3$

$\Rightarrow \quad R = 3r$

Potential on small drop

$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r} = 9 \times 10^9 \times \frac{10^{-12}}{10^{-3}} = 9\text{volt}$

Potential on big drop

$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{27q}{R} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{27q}{3r}$

$$= 9 \times \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$$
$$= 9 \times 9 = 81 \text{ V}$$

Question16

The force between two point charges kept with a separation of 9 cm in air is 98 N . If a dielectric slab of constant 4, thickness 6 cm and another dielectric slab of constant 9 , thickness 3 cm are introduced between the two charges, then the new force becomes

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Options:

A.

18 N

B.

36 N

C.

49 N

D.

84 N

Answer: A

Solution:

$F_0 = 98 \text{ N}$

$$\text{Using, } \frac{d}{k} = \frac{d_1}{k_1} + \frac{d_2}{k_2}$$
$$\Rightarrow \quad \frac{9}{k} = \frac{6}{4} + \frac{3}{9}$$
$$\Rightarrow \quad k = \frac{54}{11}$$

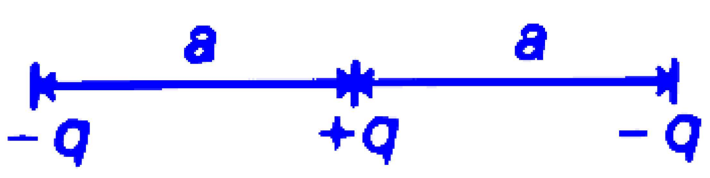
$\therefore$ New force, $F' = \frac{F_0}{k}$

$= \frac{98}{\frac{54}{11}} = 98 \times \frac{11}{54} = 19.96 \text{ N}$

Which is closest to 18 N .

Question17

Three point charges shown in the figure lie along a straight line. The energy required to exchange the position of central charge with one of the negative charges is



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Options:

A.

$\frac{q^2}{8\pi\varepsilon_0 a}$

B.

$\frac{3q^2}{8\pi\varepsilon_0 a}$

C.

$\frac{q^2}{4\pi\varepsilon_0 a}$

D.

$\frac{5q^2}{4\pi\varepsilon_0 a}$

Answer: C

Solution:

$$U_{\text{initial}} = U_{12} + U_{13} + U_{23}$$

$$= \frac{kq^2}{2a} - \frac{kq^2}{a} - \frac{kq^2}{a} = \frac{kq^2}{2a} - \frac{2kq^2}{a} = \frac{-3kq^2}{2a}$$

After exchanging the final charge with one of the negative charge, there are two - q charges separated by a distance a and one $+q$ charge separated by a distance ' a ' from one of the $-q$ charges.

$$\therefore U_{\text{final}} = U'_{12} + U'_{13} + U'_{23}$$

$$= \frac{kq^2}{a} - \frac{kq^2}{2a} - \frac{kq^2}{a} = \frac{-kq^2}{2a}$$

$$\therefore \Delta U = U_{\text{final}} - U_{\text{initial}}$$

$$= -\frac{kq^2}{2a} - \left(\frac{-3kq^2}{2a}\right) = \frac{2kq^2}{2a}$$

$$= \frac{kq^2}{a} = \frac{q^2}{4\pi\varepsilon_0 a} \quad \left[\because k = \frac{1}{4\pi\varepsilon_0}\right]$$

Question18

A particle of mass 0.5 g and charge $10\mu\text{C}$ is subjected to a uniform electric field of 8NC^{-1}. If the particle is initially at rest, the velocity of the particle after a time of 5 s is

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Options:

A. 5 ms^{-1}

B. 0.5 ms^{-1}

C. 8 ms^{-1}

D. 0.8 ms^{-1}

Answer: D

Solution:

Mass, $m = 0.5 \text{ g} = 0.5 \times 10^{-3} \text{ kg}$

Charge, $q = 10 \times 10^{-6} \text{ C}$

Electric field, $E = 8 \text{ NC}^{-1}$

First, calculate the force F on the particle using the equation:

$F = q \times E$

Substituting the values:

$F = 10 \times 10^{-6} \times 8 = 80 \times 10^{-6} = 8 \times 10^{-5} \text{ N}$

Next, find the acceleration a using the formula:

$a = \frac{F}{m}$

Substitute the values to find:

$a = \frac{8 \times 10^{-5}}{0.5 \times 10^{-3}} = 0.16 \text{ m/s}^2$

Since the particle starts from rest, the initial velocity u is 0.

Using the kinematic equation for velocity:

$v = u + at$

Substituting the known values:

$v = 0 + 0.16 \times 5 = 0.8 \text{ m/s}$

Therefore, the velocity of the particle after 5 seconds is 0.8 m/s.

Question19

125 identical charged small spheres coalesce to form a big charged sphere. If the electric potential on each small sphere is 60 mV , then the electric potential on the bigger sphere formed is

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Options:

A. 30 V

B. 15 V

C. 1.5 V

D. 3 V

Answer: C

Solution:

The electric potential V of a sphere is directly proportional to its charge Q and inversely to its radius r,

$V = \frac{kQ}{r}$

For small sphere,

$$\begin{aligned} V_{\text{small}} &= \frac{kQ_{\text{small}}}{r_{\text{small}}} = 60\text{mV} \\ V_{\text{big}} &= \frac{kQ_{\text{total}}}{r_{\text{big}}} = \frac{k \cdot 125Q_{\text{small}}}{r_{\text{big}}} \end{aligned}$$

The volume of the big sphere is 125 times the volume of small sphere, so

$$\begin{aligned} V_{\text{big}} &= \frac{k \times 125Q_{\text{small}}}{\left(125^{1/3}\right) r_{\text{small}}} \\ &= 125^{2/3} \cdot \frac{kQ_{\text{small}}}{r_{\text{small}}} \\ &= 125^{2/3} \cdot 60\text{mV} \\ &= 125^{2/3} \times 60 \times 10^{-3} = 1.5 \text{ V} \end{aligned}$$

Therefore, the electric potential on the bigger formed is 1.5 V .

Question20

Two particles of charges 4 nC and Q are kept in air with a separation of 10 cm between them. If the electrostatic potential energy of the system is 1.8μ J, then $Q =$

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Options:

A. 12 nC

B. 9 nC

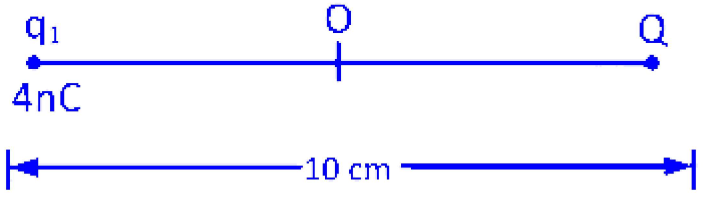
C. 5 nc

D. 7 nC

Answer: C

Solution:

Given, $q_1 = 4\text{nC} = 4 \times 10^{-9}\text{C}$
$U = 1.8\mu\text{ J} = 1.8 \times 10^{-6}\text{ J}$
$r = 10\text{ cm} = 0.1\text{ m}$



As, $Q = \dfrac{U \times r}{k \times q_1}$
$\Rightarrow Q = \dfrac{1.8 \times 10^{-6} \times 0.1}{8.9875 \times 10^{9} \times 4 \times 10^{-9}}$
$\Rightarrow Q = \dfrac{1.8 \times 10^{-7}}{35.95}$
$\Rightarrow Q = 5 \times 10^{-9}\text{C}$
$\Rightarrow Q = 5\text{nC}$

Question21

The magnitude of an electric field which can just suspend a deuteron of mass 3.2×10^{-27} kg freely in ari is

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Options:

A. $19.6 \times 10^{-8}\text{NC}^{-1}$

B. $196 \mathrm{NC}^{-1}$

C. $1.96 \times 10^{-10} \mathrm{NC}^{-1}$

D. $0.196 \mathrm{NC}^{-1}$

Answer: A

Solution:

Given:

Mass of a deuteron, $m_d = 3.2 \times 10^{-27}$ kg

Charge of a deuteron, $q_d = 1.6 \times 10^{-19}$ C

Gravitational acceleration, $g = 9.8 \mathrm{~m/s}^2$

To suspend the deuteron in the air, the electric force (F_{electric}) must equal the gravitational force (F_{gravity}):

$F_{\text{electric}} = F_{\text{gravity}}$

Thus:

$qE = mg$

Solving for E, the magnitude of the electric field:

$E = \frac{mg}{q} = \frac{3.2 \times 10^{-27} \times 9.8}{1.6 \times 10^{-19}}$

$E = \frac{3.2 \times 9.8}{1.6} \times 10^{-8}$

$E = 2 \times 9.8 \times 10^{-8} = 19.6 \times 10^{-8} \mathrm{~N/C}$

Therefore, the magnitude of the electric field required is 19.6×10^{-8} N/C.

Question22

Two charges 5 nC and -2 nC are placed at points $(5 cm \ 0, 0)$ and $(23 \mathrm{~cm}, 0, 0)$ in a region of space where there is no other external field. The electrostatic potential energy of this charge system is

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Options:

A. 10×10^{-7} J

B. 5×10^{-7} J

C. 15×10^{-7} J

D. 25×10^{-7} J

Answer: B

Solution:

Given:

$q_1 = 5\,\text{nC} = 5 \times 10^{-9}\,\text{C}$

$q_2 = -2\,\text{nC} = -2 \times 10^{-9}\,\text{C}$

These charges are positioned along the X-axis. First, let's determine the distance between them:

$$x = x_2 - x_1$$
$$= (23 - 5)\,\text{cm} = 18\,\text{cm} = 18 \times 10^{-2}\,\text{m}$$

Now, calculate the electrostatic potential energy (U) of the charges using the formula:

$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{x}$

Substitute the known values:

$U = \frac{9\times10^9\times5\times10^{-9}\times(-2\times10^{-9})}{18\times10^{-2}}$

$U = -5 \times 10^{-7}\,\text{J}$

The negative sign in the electrostatic potential energy indicates that the force between the two charges is attractive.

Question23

A neutral ammonia NH_3 in its vapour state has electric dipole moment of magnitude $5 \times 10^{-30}\text{C} - \text{m}$. How far apart are the molecules centres of positive and negative charge?

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Options:

A. 4.125×10^{-12} m

B. 3.125×10^{-12} m

C. 3125×10^{-6} m

D. 4.125×10^{-6} m

Answer: B

Solution:

Given:

Electric dipole moment, $p = 5 \times 10^{-30}\,\mathrm{C \cdot m}$

In a neutral ammonia (NH_3) molecule, there are 10 electrons and 10 protons. The electric dipole moment is expressed as:

$p = q \times 2l = 10e \times 2l$

Where e is the elementary charge ($1.6 \times 10^{-19}\,\mathrm{C}$).

To find the separation distance $2l$, we use:

$2l = \frac{p}{10e} = \frac{5 \times 10^{-30}}{10 \times 1.6 \times 10^{-19}}$

Calculating this gives:

$2l = 3.125 \times 10^{-12}\,\mathrm{m}$

Thus, the distance between the centers of positive and negative charge in the molecule is $3.125 \times 10^{-12}\,\mathrm{m}$.

Question24

If four charges $q_1 = +1 \times 10^{-8}\mathrm{C}$, $q_2 = -2 \times 10^{-8}\mathrm{C}$, $q_3 = +3 \times 10^{-8}\mathrm{C}$ and $q_4 = +2 \times 10^{-8}\mathrm{C}$ are kept at the four corners of a square of side 1 m , then the electric potential at the centre of the square is

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Options:

A. 300 V

B. 200 V

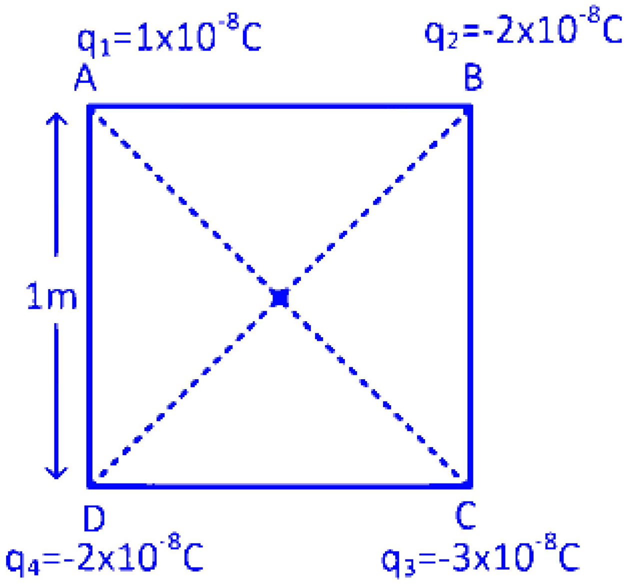
C. 510 V

D. 410 V

Answer: C

Solution:

$q_1=+1\times10^{-8}\mathrm{C}$
$q_2=-2\times10^{-8}\mathrm{C}$
$q_3=+3\times10^{-8}\mathrm{C}$
$q_4=+2\times10^{-8}\mathrm{C}$



Here,

At point A and C, charges are $q_1=1\times10^{-8}\mathrm{C}$ and $3\times10^{-1}\mathrm{C}$

$$V_{AC}=9\times10^9\left[\frac{1\times10^{-8}+3\times10^{-8}}{1}\right]\sqrt{2}$$
$$=9\times10^9\left[4\times10^{-8}\right]\sqrt{2}$$

$$=9\times10^9\times4\times10^{-8}\times\sqrt{2}$$
$$=90\times4\times\sqrt{2}=360\sqrt{2}=510\ \mathrm{V}$$

At point B and D, charges are $q_2=-2\times10^{-8}\mathrm{C}$ and $q_4=2\times10^{-8}\mathrm{C}$ Thus potential $V_{BD}=0$ Hence, answer will be 510 V

Question25

The electric field intensity E at a distance of 3 m from a uniform long straight wire of linear charge density $0.2\mu\ \mathrm{cm}^{-1}$ is

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Options:

A. $1.2 \times 10^3 \mathrm{Vm}^{-1}$

B. $0.6 \times 10^3 \mathrm{Vm}^{-1}$

C. $1.8 \times 10^3 \mathrm{Vm}^{-1}$

D. $2.4 \times 10^3 \mathrm{Vm}^{-1}$

Answer: A

Solution:

Given:

Distance $r = 3 \, \mathrm{m}$

Linear charge density $\lambda = 0.2 \, \mu\mathrm{C/m} = 0.2 \times 10^{-6} \, \mathrm{C/m}$

The electric field E at a distance r from a long straight wire is calculated using the formula:

$E = \frac{\lambda}{2\pi\varepsilon_0 r}$

Where:

ε_0 is the permittivity of free space, approximately $8.85 \times 10^{-12} \, \mathrm{C}^2/\mathrm{N} \cdot \mathrm{m}^2$

Substitute the given values into the formula:

$E = \frac{0.2 \times 10^{-6}}{2\pi \times 8.85 \times 10^{-12} \times 3}$

This calculation results in:

$E \approx 1.2 \times 10^3 \, \mathrm{V/m}$

Question26

A point charge $q\mathrm{C}$ is placed at the centre of a cube of a side length L. Then, the electric flux linked with each face of the cube is

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Options:

A. $\frac{q}{\varepsilon_0}$

B. $\frac{q}{L^2\varepsilon_0}$

C. $\frac{q}{6L^2\varepsilon_0}$

D. $\frac{q}{6\varepsilon_0}$

Answer: D

Solution:

Given:

A charge q is placed at the center of a cube.

The side length of the cube is L.

We know that the electric flux through a closed surface that encloses a charge q is given by Gauss's Law:

$\phi_t = \frac{q}{\varepsilon_0}$

Here, ϕ_t represents the total electric flux through the entire surface of the cube.

Since a cube has 6 faces, the flux through each individual face, ϕ_f, is the total flux divided equally among the six faces:

$\phi_f = \frac{1}{6} \times \phi_t = \frac{1}{6} \times \frac{q}{\varepsilon_0} = \frac{q}{6\varepsilon_0}$

This shows that the electric flux associated with each face of the cube is $\frac{q}{6\varepsilon_0}$.

Question27

Three equal electric charges of each charge q are placed at the vertices of an equilateral triangle of side of length L. Then, potential energy of the system is

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Options:

A. $\frac{1}{4\pi\varepsilon_0} \cdot \frac{3q^2}{L}$

B. $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{3L}$

C. $\frac{1}{4\pi\varepsilon_0} \cdot \frac{2q^2}{3L}$

D. $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{L}$

Answer: A

Solution:

Given:

Each side of the equilateral triangle has a length L.

Each vertex has a charge q.

The potential energy U of the system can be calculated by considering the interactions between each pair of charges. Since there are three sides in an equilateral triangle, we have three pairs of charges to consider:

$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{q \cdot q}{L} + \frac{q \cdot q}{L} + \frac{q \cdot q}{L}\right]$

Simplifying the expression:

$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{L} \cdot (1+1+1)$

$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{3q^2}{L}$

Therefore, the potential energy of the system of three equal charges at the vertices of an equilateral triangle is:

$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{3q^2}{L}$

Question28

Eight drops of mercury of equal radii and possessing equal charge combine to form a big drop. If the capacity of each drop is C, then capacity of the big drop is

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Options:

A. $4C$

B. 2 C

C. 8 C

D. 16 C

Answer: B

Solution:

To understand the change in capacitance when eight smaller drops combine to form a larger drop, consider the following:

Let R be the radius of the larger drop and r be the radius of each smaller drop. When these smaller drops combine, the total volume remains constant. Therefore, the volume of the large drop equals the total volume of the eight smaller drops:

$\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3$

This simplifies to:

$R^3 = 8r^3$

$R = 2r$

Given that the capacitance C of an isolated spherical conductor is described by the formula:

$C = 4\pi\varepsilon_0 r$

The capacitance of each smaller drop is:

$C = 4\pi\varepsilon_0 r$

For the larger drop, now having a radius $R = 2r$, the capacitance C' is calculated as follows:

$C' = 4\pi\varepsilon_0 R$

$C' = 4\pi\varepsilon_0(2r) = 2 \times 4\pi\varepsilon_0 r = 2C$

Thus, the capacitance of the larger drop is $2C$.

Question29

Three point charges $+q$, $+2q$ and $+4q$ are placed along a straight line such that the charge $+2q$ lies at equidistant from the other two charges. The ratio of the net electrostatic force on charges $+q$ and $+4q$ is

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Options:

A. 1 : 1

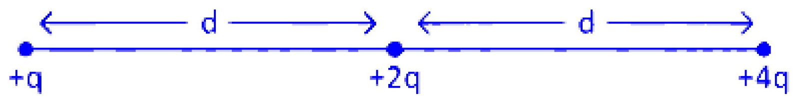
B. 1 : 2

C. 1 : 4

D. 1 : 3

Answer: D

Solution:



Electrostatic force on $+q$ due to $+2q$ and $+4q$

$E_{q,2q} = \frac{kq(2q)}{d^2} = \frac{2kq^2}{d^2} \quad \ldots \text{(i)}$

$E_{q,4q} = \frac{kq(4q)}{(2d)^2} = \frac{kq^2}{d^2} \quad \ldots \text{(ii)}$

Total force on $+q$

$= \frac{2kq^2}{d^2} + \frac{kq^2}{d^2} = \frac{3kq^2}{d^2} \quad \ldots \text{(iii)}$

Electrostatic force on $+4q$ due to $+2q$ and $+q$

$E_{4q,2q} = \frac{k(2q)(4q)}{d^2} = \frac{8k^2}{d^2} \quad \ldots \text{(iv)}$

$E_{4q,q} = \frac{k(4q)(q)}{(2d)^2} = \frac{kq^2}{d^2} \quad \ldots \text{(v)}$

Total force on $+4q = 9\frac{kq^2}{d^2} \quad \ldots \text{(vi)}$

Ratio of net force on q_1 and $+4q$.

$= \frac{3kq^2}{d^2} \times \frac{d^2}{9kq^2} = \frac{3}{9} = 1 : 3$

Question30

A particle of mass 2 g and charge $6\mu\text{C}$ is accelerated from rest through a potential difference of 60 V . The speed acquired by the particle is

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Options:

A. 0.6 ms^{-1}

B. 1.2 ms^{-1}

C. 1.8 ms^{-1}

D. 0.3 ms^{-1}

Answer: A

Solution:

To determine the speed acquired by a particle when it is accelerated through a potential difference, we need to use the concept of energy conservation. The kinetic energy gained by the particle is equal to the electrical work done on the particle due to the potential difference.

Given:

Mass of the particle, $m = 2\,\text{g} = 2 \times 10^{-3}\,\text{kg}$

Charge of the particle, $Q = 6\,\mu\text{C} = 6 \times 10^{-6}\,\text{C}$

Potential difference, $V = 60\,\text{V}$

The relationship between the kinetic energy (KE) gained and the potential difference is described by the equation:

$\text{KE} = Q \times V$

The kinetic energy can also be expressed in terms of velocity (v) as:

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

Solving for velocity v, we get:

$v = \left(\frac{2QV}{m}\right)^{1/2}$

Substituting the given values into the equation:

$v = \left(\frac{2\times6\times10^{-6}\times60}{2\times10^{-3}}\right)^{1/2}$

Simplifying further:

$v = \left(\frac{720\times10^{-6}}{2\times10^{-3}}\right)^{1/2}$

$v = (0.36)^{1/2}$

$v = 0.6\,\text{m/s}$

Thus, the speed acquired by the particle is $0.6\,\text{m/s}$.

Question31

Two spheres A and B of radii 4 cm and 6 cm are given charges of $80\mu\mathrm{C}$ and $40\mu\mathrm{C}$ respectively. If they are connected by a fine wire, the amount of charge flowing from one to the other is

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Options:

A. $32\mu\mathrm{C}$ from B to A

B. $32\mu\mathrm{C}$ from A to B

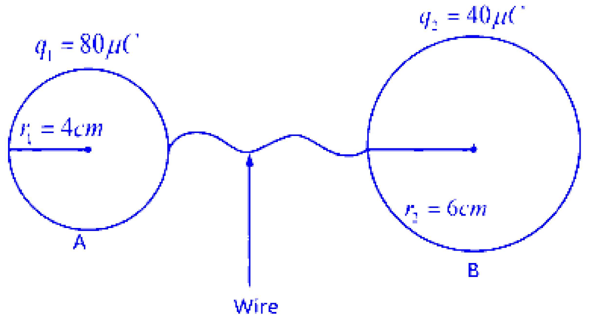
C. $20\mu\mathrm{C}$ from A to B

D. $16\mu\mathrm{C}$ from B to A

Answer: B

Solution:

When the two spheres A and B are connected by a fine wire, then the electric potential will be same on bedt the spheres.



$$\Rightarrow \quad V_A = V_B \Rightarrow \frac{kq_1}{r_1} = \frac{kq_2}{r_2}$$
$$\Rightarrow \quad \frac{q_1}{0.4} = \frac{q_2}{0.6} \Rightarrow q_2 = 1.5q_1$$

Total charges is conserved here,

Charge before connecting wire = charge after connecting wire.

$$80\mu\mathrm{C} + 40\mu\mathrm{C} = 2.5q_1$$
$$q_1 = \frac{120\mu\mathrm{C}}{2.5} = 48\mu\mathrm{C}$$

and $\quad q_2 = 1.5q_1 = 1.5 \times 48 = 72\mu\mathrm{C}$ So, we can conclude that $(72 - 40)\mu\mathrm{C} = 32\ \mu C$ charge flows from sphere A to B.

Question32

The angle between the electric dipole moment of a dipole and the electric field strength due to it on the equatorial line is

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Options:

A. 0°

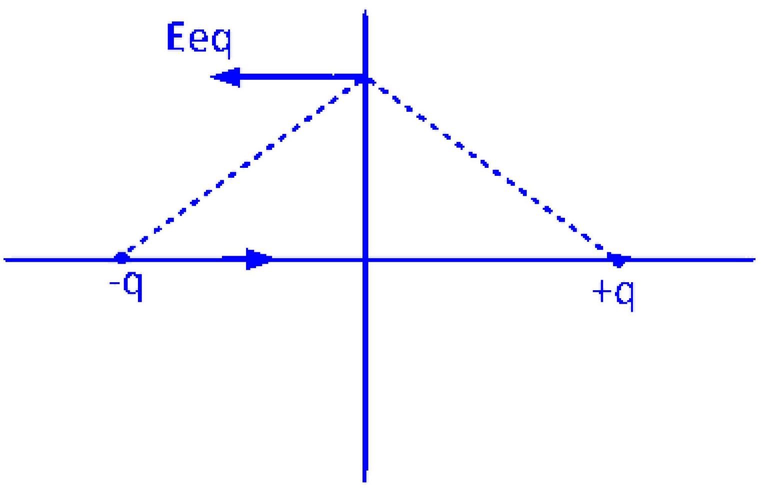
B. 90°

C. 180°

D. 270°

Answer: C

Solution:



From the above figure, it can be concluded that the dipole moment of a dipole and electric field strength are opposite to each other on equatorial line. Thus, the angle between them is 180°.

Question33

Two particles of equal mass m and equal charge q are separated by a distance of 16 cm . They do not experience any force. The value of $\frac{q}{m}$

is (if G is the universal gravitational constant and g is the acceleration due to gravity)

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Options:

A. $\sqrt{4\pi\varepsilon_0 G}$

B. $\sqrt{\frac{G}{4\pi\varepsilon_0}}$

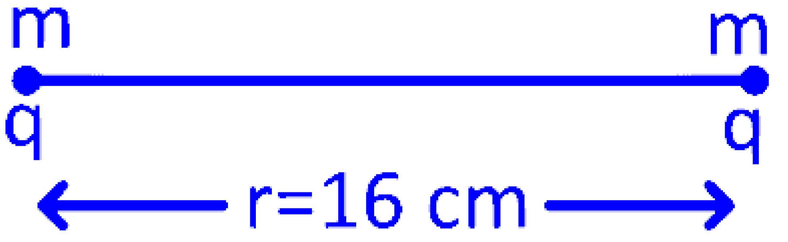
C. $\sqrt{\frac{\pi\varepsilon_0}{G}}$

D. $\sqrt{4\pi\varepsilon_0 g}$

Answer: A

Solution:

In the given scenario, two particles with equal mass m and charge q, separated by a distance of 16 cm, are in a state where they do not experience any net force. This implies that the electrostatic force and gravitational force between the particles are equal and opposite.



Initially, the electrostatic force (F_c) between the particles is given by Coulomb's Law:

$$F_c = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$$

where ε_0 is the permittivity of free space, q is the charge, and r is the separation distance.

The gravitational force (F_g) can be expressed using Newton's Law of Gravitation:

$$F_g = \frac{Gm^2}{r^2}$$

where G is the universal gravitational constant and m is the mass of each particle.

According to the problem, $F_c = F_g$. Therefore, we equate the two equations:

$$\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2} = \frac{Gm^2}{r^2}$$

Canceling r^2 from both sides:

$\frac{q^2}{4\pi\varepsilon_0} = Gm^2$

This simplifies to:

$\frac{q^2}{m^2} = 4\pi\varepsilon_0 G$

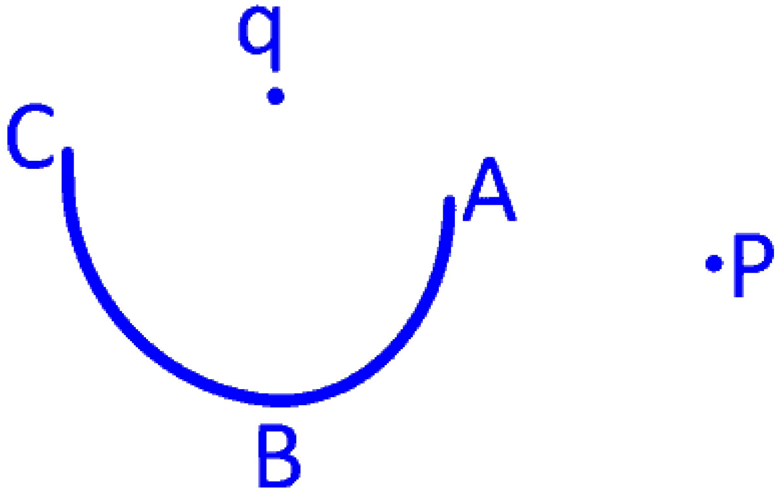
Taking the square root of both sides gives us:

$\frac{q}{m} = \sqrt{4\pi\varepsilon_0 G}$

This expression gives the value of $\frac{q}{m}$ in terms of known constants.

Question34

In the following diagram, the work done in moving a point charge from point P to points A, B and C are W_A, W_B and W_C respectively. Then (A, B, C are points on semi-circle and point charge q is at the centre of semi-circle)



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Options:

A. $W_A = W_B = W_C \neq 0$

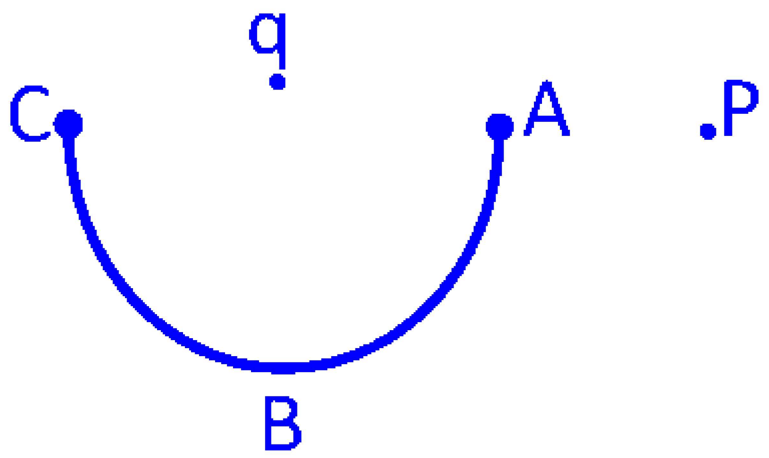
B. $W_A = W_B = W_C = 0$

C. $W_A > W_B > W_C$

D. $W_A > W_B > W_C$

Answer: B

Solution:



For the given situation, points A, B and C are at equipotential surface.

i.e., $V_A = V_B = V_C$

$\therefore$ $W_A = W_B = W_C = 0$

Question35

Two point charges $+6\mu\text{C}$ and $+10\mu\text{C}$ kept at certain distance repel each other with a force of 30 N . If each charge is given an additional charge of $-8\mu\text{C}$, the jwo charges

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Options:

A. atrinct with a force of 2 N

B. reper with a force of 2 N

C. atract with a lorce of 15 N

D. repel with a force of 15 N

Answer: A

Solution:

Given:

Initial charges:

$q_1 = +6\,\mu\text{C} = 6 \times 10^{-6}\,\text{C}$

$q_2 = +10\,\mu\text{C} = 10 \times 10^{-6}\,\text{C}$

Force of repulsion: $F = 30\,\text{N}$

Using Coulomb's Law:

$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$

Solve for r^2:

$r^2 = \frac{9\times10^9\times6\times10\times10^{-12}}{30}$

$r^2 = 18 \times 10^{-3} \quad \ldots(\text{Equation 1})$

Adding Additional Charges:

Each charge receives an additional $-8\mu\text{C}$:

$q_1' = +6 - 8 = -2\mu\text{C}$

$q_2' = +10 - 8 = +2\mu\text{C}$

Recalculate the Force Using Coulomb's Law:

$F' = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1' \cdot q_2'}{r^2}$

Substitute q_1' and q_2':

$F' = \frac{9\times10^9\times2\times2\times10^{-12}}{18\times10^{-3}}$

(From Equation 1)

$F' = 2\,\text{N}$

Since one charge is positive and the other is negative, they attract each other with a force of $2\,\text{N}$.

Question36

In a region, the electric field is $30\hat{\mathbf{i}} + 40\hat{\mathbf{j}}\text{NC}^{-1}$, If the electric potential at the origin is zero. The electric potential at the point ($1\text{ m}, 2\text{ m}$) is

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Options:

A. -60 V

B. -75 V

C. -55 V

D. -110 V

Answer: D

Solution:

To find the electric potential at the point $(1\,\mathrm{m}, 2\,\mathrm{m})$, we begin with the given electric field and displacement vector:

$\mathbf{E} = (30\hat{\mathbf{i}} + 40\hat{\mathbf{j}})\,\mathrm{N/C}$

$\mathbf{d} = (1\hat{\mathbf{i}} + 2\hat{\mathbf{j}})\,\mathrm{m}$

The formula for electric potential V with respect to a chosen reference point is given by:

$V = -\mathbf{E} \cdot \mathbf{r}$

Applying the formula, we compute the dot product:

$V = -(30\hat{\mathbf{i}} + 40\hat{\mathbf{j}}) \cdot (1\hat{\mathbf{i}} + 2\hat{\mathbf{j}})$

Break it down as follows:

$V = -(30 \cdot 1 + 40 \cdot 2)$

$V = -(30 + 80)$

$V = -110\,\mathrm{V}$

Thus, the electric potential at the point $(1\,\mathrm{m}, 2\,\mathrm{m})$ is $-110\,\mathrm{V}$.

Question37

A large number of positive charges each of magnitude q are placed along the X-axis at the origin and at every 1 cm distance in both the directions. The electric flux through a spherical surface of radius 2.5 cm centred at the origin is

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Options:

A. $\frac{5q}{\varepsilon_0}$

B. $\frac{8q}{\varepsilon_0}$

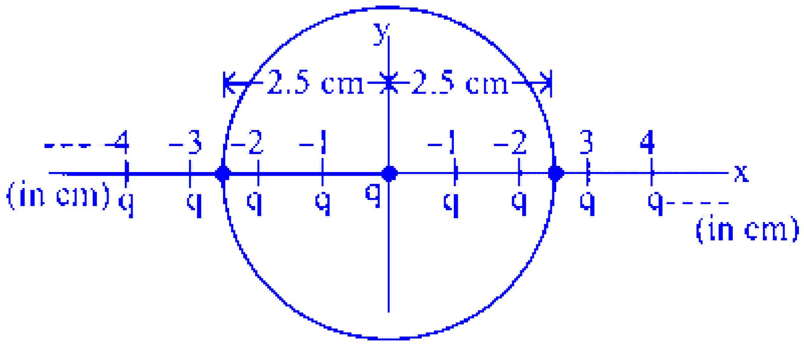
C. 0

D. ∞

Answer: A

Solution:

The given situation is shown below



From the above figure total charge enclosed by the sphere of radius 2.5 cm = 5q

$\therefore$ According to gauss law, total electric flux passing through spherical surface,

$$\phi = \frac{\text{total charge enclosed}}{\varepsilon_0}$$

$$= \frac{5q}{\varepsilon_0}$$

Question38

The electric field in a region of space is given as $\mathbf{E} = \left(5 \mathrm{NC}^{-1}\right) x \hat{i}$. Consider point A on the Y-axis at $y = 5$ m and point B on the X-axis at $x = 2$ m. If the potentials at points A and B are V_A and V_B respectively, then $(V_B - V_A)$ is

AP EAPCET 2022 - 5th July Morning Shift

Options:

A. -15 V

B. 8 V

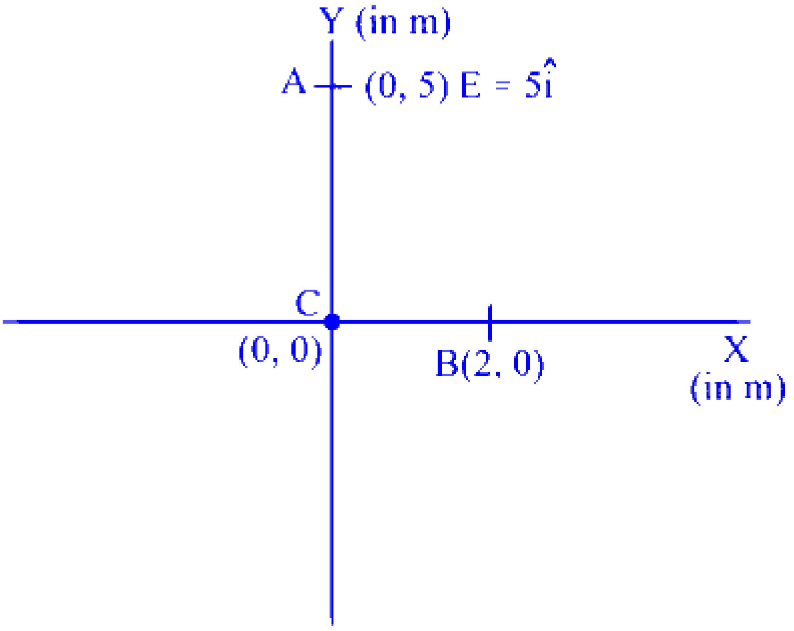
C. -10 V

D. -12.5 V

Answer: C

Solution:

The given situation is shown below



Since, electric field is directed along the X-axis, hence, point A and C lie on equipotential surface

$\therefore$ Potential at point $C =$ Potential at point A

$$\Rightarrow \quad V_C = V_A$$
$$\therefore \quad V_B - V_A = V_B - V_C$$
$$= -E\Delta x = -5(2-0) = -10 \text{ V}$$

Question39

A solid sphere of radius R carries a positive charge Q distributed uniformly throughout its volume. A very thin hole is drilled through it's centre. A particle of mass m and charge $-$q performs simple harmonic motion about the centre of the sphere in this hole. The frequency of oscillation is

Options:

A. $\frac{1}{2\pi}\left[\frac{Qq}{4\pi\varepsilon_0 R^3 m}\right]^{\frac{1}{2}}$

B. $\frac{1}{2\pi}\left[\frac{Qq}{4\pi\varepsilon_0 R^2 m}\right]^{\frac{1}{2}}$

C. $\frac{1}{2\pi}\frac{Q}{[4\pi\varepsilon_0 m R^3]^{\frac{1}{2}}}$

D. $\frac{1}{2\pi}\left[\frac{Qq}{4\pi\varepsilon_0 m R}\right]^{\frac{1}{2}}$

Answer: A

Solution:

According to given situation, electric field produced in the region of drilled hole at a distance x from its centre,

$E=\frac{Qx}{4\pi\varepsilon_0 R^3}$ .... (i)

Force on charge $(-q)$ when it is placed at a distance x,

$$F=-qE$$
$$\Rightarrow \quad ma=-qE$$
$$a=\frac{-qE}{m}=\frac{-q}{m}\cdot\frac{Qx}{4\pi\varepsilon_0 R^3}$$
$$\Rightarrow \quad a=\frac{-Qqx}{4\pi\varepsilon_0 m R^3}$$
$$\Rightarrow \quad -\omega^2 x=\frac{-Qqx}{4\pi\varepsilon_0 m R^3}$$
$$\therefore \quad \omega^2=\frac{Qq}{4\pi\varepsilon_0 m R^3}$$
$$(2\pi f)^2=\frac{Qq}{4\pi\varepsilon_0 m R^3}$$
$$\Rightarrow \quad f=\frac{1}{2\pi}\left(\frac{Qq}{4\pi\varepsilon_0 m R^3}\right)^{1/2}$$

Question40

Assertion (A) In a region of constant potential, the electric field is zero and there can be no charge inside the region.

Reason (R) According to Gauss law, charge inside the region should be zero if electric field is zero.

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Options:

A. Both A and R are true; R is correct explanation of A.

B. Both A and R are true; R is not correct explanation of A.

C. A is true, R is false.

D. A is false, R is true.

Answer: B

Solution:

We know that, electric field (E) and electric potential are related as

$E=\frac{-dV}{dr}$

For the region of constant potential (V)

$E=0$

According to Gauss's, law, electric flux through closed Gaussian surface

$\phi=\oint E . d s=\frac{q}{\varepsilon_0}$ ... (i)

$$\begin{aligned} & \text{if} \quad E=0 \\ & \Rightarrow \quad \oint E . d s=0\end{aligned}$$

Hence, from Eq (i) , $q=0$

Question41

Statement (A) Inside a charged hollow metal sphere, $E=0, V \neq 0$, (where, $E=$ electric field, $V=$ electric potential).

Statement (B) The work done in moving a positive charge on an equipotential surface is zero.

Statement (C) When two like charges are brought closer, their mutual electrostatic potential energy will increase.

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Options:

A. A, B, C are true

B. A, B are true, C is false

C. A, C are true, B is false

D. B, C are true, A is false

Answer: A

Solution:

Inside a charged hollow metal sphere, electric field (E) is zero but electric potential (V) is not zero and equal to same potential as on its surface. Work done to move a charge particle (either $+ve$ or $-ve$) on a equipotential surface between any two points is always zero.

$$\begin{aligned} \text{Since, } W &= q\left(V_1 - V_2\right) \\ &= q(V - V) \quad (\because V_1 = V_2 = V) \\ &= 0 \end{aligned}$$

Potential energy of system of two like charges placed at a distance r is given as,

$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$

When both like charges q_1 and q_2 are brought closer, then r decreases, hence potential energy U increases.

Therefore, statements (A), (B) and (C), all are true.

Question42

Electrostatic force between two identical charges placed in vacuum at distance of r is F. A slab of width $\frac{r}{5}$ and dielectric constant 9 is

inserted between these two charges, then the force between the charges is

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Options:

A. F

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

C. $\frac{25}{81} F$

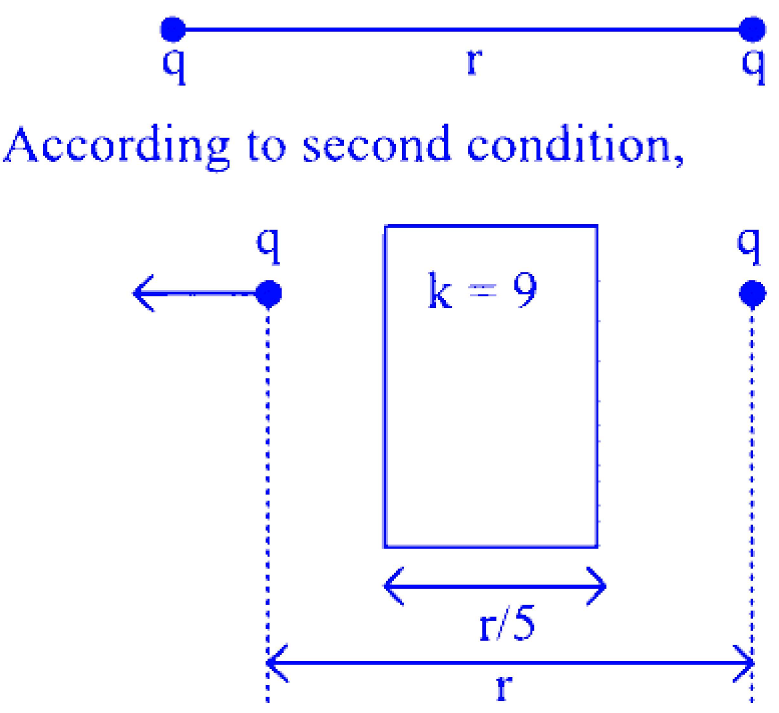
D. $\frac{25}{49} F$

Answer: D

Solution:

According to first condition,

$F = \frac{1}{4\pi\varepsilon_0} \frac{q^2}{r^2}$ ... (i)



Electric field produced due to dielectric material,

$$E=\frac{9}{4\pi\varepsilon_0\left(r-\frac{r}{5}+\sqrt{k}\frac{r}{5}\right)^2}$$

$$=\frac{q}{4\pi\varepsilon_0\frac{r^2}{25}(4+\sqrt{k})^2}$$

$$=\frac{q}{4\pi\varepsilon_0\frac{r^2}{25}}(4+\sqrt{9})^2 \quad (\because k=9)$$

$$E=\frac{q}{4\pi\varepsilon_0 r^2}\left(\frac{25}{49}\right)$$

Force between the charges,

$$F'=qE=q\cdot\frac{q}{4\pi\varepsilon_0 r^2}\left(\frac{25}{49}\right)$$

$$=\frac{25}{49}\frac{q^2}{4\pi\varepsilon_0 r^2}$$

$$=\frac{25}{49}F$$

Question43

An electric dipole with dipole moment $5\times10^{-7}\mathrm{C-m}$ is in the electric field of $2\times10^4\mathrm{NC}^{-1}$ at an angle of 60° with the direction of the electric field. The torque acting on the dipole is

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Options:

A. $9\times10^{-3}\ \mathrm{N-m}$

B. $1\times10^{-4}\ \mathrm{N-m}$

C. $8.66\times10^{-3}\ \mathrm{N-m}$

D. $2.88\times10^{-3}\ \mathrm{N-m}$

Answer: C

Solution:

Electric dipole moment,

$p = 5 \times 10^{-7}\text{C}$

Angle, $\theta = 60^\circ$

Electric field, $E = 2 \times 10^4 \text{ N/C}$

Torque,

$$\begin{aligned}\tau &= pE \sin\theta \\ &= 5 \times 10^{-7} \times 2 \times 10^4 \times \sin 60^\circ \\ &= 10^{-2} \times \frac{\sqrt{3}}{2} = 8.66 \times 10^{-3} \text{ N} - \text{m}\end{aligned}$$

Question44

Two positive point charges of $10\mu\text{C}$ and $12\mu\text{C}$ are placed 10 cm apart in air. The work done to bring them 6 cm closer is

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Options:

A. 8.1 J

B. 3.2 J

C. 9 J

D. 13.5 J

Answer: A

Solution:

Given, $q_1 = 10\mu\text{C} = 10^{-5}\text{C}$
$q_2 = 12\mu\text{C} = 1.2 \times 10^{-5}\text{C}$
$r_1 = 10 \text{ cm} = 10^{-1} \text{ m}$

We have to find work done in bringing them

Closer when, $r_2 = 6 \text{ cm}$

$= 6 \times 10^{-2} \text{ m}$

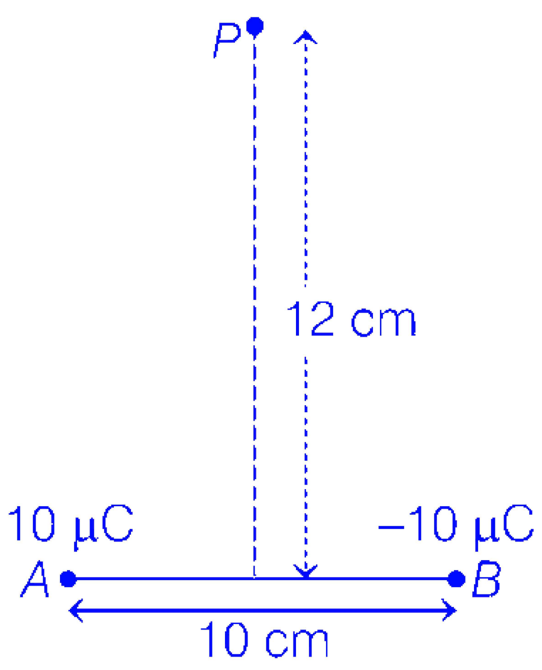
Work done, $W =$ change in potential energy in two configuration of charges

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_2} - \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r_1}$$
$$= \frac{1}{4\pi\varepsilon_0} q_1 q_2 \left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$
$$= 9 \times 10^9 \times 10^{-5} \times 1.2 \times 10^{-5} \left(\frac{1}{6 \times 10^{-2}} - \frac{1}{10^{-1}}\right)$$
$$= 1.08 \left(\frac{100}{6} - 10\right) = \left(\frac{40}{6}\right) \times 1.08 = 7.2 \text{ J}$$

Which is nearest to 8.1 J hence, option (a) is correct.

Question45

Two charges $10\ \mu\text{C}$ and $-10\ \mu\text{C}$ are placed at points A and B separated by a distance of 10 cm. Find the electric field at a point P on the perpendicular bisector of AB, at a distance of 12 cm from its mid-point.



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Options:

A. $16.4 \times 10^6 \mathrm{NC}^{-1}$

B. $28.4 \times 10^6 \mathrm{NC}^{-1}$

C. $8.2 \times 10^6 \mathrm{NC}^{-1}$

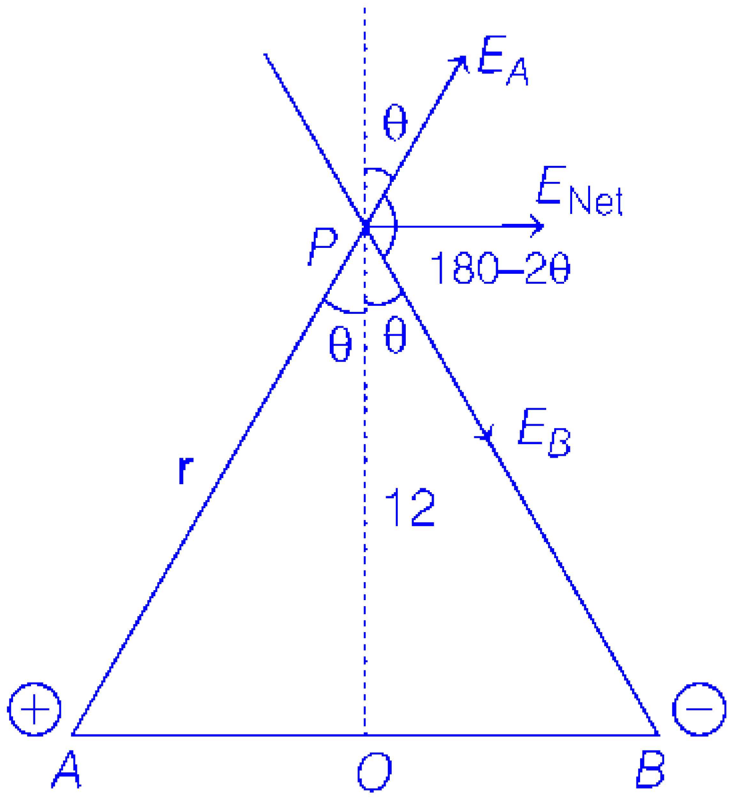
D. $4.1 \times 10^6 \mathrm{NC}^{-1}$

Answer: D

Solution:

Given, charges at point A and B are $q_A, q_B = 10\mu\mathrm{C}$ and $-10\mu\mathrm{C}$

Separation between A and B = 10 cm = 10×10^{-2} m



Let O is mid-point of AB.

$$\therefore \quad OA = 5 \times 10^{-2} \mathrm{~m} \Rightarrow OP = 12 \times 10^{-2} \mathrm{~m}$$

$$\text{and } AP = \sqrt{12^2 + 5^2}$$

$$= \sqrt{169} = 13 \times 10^{-2} \mathrm{~m}$$

As we know that, Electric field $(E) = \frac{kq}{r^2}$

where, k is Coulomb's constant $= 9 \times 10^9 \mathrm{C}^2 \mathrm{~m}^{-2} \mathrm{~N}^{-1}$, q is charge and r is separation between A and P.

$\therefore$ Electric field due to charge A

$E_A = \frac{9\times10^9\times10\times10^{-6}}{(13\times10^{-2})^2} = 5.3\times10^6\ \mathrm{N/C}$

Similarly, electric field due to charge at B, $E_B = 5.3\times10^6\ \mathrm{N/C}$

$\therefore$ Net Electric field $(E_{\text{net}}) = 2E\sin\theta$

$$= 2\times5.3\times10^6\times\frac{5}{13} = \frac{53}{13}\times10^6$$
$$= 4.07\times10^6\ \mathrm{N/C}$$
$$= 4.1\times10^6\ \mathrm{N/C}$$

Question46

When a number of charged liquid dropscoalesce, which of the following quantitydoes not change?

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Options:

A. Charge

B. Capacitance

C. Electrostatic energy

D. Potential

Answer: A

Solution:

As we know that, charge is a conservedquantity i.e. charge of any isolated system remainssame.

Hence, net charge of the system doesn't change.

Question47

What is the angle between maximum value of potential gradient and equipotential surface?

Options:

A. 0

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

C. $\frac{\pi}{2}$

D. π

Answer: C

Solution:

As we know that, on equipotential surfacepotential remains same everywhere and electricfield lines are always perpendicular toequipotential surface.

Since, $E=-dV/dx$

$= -$ (Potential gradient)

$\therefore$ Angle between potential and potential gradient = $\frac{\pi}{2}$ rad

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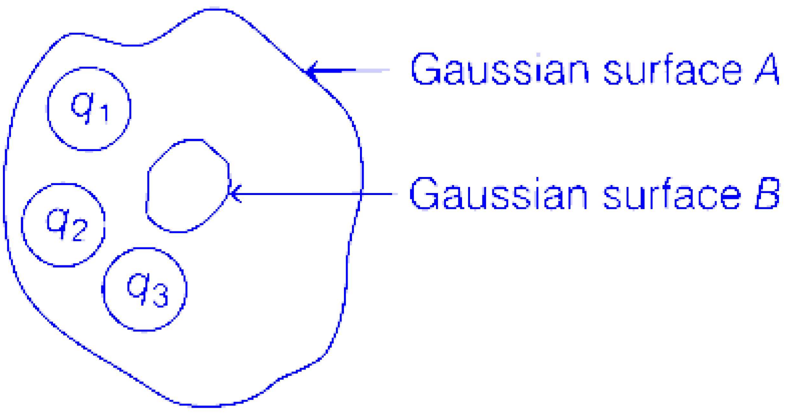
Question48

What is the electric flux for Gaussian surface A that encloses the charged particles in free space? [Given, $q_1=-14 \text{ nC}, q_2=78.85 \text{ nC}, q_3=-56 \text{ nC}$]



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Options:

A. $10^3\ \mathrm{N}-\mathrm{m}^2\mathrm{C}^{-1}$

B. $10^3\mathrm{C}-\mathrm{N}^{-1}\ \mathrm{m}^{-2}$

C. $632\times10^3\ \mathrm{N}-\mathrm{m}^2\mathrm{C}^{-1}$

D. $632\times10^3\mathrm{C}-\mathrm{N}^{-1}\ \mathrm{m}^{-2}$

Answer: A

Solution:

Given,

charges q_1, q_2 and q_3 are -14 nC, 78.85 nC and -56 nC.

As we know that,

$$\text{flux, } \phi=\frac{Q_{\text{enclosed}}}{\varepsilon_0}$$

where, ε_0 is free space permittivity

$$\begin{aligned} &= 8.854\times10^{-12}\mathrm{C}^2\ \mathrm{N}^{-1}\ \mathrm{m}^{-2}\\ \therefore\quad \phi_{\text{net}} &= \frac{(-14+78.85-56)\times10^{-9}}{8.854\times10^{-12}}\\ &= 10^3\ \mathrm{N}-\mathrm{m}^2\mathrm{C}^{-1}\end{aligned}$$

Question49

Two charges 8 μC each are placed at the corners A and B of an equilateral triangle of side 0.2 m in air. The electric potential at the third corner C is

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Options:

A. 7.2×10^5 V

B. 1.8×10^5 V

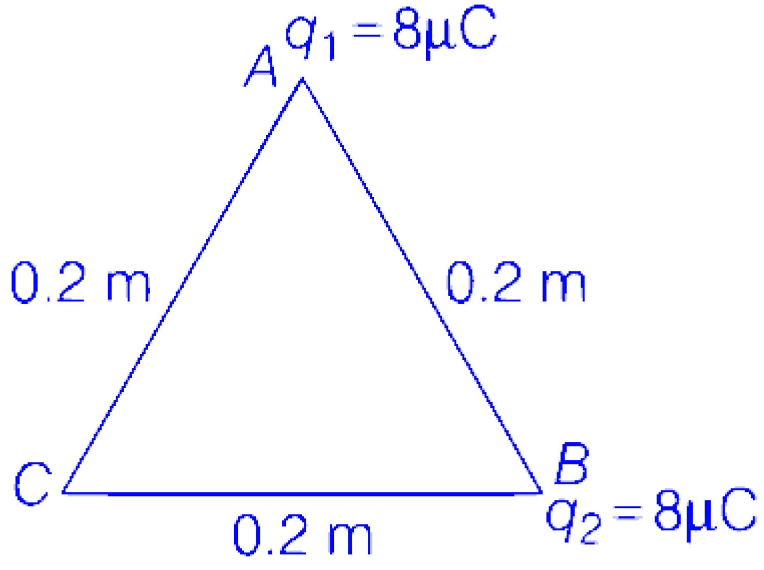
C. 3.6×10^5 V

D. 3.6×10^4 V

Answer: A

Solution:

Given, $q_1 = q_2 = 8 \propto \mathrm{C} = 8 \times 10^{-6}\mathrm{C}$ and side of triangle, $x = 0.2$ m



Since, electric potential, $V = \frac{kq}{r}$

$\therefore$ Potential at third point, $V_3 = \frac{kq_1}{r} + \frac{kq_2}{r}$

$\Rightarrow V_3 = \frac{9\times10^9\times8\times10^{-6}}{0.2} \times 2 = 7.2 \times 10^5$ V

Question50

Gauss's law helps in

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Options:

A. determination of electric force between point charges

B. situation where Coulomb's law fails

C. determination of electric field due to symmetric charge distributions

D. determining electric potential due to symmetric charge distributions

Answer: C

Solution:

As we know that according to Gauss's law,

$\oint \mathbf{E} \cdot ds = \frac{q_{\text{enc.}}}{\varepsilon_0}$

Hence, Gauss's law is used to determine electric field due to symmetric charge distribution inside the Gaussian surface.

Question51

Charge on the outer sphere is q and the inner sphere is grounded. The charge on the inner sphere is q', for $(r_2 > r_1)$. Then,

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Options:

A. $q' r_1 = q r_2$

B. $q' = q$

C. $q' = \frac{r_1}{r_2} q$

D. $q' = -\left(\frac{r_1}{r_2}\right) q$

Answer: D

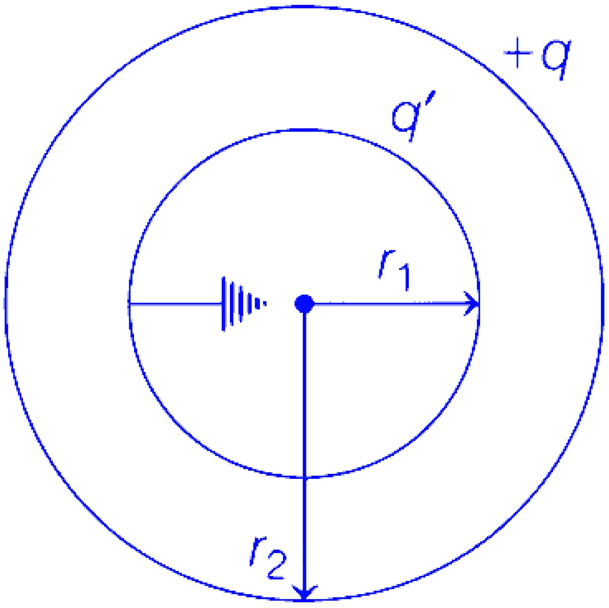
Solution:

Given, charge on outer sphere = q

Inner sphere is grounded.

Since, charge flows till potential (V) becomes same.

and $V = \frac{kq}{r}$



where, r is radius of sphere $(r_2 > r_1)$.

$$\frac{kq'}{r_1} = \frac{-kq}{r_2}$$

$$\Rightarrow \quad q' = -q\left(\frac{r_1}{r_2}\right)$$

Question52

Which statement(s) among the following areincorrect?

(i) A negative test charge experiences a forceopposite to the direction of the field.

(ii) The tangent drawn to a line of forcerepresents the direction of electric field.

(iii) The electric field lines never intersect.

(iv) The electric field lines form a closed loop.

Options:

A. Only (i)

B. Both (i) and (ii)

C. Only (iii)

D. Only (iv)

Answer: D

Solution:

As we know that,

Electric field lines emerge from the positive chargeand converge to negative charge. Tangent drawnat any point on the field line gives the direction ofelectric field at that point.

Electric field lines do not intersect each other. Ifthey do, so there will be two directions of force ata single point which is not possible.

Hence, statement (d) is incorrect.
