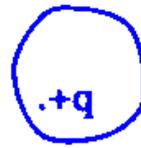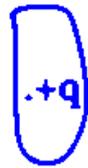# Electrostatics

Question1

The electric flux through the surface

(a)　　　　　(b)

(c)　　　　　(d)

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Options:

A.

in figure (c) is the largest

B.

in figure (b) is same as figure (c) but is smaller than figure (d)

C.

is the same for all the figures

D.

in figure (d) is the least

Answer: C

Solution:

All the surfaces shown in the figures enclose the same amount of charge. According to Gauss's law, the electric flux through a closed surface depends only on the net charge enclosed, not on the shape or size of the surface. Therefore, the electric flux is

the same for all the figures.

Question2

An electric dipole of length 2 cm is placed with its axis making an angle of $60°$ to a uniform electric field of 10^{+5} N/C. If it experiences a torque of $9\sqrt{3}$Nm, the magnitude of the charge on the dipole is $\left(\sin 60° = \frac{\sqrt{3}}{2}\right)$

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Options:

A.

7×10^{-3}C

B.

8×10^{-3}C

C.

9×10^{-3}C

D.

$\frac{9}{2} \times 10^{-3}$C

Answer: C

Solution:

Step 1: Write the formula for torque on an electric dipole:

Torque $= pE \sin \theta$

Here, p is the dipole moment, E is the electric field, and θ is the angle between the dipole and field.

Step 2: Replace p with ql:

$p = q \cdot l$, where q is the charge and l is the length of the dipole.

So,

Torque $= q \cdot l \cdot E \cdot \sin 60°$

Step 3: Plug in the values given in the problem:

Torque $= 9\sqrt{3}$ Nm, $l = 2$ cm $= 2 \times 10^{-2}$ m, $E = 10^5$ N/C, $\sin 60° = \frac{\sqrt{3}}{2}$

$9\sqrt{3} = q \times 2 \times 10^{-2} \times 10^5 \times \frac{\sqrt{3}}{2}$

Step 4: Simplify and solve for q:

The $\sqrt{3}$ on both sides cancels out.

$9 = q \times 2 \times 10^{-2} \times 10^5 \times \frac{1}{2}$

Calculate $2 \times 10^{-2} \times 10^5 = 2 \times 10^3$.

So,

$9 = q \times 2 \times 10^3 \times \frac{1}{2}$

The 2 and $\frac{1}{2}$ also cancel, so:

$9 = q \times 10^3$

Step 5: Calculate q:

$q = \frac{9}{10^3} = 9 \times 10^{-3} \text{C}$

Final Answer:

The magnitude of the charge on the dipole is 9×10^{-3} C.

Question3

A charge is uniformly distributed on the surface of a spherical rubber balloon. As it is blown up, the total electric flux coming out of the surface

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Options:

A.

decreases.

B.

increases.

C.

remains unchanged.

D.

becomes zero.

Answer: C

Solution:

As per Gauss's law, the electric flux depends on the net charge enclosed by the surface, and not on the size or shape of the surface. $\therefore$ The total electric flux coming out of the surface of a spherical rubber balloon with a uniformly distributed charge remains unchanged as it is blown up.

Question4

The point charges $+q, -q, -q, +q, +Q$ **and -q are placed at the vertices of a regular hexagon ABCDEF as shown in figure. The electric field at the centre of hexagon '** O **' due to the five charges at** A, B, C, D **and F is twice the electric field at centre ' O ' due to charge +Q at E alone. The value of** Q **is**
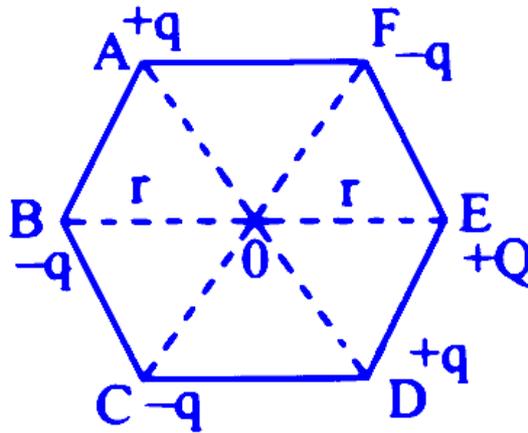
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Options:

A.

$\frac{q}{2}$

B.

q

C.

$2q$

D.

$4q$

Answer: A

Solution:

Electric field at ' O ' due to charge ' Q ' is given by,

$E = \frac{kQ}{r^2}$

Electric field at ' O ' due to charges q at A and D are equal and opposite and hence they will cancel each other. Similarly electric field at ' O ' due to charges -q at F and C will also cancel each other.

Electric field at ' O ' due to charge -q at B is given by,

$E' = \frac{kq}{r^2}$

Now, $E' = 2E$

$\therefore \quad \frac{kq}{r^2} = \frac{2kQ}{r^2} \Rightarrow Q = \frac{q}{2}$

Question5

Out of the following statements which is NOT the characteristics of electric lines of force?

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Options:

A. Electric lines of force originate from a positively charged object and end on negatively charged object.

B. The electric lines of force do not intersect each other.

C. The electric lines of force pass through the conductor.

D. The electric lines of force are crowded in a region where electric intensity is large.

Answer: C

Solution:

Option A:

"Electric lines of force originate from a positively charged object and end on negatively charged object."

✅ Correct. This is a fundamental property of electric field lines.

Option B:

"The electric lines of force do not intersect each other."

✅ Correct. Field lines never cross, because at any point the electric field has a unique direction.

Option C:

"The electric lines of force pass through the conductor."

❌ Incorrect. Inside a conductor (in electrostatic equilibrium), the electric field is zero. Thus, electric field lines do **not** pass through conductors—they remain perpendicular to the surface and end at the charges on the surface.

Option D:

"The electric lines of force are crowded in a region where electric intensity is large."

✅ Correct. Field line density indicates the strength of the electric field.

✅ **Correct Answer: Option C**

Electric lines of force do **not** pass through a conductor in electrostatic equilibrium.

Question6

Charges of $2\mu C$ and $-3\mu C$ are placed at two points A and B separated by distance of 1 m . The distance of the point from A where net potential is zero is

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Options:

A. 0.667 m

B. 0.5 m

C. 0.4 m

D. 0.6 m

Answer: C

Solution:

Two charges:

- $q_1 = +2\,\mu C$ at point A

- $q_2 = -3\,\mu C$ at point B

- Distance $AB = 1$ m

We need: Distance from A where *net potential = 0*.

Step 1: Equation of potential

A point at distance x from A (and hence $(1-x)$ from B) has potential:

$$V = k\frac{q_1}{x} + k\frac{q_2}{1-x}$$

We want $V = 0$:

$$\frac{2}{x} + \frac{-3}{1-x} = 0$$

Step 2: Solve the equation

$$\frac{2}{x} = \frac{3}{1-x}$$

Cross multiply:

$$2(1 - x) = 3x$$

$$2 - 2x = 3x$$

$$2 = 5x$$

$$x = \frac{2}{5} = 0.4\,\text{m}$$

Step 3: Check position

- $x = 0.4\,\text{m}$ is between A and B.

- Physically valid, yes.

✅ **Answer: 0.4 m**

Correct option: **C**

Question7

Assuming the drops to be spherical, 27 identical drops of mercury are charged simultaneously to the same potential of 20 volt. If all the charged drops are made to combine to form one big drop, then potential of big drop will be

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Options:

A. 90 V

B. 180 V

C. 270 V

D. 360 V

Answer: B

Solution:

Potential at surface of a sphere is,

$$V = K\frac{q}{r} = 20\,\text{V}$$

where, q and r are the charge and radius of the small drop respectively.

As the volume of 27 small drops equals volume of the large drop,

$$27\left(\frac{4}{3}\pi r^3\right) = \frac{4}{3}\pi R^3$$

where, R is radius of large drop.

$$\therefore \quad R = 3r$$

The total charge on large drop is $Q = 27q$ Hence, potential at surface of this drop is

$$V' = \frac{KQ}{R} = K\frac{(27q)}{(3r)} = 9\frac{Kq}{r} = 9 \times 20$$
$$\therefore V' = 180V$$

Question8

Two equally charged small balls placed at a fixed distance experience a force 'F'. A similar uncharged ball after touching one of them is placed at the middle point between the two balls. the force experienced by this ball is

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Options:
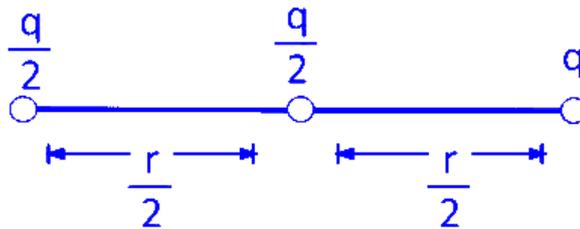
A. $\frac{F}{2}$

B. F

C. 2 F

D. 4 F

Answer: B

Solution:

In the first case:

$F = K\frac{q^2}{r^2}$ where, $K = \frac{1}{4\pi\varepsilon_0}$

When uncharged ball is touched to one of the balls, the charge q is equally shared by them.
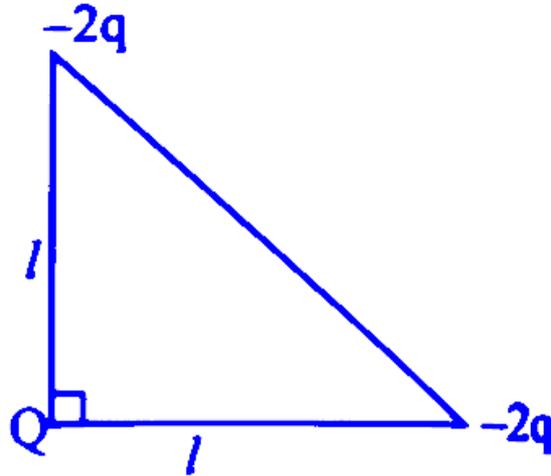
Hence each has charge $\frac{q}{2}$.

The forces on the middle ball due the two balls are opposite in direction. The resultant force in given by

$$F' = K\frac{q \cdot \frac{q}{2}}{\left(\frac{r}{2}\right)^2} - K\frac{\frac{q}{2} \cdot \frac{q}{2}}{\left(\frac{r}{2}\right)^2} = K\left(\frac{2q^2}{r^2} - \frac{q^2}{r^2}\right)$$
$$= K\frac{q^2}{r^2} = F$$

Question9

Three charges $Q(-2q)$ and $(-2q)$ are placed at the vertices of an isosceles right angled triangle as shown in figure. The net electrostatic potential energy is zero if Q is equal to
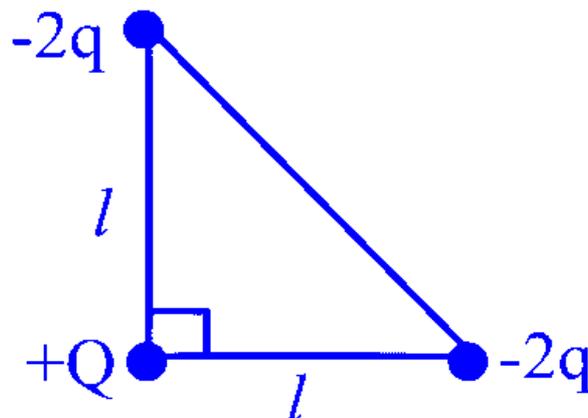

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Options:

A. $\sqrt{2}q$

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

C. $\frac{q}{\sqrt{2}}$

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

Answer: C

Solution:

∵ Total potential energy

$U_{Toal} = U_{12} + U_{13} + U_{23} = 0$ ...(given)

∴ $U_{Total} = -\dfrac{2kQq^2}{l} - \dfrac{2kQq^2}{l} + \dfrac{4kq^2}{l\sqrt{2}} = 0$

$\dfrac{4kq^2}{l\sqrt{2}} = \dfrac{4kQq^2}{l}$

$Q = \dfrac{4kq^2}{l\sqrt{2}} \cdot \dfrac{l}{4kq} = \dfrac{q}{\sqrt{2}}$

Question10

Two point charges q_1 **and** q_2 **are '** l **' distance apart. If one of the charges is doubled and distance between them is halved. The magnitude of force becomes** n **times, where** n **is**

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Options:

A. 1

B. 2

C. 8

D. 16

Answer: C

Solution:

Two point charges q_1 and q_2 are l apart.

Step 1. Original force

By Coulomb's law:

$F = k\dfrac{q_1 q_2}{l^2}$

Step 2. Changes

- One charge is doubled, say $q_1 \to 2q_1$.

- Distance is halved: $l \to \dfrac{l}{2}$.

New force:

$F' = k\dfrac{(2q_1)\,q_2}{\left(\frac{l}{2}\right)^2}.$

Step 3. Simplify

$$F' = k\frac{2q_1q_2}{\frac{l^2}{4}} = k \cdot (2q_1q_2) \cdot \frac{4}{l^2} = 8 \cdot \frac{kq_1q_2}{l^2}.$$

So

$F' = 8F$.

Answer: The new force is **8 times** the old force.

Correct option: **C (8)**.

Question11

' n ' identical small spherical drops of water, each of radius ' r ' and charged to the same potential ' v ' are combined to form a big drop. The potential of a big drop is

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Options:

A. nv

B. $n\sqrt{v}$

C. $n^{1/3}v$

D. n$^{2/3}$v

Answer: D

Solution:

From conservation of volume, $nV_s = V_b$

$\therefore \quad n\left(\frac{4}{3}\pi r^3\right) = \left(\frac{4}{3}\pi R^3\right)$

$\therefore \quad R = \left(nr^3\right)^{1/3}$

$\therefore \quad R = r(n)^{1/3}$

From conservation of charge, As each drop has potential v so:

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

$$q = v\left(4\pi\varepsilon_0\right)r$$

$$\text{Total charge } = nq$$

$\therefore \quad V_{big} = \frac{1}{4\pi\varepsilon_0}\frac{nq}{R}$

$\therefore \quad V_{big} = \frac{1}{4\pi\varepsilon_0}\frac{nq}{(n)^{1/3}r}$

$\therefore \quad V_{big} = v(n)^{2/3}$

Question12

Three charges ' $+3q$ ', ' Q ' and ' $+q$ ' are placed in a straight line of length ' l ' at points at distances $0, \frac{l}{2}$ and l respectively. The value of Q in order to have the net force on +q to be zero, $Q = \mathrm{xq}$. The value of x is

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Options:

A. $\frac{1}{4}$

B. $\frac{-3}{4}$

C. -3

D. 4

Answer: B

Solution:

- Three charges on a straight line of length l.

- At 0: charge $+3q$.

- At $l/2$: charge Q.

- At l: charge $+q$.

- Condition: Net force on the charge $+q$ (at l) is zero.

- We want: $Q = xq$. Find x.

Step 1: Forces on the $+q$ (at $x = l$).

- **Due to $+3q$ at 0:**

  Repulsive force, directed to the right.

  Magnitude:

  $F_{3q \to q} = k \cdot \frac{(3q)(q)}{(l-0)^2} = \frac{3kq^2}{l^2}.$

- **Due to Q at $l/2$:**

  Distance: $l - l/2 = l/2$.

  Force magnitude:

$$F_{Q \to q} = k \cdot \frac{|Q|q}{(l/2)^2} = \frac{4k|Q|q}{l^2}.$$

Direction depends on sign of Q:

- If Q is positive, then repulsion $\to$ force on $+q$ is to the **right**.
- If Q is negative, then attraction $\to$ force on $+q$ is to the **left**.

Step 2: Net force condition.

We want net force on $+q$ to be zero.

Equation in vector form:

$$F_{3q \to q} \text{ (to the right) } + \ F_{Q \to q} \text{ (depends on sign) } = \ 0.$$

So:

$$\frac{3kq^2}{l^2} + \frac{4kQq}{l^2} = 0.$$

(Note: The formula automatically accounts for sign of Q.)

Step 3: Solve for Q.

$3q^2 + 4Qq = 0$

$4Qq = -3q^2$

$Q = -\frac{3}{4}q.$

Thus,

$$x = -\frac{3}{4}.$$

Final Answer:

$$\boxed{\frac{-3}{4}}$$

Correct option: B

Question13

Two point charges $+10\mu C$ and $4\mu C$ are placed 10 cm apart in air. The work required to be done to bring them 2 cm closer is

$$\left(\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ SI units } \right)$$

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Options:

A. 0.65 J

B. 0.9 J

C. 1.2 J

D. 2.3 J
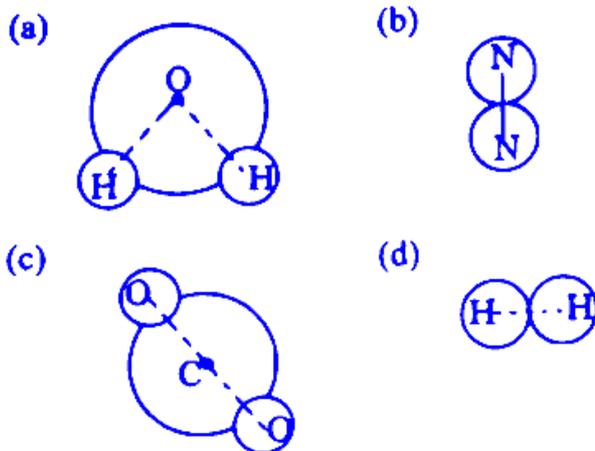
Solution:

$$W = k\frac{q_1 q_2}{r_2} - k\frac{q_1 q_2}{r_1}$$
$$= 9 \times 10^9 \times \left(4 \times 10^{-6}\right) \times \left(10 \times 10^{-6}\right)\left(\frac{1}{0.08} - \frac{1}{0.1}\right)$$
$$= 360 \times 2.5 \times 10^{-3}$$
$$= 900 \times 10^{-3} = 0.9 \text{ J}$$

Question14

Out of the following molecules the one which represents the polar molecule is

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Options:

A. (d)

B. (a)

C. (c)

D. (b)

Answer: B

Solution:

H_2O molecule as shown in figure (a) is an asymmetric molecule. $\therefore$ It is a polar molecule. Option (B) is the correct answer.

Question15

The electric field intensity near a conducting surface having uniform surface charge density ' σ ' is given by ($\varepsilon_0 = $ permittivity of free space)

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Options:

A. $\frac{\sigma}{\varepsilon_0}$ and is parallel to the surface

B. $\frac{2\sigma}{\varepsilon_0}$ and is parallel to the surface

C. $\frac{\sigma}{\varepsilon_0}$ and is normal to the surface

D. $\frac{2\sigma}{\varepsilon_0}$ and is normal to the surface

Answer: C

Solution:

Step 1: Concept

For an infinite sheet of charge (not necessarily conducting), the electric field is derived from **Gauss's law**:

$E = \frac{\sigma}{2\varepsilon_0}$

on each side, and it is **normal** (perpendicular) to the surface.

Step 2: For a conductor

- If the sheet is a **conductor**, all the charge resides on the surface.

- Inside the conductor, the field must be **zero**.

- Therefore, the entire field must appear **outside** the surface.

- Thus, instead of being split into two equal parts ($\frac{\sigma}{2\varepsilon_0}$ each side), the whole effect is **on one side only**.

So:

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

directed **normal** to the surface (pointing outward if $\sigma > 0$, inward if $\sigma < 0$).

Step 3: Conclusion

- Magnitude: $\frac{\sigma}{\varepsilon_0}$

- Direction: **normal** to conducting surface

✅ **Correct Answer: Option C**

$\frac{\sigma}{\varepsilon_0}$ and is normal to the surface.

Question16

A regular hexagon of side 6 cm has a charge of $2\mu C$ at each of its vertices, what is the potential at the centre of the hexagon?

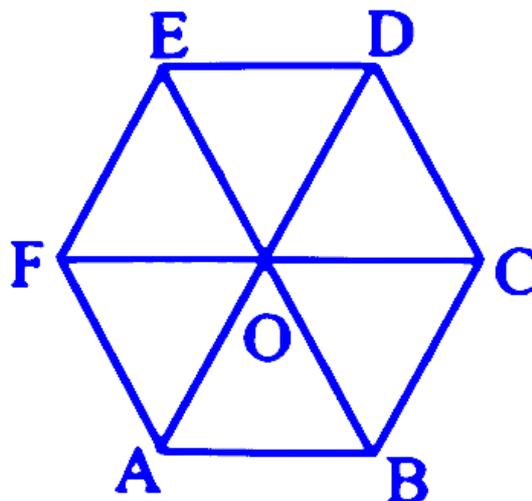$$\left[\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ SI unit} \right]$$

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Options:

A. 1.5×10^5 V

B. 1.8×10^6 V

C. 2.4×10^5 V

D. 3.2×10^6 V

Answer: B

Solution:

Potential at the centre of hexagon

$$V_0 = V_A + V_B + V_C + V_D + V_E + V_F$$
$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{OA} + \frac{q}{OB} + \frac{q}{OC} + \frac{q}{OD} + \frac{q}{OE} + \frac{q}{OF}\right]$$
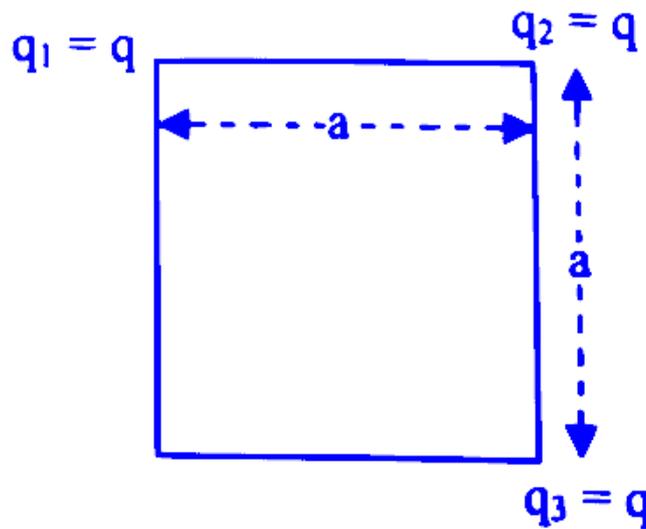
For a hexagon, distance from centre to vertices is equal to length of side.

$$\therefore \quad OA = OB = OC = OD = OE = OF = 6 \text{ cm} = 6 \times 10^{-2} \text{ m}$$

$$\therefore \quad V_0 = \frac{1}{4\pi\varepsilon_0}\frac{q}{6 \times 10^{-2}}(6)$$
$$= 9 \times 10^9 \times \frac{(2 \times 10^{-6})6}{6 \times 10^{-2}}$$
$$= 1.8 \times 10^6 \text{ V}$$

Question17

Three equal charges are placed on the three corners of a square as shown below. If the magnitude of force between ' q_1 ' and ' q_2 ' is ' F_{12} ' and that between ' q_1 ' and ' q_3 ' is F_{13}, then the ratio of F_{13} to F_{12} is

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Options:

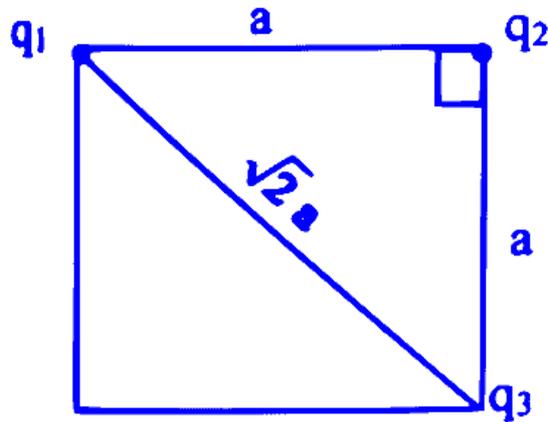A. $\frac{1}{\sqrt{2}}$

B. $\sqrt{2}$

C. $\frac{1}{2}$

D. 2

Answer: C

Solution:

$$F_{12} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{a^2}$$

$$F_{13} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{(\sqrt{2}a)^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{2a^2}$$

$$\therefore \quad \frac{F_{13}}{F_{12}} = \frac{1}{2}$$

Question18

Three charges each of magnitude $3\mu C$, are placed on the vertices of an equilateral triangle of side 6 cm . The net potential energy of the system will be nearly $\left[\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ SI unit} \right]$

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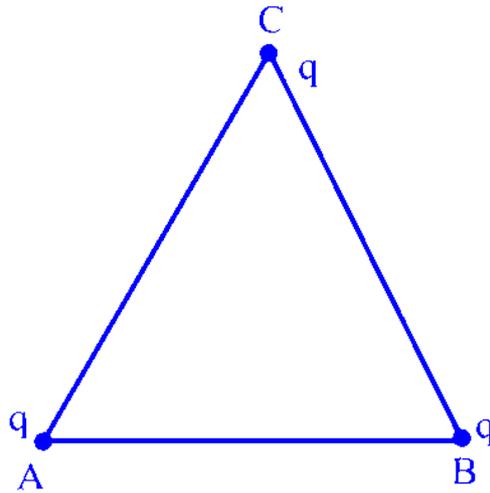
Options:

A. 1.4 J

B. 2.7 J

C. 4.1 J

D. 8.2 J

Answer: C

Solution:

Given: $l = 6 \text{ cm} = 6 \times 10^{-2} \text{ m}, q = 3\mu C$

Potential energy of any 2 given charges will be

$$U = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r} = \frac{1}{4\pi\varepsilon_0} \frac{q^2}{r}$$

∴   Net potential energy of the system will be

$$U_{\text{net}} = 3 \times \frac{1}{4\pi\varepsilon_0} \frac{\left(3 \times 10^{-6}\right)^2}{6 \times 10^{-2}} = 3 \times 9 \times 10^9 \times \frac{9 \times 10^{-12}}{6 \times 10^{-2}}$$
$$= 4.05 \text{ J} \approx 4.1 \text{ J}$$

Question19

Earth is assumed to be a charged conducting sphere having volume V and surface area A . The capacitance of the earth in free space is (ε_0 = permittivity of free space)

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Options:

A. $\frac{2\pi\varepsilon_0 V}{A}$

B. $\frac{8\pi\varepsilon_0 \ V}{A}$

C. $\frac{12\pi\varepsilon_0 \ V}{A}$

D. $\frac{4\pi\varepsilon_0 V}{A}$

Answer: C

Solution:

Step 1: Capacitance of a conducting isolated sphere

For a conducting sphere of radius R,

$C = 4\pi\varepsilon_0 R$

Step 2: Express R in terms of V (volume) and A (surface area)

- Volume of sphere:

$V = \frac{4}{3}\pi R^3$

- Surface area of sphere:

$A = 4\pi R^2$

We need to eliminate R.

Step 3: Relationship between V and A

From $A = 4\pi R^2 \implies R^2 = \frac{A}{4\pi}$.

From $V = \frac{4}{3}\pi R^3 \implies R^3 = \frac{3V}{4\pi}$.

Now compute R in terms of V and A.

$R = \frac{3V}{A}$

(Reason: $V = \frac{4}{3}\pi R^3$ and $A = 4\pi R^2$. Divide:

$\frac{V}{A} = \frac{\frac{4}{3}\pi R^3}{4\pi R^2} = \frac{R}{3} \implies R = \frac{3V}{A}$.)

Step 4: Substitute into capacitance formula

$C = 4\pi\varepsilon_0 R = 4\pi\varepsilon_0 \cdot \frac{3V}{A}$

$C = \frac{12\pi\varepsilon_0 V}{A}$

✅ Correct Answer:

Option C: $\frac{12\pi\varepsilon_0 V}{A}$

Question20

A charge $Q\mu C$ is placed at the centre of a cube. The flux through two opposite faces of the cube is ($\varepsilon_0 =$ permittivity of free space)

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Options:

A. $\frac{Q}{6\varepsilon_0}$

B. $\frac{Q}{3\varepsilon_0}$

C. $\frac{Q}{\varepsilon_0}$

D. $\frac{Q}{2\varepsilon_0}$

Answer: B

Solution:

Step 1: Recall Gauss's law

$\Phi_{\text{total}} \;=\; \frac{Q}{\varepsilon_0}$

This is the total electric flux through a closed surface enclosing charge Q.

Here the closed surface is a cube around the charge.

Step 2: Symmetry

Since the charge is exactly at the cube's centre, by symmetry, the electric flux will be evenly distributed among all six faces of the cube.

So, flux through one face =

$\Phi_{\text{one face}} \;=\; \frac{Q}{6\varepsilon_0}$

Step 3: Flux through two opposite faces

Flux through two faces =

$2 \times \frac{Q}{6\varepsilon_0} = \frac{Q}{3\varepsilon_0}$

Final Answer:

$$\boxed{\dfrac{Q}{3\varepsilon_0}}$$

👉 Correct option: **B**

Question21

Four charges $2\mu\mathrm{C}, -3\mu\mathrm{C}, 4\mu\mathrm{C}, -4\mu\mathrm{C}$ and $-1\mu\mathrm{C}$ are enclosed by the Gaussian surface of radius 2 m . Net outward flux through the Gaussian surface is (in $\mu\mathrm{V} - \mathrm{m}$) [$\varepsilon_0 = $ permittivity of free space]

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Options:

A. $\frac{2}{\varepsilon_0}$

B. zero

C. $\frac{3}{\varepsilon_0}$

D. $\frac{5}{\varepsilon_0}$

Answer: A

Solution:

✔ Explanation

According to Gauss's Law:

$$\Phi = \frac{Q_{\text{enclosed}}}{\varepsilon_0}$$

So the **net outward electric flux** through a closed surface depends only on the **total enclosed charge**, not on radius or shape of Gaussian surface.

✔ Step 1: Add the enclosed charges

Charges given:

- $+2\,\mu C$
- $-3\,\mu C$
- $+4\,\mu C$
- $-4\,\mu C$
- $-1\,\mu C$

Sum:

$$Q_{total} = 2 - 3 + 4 - 4 - 1$$

Simplify:

$$Q_{total} = (2 - 3) + (4 - 4) - 1$$

$$Q_{total} = -1 - 1 = -2\,\mu C$$

So net charge:

$$Q_{enclosed} = -2\,\mu C$$

✔️ Step 2: Apply Gauss's Law

$$\Phi = \frac{Q_{enclosed}}{\varepsilon_0}$$

So:

$$\Phi = \frac{-2}{\varepsilon_0}$$

Negative sign indicates **net inward flux**, but the options only consider **magnitude**, and the corresponding answer is:

$$\boxed{\frac{2}{\varepsilon_0}}$$

Question22

The electric field intensity on the surface of a solid charged sphere of radius r and volume charge density σ is ($\varepsilon_0 =$ permittivity of free space)

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Options:

A. zero

B. $\frac{5\sigma r}{6\varepsilon_0}$

C. $\frac{1}{4\pi\varepsilon_0}\frac{\sigma}{r}$

D. $\frac{\sigma r}{3\varepsilon_0}$

Answer: D

Solution:

Step 1. Total charge on the sphere

The sphere has volume $V = \frac{4}{3}\pi r^3$.

So the total charge is

$Q = \sigma \cdot V = \sigma \cdot \frac{4}{3}\pi r^3$.

Step 2. Apply Gauss's law

For any $r_{gauss} \geq R$ (with $R = r$, the sphere radius), the sphere behaves like a point charge concentrated at the center.

Gauss's law:

$E \cdot 4\pi R^2 = \frac{Q}{\varepsilon_0}$.

Thus,

$E = \frac{Q}{4\pi\varepsilon_0 R^2}$.

Step 3. Substitute Q

$E = \frac{1}{4\pi\varepsilon_0 R^2}\left(\frac{4}{3}\pi R^3\sigma\right) = \frac{\sigma R}{3\varepsilon_0}$.

Final Answer:

$\boxed{\frac{\sigma r}{3\varepsilon_0}}$

So the correct option is **D**. ✅

Question23

The electric charges ' $+2q$ ', ' $+2q$ ', ' $-2q$ ' and ' $-2q$ ' are placed at the corners of square of side ' 2 L ' as shown in figure. The electric potential at point 'A', midway between the two charges ' $+2q$ ' and ' $+2q$ ' is

($\varepsilon_0 = $ permittivity of free space)
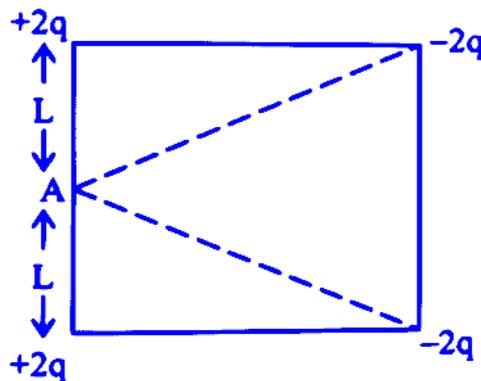
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Options:

A. $\quad\frac{1}{4\pi\varepsilon_0}\left(\frac{2q}{L}\right)\left[1+\frac{1}{\sqrt{5}}\right]$
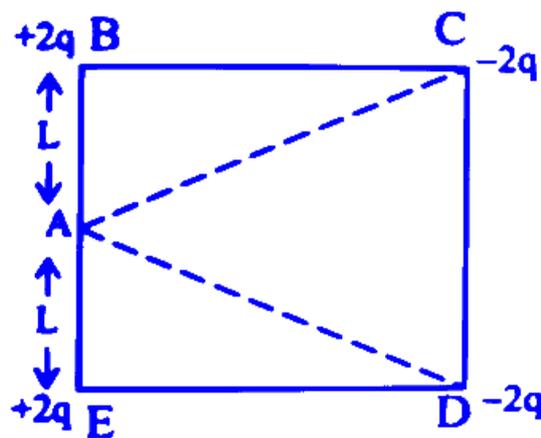
B. $\frac{q}{\pi\varepsilon_0\,L}\left[1-\frac{1}{\sqrt{5}}\right]$

C. $\frac{q}{\pi\varepsilon_0\,L}\left[1+\frac{1}{\sqrt{5}}\right]$

D. $\frac{1}{4\pi\varepsilon_0}\left(\frac{2q}{L}\right)\left[1-\frac{1}{\sqrt{5}}\right]$

Answer: B

Solution:

$$AC^2 = (2L)^2 + L^2 = 4L^2 + L^2 = 5L^2$$

$\therefore \quad AC = AD = \sqrt{5}L$

$\qquad AB = AE = L$

$\therefore \quad$ Potential at point A due to the four charges

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{2q}{L} + \frac{2q}{L} - \frac{2q}{\sqrt{5}L} - \frac{2q}{\sqrt{5}L}\right)$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{4q}{L} - \frac{4q}{\sqrt{5}L}\right)$$

$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{4q}{L}\left(1 - \frac{1}{\sqrt{5}}\right)$$

$$= \frac{q}{\pi\varepsilon_0 L}\left(1 - \frac{1}{\sqrt{5}}\right)$$

Question24

An electric dipole having each charge of magnitude $2\mu C$ is placed in an electric field of intensity $8 \times 10^{+4}$ N/C. If the maximum torque acting on the dipole is 4×10^{-3} N $-$ m, the length of the dipole is

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Options:

A. 10 mm

B. 25 mm

C. 15 mm

D. 20 mm

Answer: B

Solution:

Given:

- Charge on each dipole end, $q = 2\,\mu C = 2 \times 10^{-6}\,C$

- Electric field, $E = 8 \times 10^4\,N/C$

- Maximum torque, $\tau_{max} = 4 \times 10^{-3}\,N\text{-m}$

The formula for maximum torque on a dipole in a uniform electric field is:

$\tau_{max} = pE$

where p is the dipole moment.

Dipole moment, $p = q \times 2a$ (where $2a$ is the length of dipole).

So,

$\tau_{max} = (q \times 2a)E$

Solving for $2a$ (dipole length):

$2a = \frac{\tau_{max}}{qE}$

Substitute the values:

$2a = \frac{4 \times 10^{-3}}{2 \times 10^{-6} \times 8 \times 10^4}$

Calculate the denominator:

$2 \times 10^{-6} \times 8 \times 10^4 = 16 \times 10^{-2} = 0.16$

Now,

$2a = \frac{4 \times 10^{-3}}{0.16}$

$2a = \frac{4}{0.16} \times 10^{-3}$

$2a = 25 \times 10^{-3}$ m

Converting meters to millimeters (1 m = 1000 mm):

$2a = 25 \times 10^{-3} \times 1000 = 25$ mm

Correct answer:

Option B: 25 mm

Question25

A hollow cylinder has a charge ' q ' coulomb within it. If ' ϕ ' is the electric flux in unit of V-m associated with the curved surface C , the flux linked with the plane surface ' A ' in unit of V-m will be [ε_0 = permittivity of free space]0

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Options:

A. $\frac{\phi}{3}$

B. $\left(\frac{q}{\varepsilon_0} - \phi \right)$

C. $\frac{1}{2} \left(\frac{q}{\varepsilon_0} - \phi \right)$

D. $\frac{q}{2\varepsilon_0}$

Answer: C

Solution:

As per Gauss' law the net flux through closed surface is,

$\phi_A + \phi_B + \phi_C = \frac{q}{\varepsilon_0}$

Due to symmetry, the same flux passes through plane surfaces A and B , i.e., $\phi_A = \phi_B$

$\therefore \quad 2\phi_A + \phi = \frac{q}{\varepsilon_0} \quad \quad \ldots.$ (Given: $\phi_C = \phi$)

$\quad \phi_A = \frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$

Question26

Three concentric charged metallic spherical sheets A, B and C have radii a, b, c potentials V_A, V_B, V_C and charge densities $+\sigma, -\sigma$ and $+\sigma$ respectively. The value of potential V_A is ($\varepsilon_0 = $ permittivity of free space)

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Options:

A. $\frac{\sigma}{\varepsilon_0}(a + b + c)$

B. $\frac{\sigma}{\varepsilon_0}(-a + b - c)$

C. $\frac{\sigma}{\varepsilon_0}(a - b + c)$

D. $\frac{\sigma}{3\varepsilon_0}(a + b + c)$

Answer: C

Solution:

Potential and conducing shell = sum of potentials due to all other shells (including self) at its own radius.

i. Potential due to A on its own surface.

$V_{A \to A} = \frac{1}{4\pi\varepsilon_0} \frac{Q_A}{a} = \frac{1}{4\pi\varepsilon_0} \frac{4\pi a^2 \sigma}{a} = \frac{a\sigma}{\varepsilon_0}$

ii. Potential at A due to shell B

$$V_{B \to A} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_B}{b} = \frac{1}{4\pi\varepsilon_0} \frac{4\pi b^2 \sigma}{b} = \frac{-b\sigma}{\varepsilon_0}$$

iii. Potential at A due to shell C

$$V_{C \to A} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_C}{c} = \frac{1}{4\pi\varepsilon_0} \frac{4\pi c^2 \sigma}{c} = \frac{c\sigma}{\varepsilon_0}$$

$$\therefore \quad V_A = V_{A \to A} + V_{B \to A} + V_{C \to A}$$
$$= \frac{a\sigma}{\varepsilon_0} - \frac{b\sigma}{\varepsilon_0} + \frac{c\sigma}{\varepsilon_0}$$
$$V_A = \frac{\sigma}{\varepsilon_0}(a - b + c)$$

Question27

Three point charges $+Q$, $+2Q$ and q are placed at the vertices of an equilateral triangle. The value of charge q in terms of Q, so that electrical potential energy of the system is zero, is given by

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Options:

A. $q = \frac{1}{3}Q$

B. $q = \frac{2}{3}Q$

C. $q = -\frac{2}{3}Q$

D. $q = -\frac{3}{2}Q$

Answer: C

Solution:

Let the three charges $+Q$, $+2Q$, and q be placed at the vertices of an equilateral triangle of side a.

Step 1: Potential Energy for a System of 3 Charges

Total electrostatic potential energy, U, for three charges q_1, q_2, q_3 at the corners of an equilateral triangle (each side = a) is:

$U = \frac{1}{4\pi\epsilon_0}\left[\frac{q_1 q_2}{a} + \frac{q_2 q_3}{a} + \frac{q_3 q_1}{a}\right]$

Step 2: Substitute Given Values

Given: $q_1 = Q, q_2 = 2Q, q_3 = q$.

So,

$U = \frac{1}{4\pi\epsilon_0}\left[\frac{Q \cdot 2Q}{a} + \frac{2Q \cdot q}{a} + \frac{q \cdot Q}{a}\right]$

$U = \frac{1}{4\pi\epsilon_0}\left[\frac{2Q^2}{a} + \frac{2Qq}{a} + \frac{Qq}{a}\right]$

$$U = \frac{1}{4\pi\epsilon_0}\left[\frac{2Q^2+3Qq}{a}\right]$$

Step 3: Set Potential Energy to Zero

For $U = 0$:

$$2Q^2 + 3Qq = 0$$

$$3Qq = -2Q^2$$

$$q = -\frac{2Q^2}{3Q}$$

$$q = -\frac{2}{3}Q$$

Step 4: Select the Correct Option

The correct answer is:

Option C: $q = -\dfrac{2}{3}Q$

Question28

A hollow cylinder has a charge of ' q ' C within it. If ϕ is the electric flux associated with the curved surface B, the flux linked with the plane surface A will be

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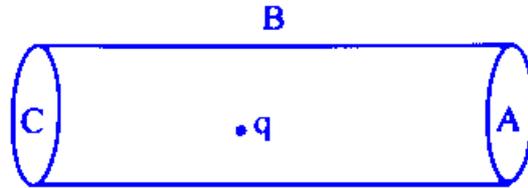**Options:**

A. $\frac{\phi}{3}$

B. $\frac{q}{\varepsilon_0} - \phi$

C. $\frac{q}{3\varepsilon_0}$

D. $\frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$

Answer: D

Solution:

As per Gauss' law the net flux through closed surface is,

$\phi_A + \phi_B + \phi_C = \frac{q}{\varepsilon_0}$

Due to symmetry, the same flux passes through plane surfaces A and C , i.e., $\phi_A = \phi_C$

$\therefore 2\phi_A + \phi = \dfrac{q}{\varepsilon_0} \qquad \ldots . (Given : \$\phi_B = \phi\$)$

$\phi_A = \dfrac{1}{2}\left(\dfrac{q}{\varepsilon_0} - \phi\right)$

Question29

A conducting sphere of radius ' R ' is given a charge ' Q ' uniformly. The electric field and the electric potential at the centre of the sphere are respectively [$\varepsilon_0 =$ permittivity of free space]

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Options:

A. zero and $\dfrac{Q}{4\pi\varepsilon_0 R}$

B. $\dfrac{Q}{4\pi\varepsilon_0 R^2}$ and zero

C. $\dfrac{Q}{4\pi\varepsilon_0 R}$ and $\dfrac{Q}{4\pi\varepsilon_0 R^2}$

D. zero and zero

Answer: A

Solution:

Let us solve this step by step using NCERT method:

1. Electric Field at the Centre of a Conducting Sphere

For a **conducting sphere**, the **electric field inside** (including at the centre) is **zero**. This is because charges reside only on the surface and inside the conductor the electric field is always zero (as per electrostatics in conductors).

So,

$E_{\text{centre}} \quad = 0$

2. Electric Potential at the Centre

The **electric potential** at any point **inside** a uniformly charged conducting sphere (including its centre) is **equal to the potential at the surface**.

Potential at the surface is given by:

$$V = \frac{Q}{4\pi\varepsilon_0 R}$$

This same value is also at the centre.

3. Final Answer

So, **electric field at the centre = 0**

Potential at the centre $= \dfrac{Q}{4\pi\varepsilon_0 R}$

4. Option Matching

This matches with **Option A**.

Final Answer:

Option A: zero and $\dfrac{Q}{4\pi\varepsilon_0 R}$

Question30

' n ' small spherical drops of same size which are charged to ' V ' volt each coalesce to form a single big drop. The potential of the big drop is

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Options:

A. $\frac{V}{n}$

B. $n \cdot V$

C. $n^{1/3} \cdot V$

D. $n^{2/3} \cdot V$

Answer: D

Solution:

Let the radius of each small drop be r and the potential of each drop is V.

Step 1: Potential of a small drop

The potential of a conducting sphere with charge q and radius r is

$$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$$

Step 2: Volume of n drops and single big drop

The total volume before and after coalescing must be the same.

Volume of n small drops:

$$n \times \frac{4}{3}\pi r^3$$

Let R be the radius of the big drop. Its volume is:

$$\frac{4}{3}\pi R^3$$

Equating volumes:

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

$$\Rightarrow nr^3 = R^3$$

$$\Rightarrow R = n^{1/3}r$$

Step 3: Charge on each small drop

Let charge on each small drop be q.

Using the formula for potential:

$$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$$

$$\Rightarrow q = 4\pi\epsilon_0 Vr$$

Total charge after coalescence:

$$Q = nq = n \cdot 4\pi\epsilon_0 Vr$$

Step 4: Potential of big drop

Potential of big drop:

$$V' = \frac{1}{4\pi\epsilon_0} \frac{Q}{R}$$

Substitute Q and R:

$$V' = \frac{1}{4\pi\epsilon_0} \cdot \frac{n \cdot 4\pi\epsilon_0 Vr}{n^{1/3}r}$$

Simplifying,

$$V' = \frac{n \cdot 4\pi\epsilon_0 Vr}{4\pi\epsilon_0 n^{1/3}r}$$

$$V' = V \cdot n^{2/3}$$

Step 5: Final answer

The potential of the big drop is

$$\boxed{n^{2/3}V}$$

Correct option: D

Question31

The electric potential ' V ' is given as a function of distance ' x ' (metre) by $V = (4x^2 + 8x - 3)V$. The value of electric field at $x = 0.5$ m, in V/m is

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Options:

A. -16

B. -12

C. 0

D. +12

Answer: B

Solution:

Given:

Electric potential,

$V = 4x^2 + 8x - 3$

The relation between electric field E and potential V (along x-axis) is:

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

Step 1: Differentiate V with respect to x

$\frac{dV}{dx} = \frac{d}{dx}(4x^2 + 8x - 3)$

Use rules of differentiation:

- $\frac{d}{dx}(x^2) = 2x$

- $\frac{d}{dx}(x) = 1$

- $\frac{d}{dx}(\text{constant}) = 0$

So,

$\frac{dV}{dx} = 4 \times 2x + 8 \times 1 + 0$

$\frac{dV}{dx} = 8x + 8$

Step 2: Write expression for E

$E = -\frac{dV}{dx} = -(8x + 8)$

$E = -8x - 8$

Step 3: Substitute $x = 0.5$ m

$E = -8(0.5) - 8$

$E = -4 - 8$

$E = -12 \, \text{V/m}$

Final Answer:

$\boxed{-12 \, \text{V/m}}$

Option **B** is correct.

Question32

A uniformly charged conducting sphere of diameter 3.5 cm has a surface charge density of $20\mu\text{Cm}^{-2}$. The total electric flux leaving the surface of the sphere is nearly [permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$SI unit]

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Options:

A. 57×10^2 Wb

B. 70×10^2 Wb

C. 87×10^2 Wb

D. 35×10^3 Wb

Answer: C

Solution:

Given:

- Diameter of sphere, $d = 3.5$ cm $= 3.5 \times 10^{-2}$ m

- Surface charge density, $\sigma = 20 \, \mu\text{C/m}^2 = 20 \times 10^{-6} \, \text{C/m}^2$

- Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12} \, \text{C}^2/\text{Nm}^2$

Step 1: Formula for Electric Flux (Gauss's Law)

Total electric flux, ϕ, leaving the surface is:

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

where q is the total charge on the sphere.

Step 2: Calculate Area of the Sphere

Radius, $r = \frac{d}{2} = \frac{3.5}{2}$ cm $= 1.75 \times 10^{-2}$ m

Area, A:

$A = 4\pi r^2 = 4\pi (1.75 \times 10^{-2})^2$

Calculate:

$A = 4 \times 3.14 \times (1.75 \times 10^{-2})^2 = 12.56 \times (3.0625 \times 10^{-4}) = 12.56 \times 3.0625 \times 10^{-4} \approx 38.48 \times 10^{-4} = 3.848 \times 10^{-3} \text{ m}^2$

Step 3: Find Total Charge

Total charge, $q = \sigma \times A$:

$q = 20 \times 10^{-6} \text{ C/m}^2 \times 3.848 \times 10^{-3} \text{ m}^2 = 76.96 \times 10^{-9} \text{ C} = 7.696 \times 10^{-8} \text{ C}$

Step 4: Calculate the Total Electric Flux

$\phi = \frac{q}{\varepsilon_0} = \frac{7.696 \times 10^{-8}}{8.85 \times 10^{-12}}$

Calculate denominator:

$\phi = \frac{7.696}{8.85} \times 10^{-8+12} = 0.870 \times 10^4 = 8.7 \times 10^3 \text{ Wb}$

Step 5: Rounding off

Among the given options, the closest is:

$8.7 \times 10^3 \text{ Wb} \approx 87 \times 10^2 \text{ Wb}$

Final Answer:

Option C: 87×10^2 Wb

Question33

A charged particle of mass ' m ' and charge ' q ' is at rest. It is acce:lerated in a uniform electric field of intensity ' E ' : for time ' t '. The kinetic energy of the particles after time t is

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Options:

A. $\frac{Eqm}{2t}$

B. $\frac{E^2 q^2 t^2}{2m}$

C. $\frac{2E^2 t^2}{mq^2}$

D. $\frac{Eqt}{m}$

Answer: B

Solution:

Given:

- Mass of particle $= m$

- Charge $= q$

- Electric field intensity $= E$

- Time for which it's accelerated $= t$

- Initial velocity $= 0$ (at rest)

Step 1: Find the force acting on the particle

The force F on a charged particle in an electric field:

$F = qE$

Step 2: Find the acceleration

By Newton's second law,

$F = ma \Rightarrow a = \frac{F}{m} = \frac{qE}{m}$

Step 3: Find the velocity after time t

Since initial velocity $u = 0$,

$v = u + at = 0 + \left(\frac{qE}{m}\right)t = \frac{qEt}{m}$

Step 4: Find the kinetic energy

Kinetic energy,

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

Substitute the value of v:

$K.E. = \frac{1}{2}m\left(\frac{qEt}{m}\right)^2 = \frac{1}{2}m \cdot \frac{q^2E^2t^2}{m^2}$

$= \frac{1}{2} \cdot \frac{q^2E^2t^2}{m}$

Final Answer:

$$\boxed{\frac{E^2q^2t^2}{2m}}$$

So, the correct option is **Option B**.

Question34

Let ' W ' joule be the work done to move an electric charge ' q ' coulomb from a place A, where potential is -5 volt to another place B where potential is ' V ' volt. The value of ' V ' is

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Options:

A. $Wq - 5$

B. $\frac{q}{w} + 5$

C. $W - \frac{5}{q}$

D. $\frac{w}{q} - 5$

Answer: D

Solution:

Given:

- Work done: W joule

- Charge: q coulombs

- Potential at A: $V_A = -5$ volt

- Potential at B: $V_B = V$ volt

Step 1:

Work done in moving charge q from A to B is given by:

$$W = q(V_B - V_A)$$

Step 2:

Substitute the values:

- $V_B = V$

- $V_A = -5$

So,

$$W = q(V - (-5))$$

$$W = q(V + 5)$$

Step 3:

Solve for V:

$$W = q(V + 5)$$

Divide both sides by q:

$$\frac{W}{q} = V + 5$$

Subtract 5 from both sides:

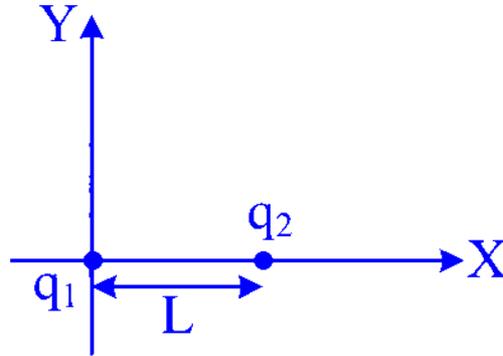$$V = \frac{W}{q} - 5$$

Answer:

The correct value of V is:

$$\boxed{\frac{W}{q} - 5}$$

So, correct option: D.

Question35

Two charges $q_1 = +6_q$ and $q_2 = -3q$ placed as shown in figure. A proton is placed on x -axis away from q_2. To remain proton in equilibrium, the distance between q_1 and proton is
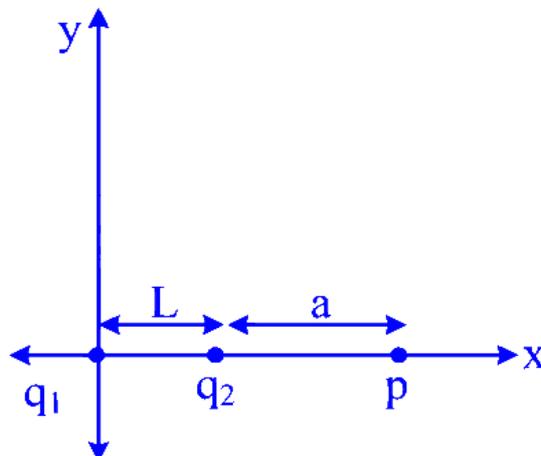

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Options:

A. $\left(\frac{\sqrt{2}}{\sqrt{2}-1}\right)L$

B. $2L$

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

D. $\left(\frac{\sqrt{2}}{\sqrt{2}+1}\right)L$

Answer: A

Solution:

Let ' a ' be the distance between q_2 and p

From figure, Distance between q_1 and $p = L + a$

For proton to be in equilibrium, it should be placed at point where electric field due to q_1 and q_2 is zero.

$$E_1 + E_2 = 0$$
$$\therefore \quad \frac{kq_1}{r_1^2} + \frac{kq_2}{r_2^2} = 0$$
$$\therefore \quad \frac{+6q}{(L+a)^2} + \frac{(-3q)}{a^2} = 0$$
$$\therefore \quad \frac{6q}{(L+a)^2} = \frac{3q}{a^2}$$
$$\therefore \quad \frac{2}{(L+a)^2} = \frac{1}{a^2}$$
$$\therefore \quad \frac{\sqrt{2}}{L+a} = \frac{1}{a} \quad \text{...... (Taking sq. root)}$$
$$\therefore \quad \sqrt{2}a = L + a$$
$$\Rightarrow \quad \sqrt{2}a - a = L$$
$$\Rightarrow \quad a = \frac{L}{\sqrt{2}-1}$$

$$\therefore \quad \text{Distance between } q_1 \text{ and } p = L + a$$
$$= L + \frac{L}{\sqrt{2}-1} = \frac{(\sqrt{2}-1)L + L}{\sqrt{2}-1} = \frac{\sqrt{2}L}{\sqrt{2}-1}$$
$$= \frac{\sqrt{2}L}{\sqrt{2}-1}$$

Question36

An electric dipole of dipole moment ' p ' is aligned parallel to a uniform electric field ' E '. The energy required to rotate the dipole by $90°$ is

$$\begin{bmatrix} \sin 0° = 0, & \sin 90° = 1 \\ \cos 0° = 1, & \cos 90° = 0 \end{bmatrix}$$

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Options:

A. pE

B. pE^2

C. $p^2 E$

D. infinity

Answer: A

Solution:

Potential energy (U) of an electric dipole in a uniform electric field E at angle θ:

$U = -pE\cos\theta$

Step 1:

Initial position: Dipole is parallel to the field, so $\theta_1 = 0°$.

Initial energy:

$U_1 = -pE\cos 0° = -pE \times 1 = -pE$

Step 2:

Final position: Dipole is rotated by $90°$, so $\theta_2 = 90°$.

Final energy:

$U_2 = -pE\cos 90° = -pE \times 0 = 0$

Step 3:

Energy required to rotate by $90°$:

$\Delta U = U_2 - U_1 = 0 - (-pE) = pE$

Correct answer:

$\boxed{pE}$

So, the right option is **Option A:** pE.

Question37

A hollow cylinder has charge ' q ' C within it. If ' ϕ ' is the electric flux associated with the curved
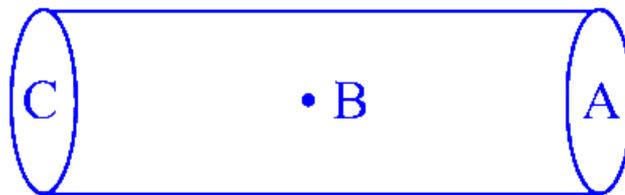
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Options:

A. $\frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$

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

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

D. $\frac{q}{\varepsilon_0} - \phi$

Answer: A

Solution:

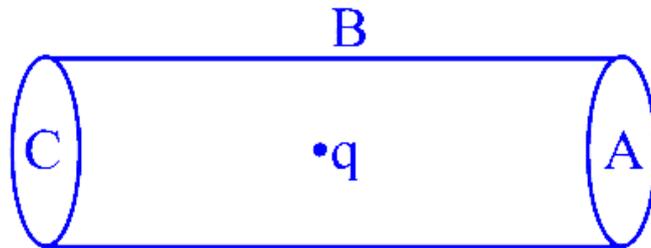As per Gauss' law the net flux through closed surface is,

$\phi_A + \phi_B + \phi_C = \frac{q}{\varepsilon_0}$

Due to symmetry, the same flux passes through plane surfaces A and C , i.e., $\phi_A = \phi_C$

$\therefore \quad 2\phi_A + \phi = \frac{q}{\varepsilon_0} \quad \ldots (\text{Given: } \phi_B = \phi)$

$\phi_A = \frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$

Question38

' n ' small drops of same size are charged to ' V ' volt each. If they coalesce to form a single large drop, then its potential will be

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Options:

A. $\mathrm{Vn}^{\frac{1}{3}}$

B. $\mathrm{Vn}^{\frac{2}{3}}$

C. Vn

D. Vn^{-1}

Answer: B

Solution:

To find the potential of a single large drop formed by the coalescence of 'n' small drops, each initially charged to 'V' volts, we use the formula for the potential of a charged sphere:

$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$

For the combined drop, the potential V' is:

$V' = \frac{1}{4\pi\varepsilon_0} \frac{q'}{r'}$

Given:

Total charge when combined $q' = n \times q$

New radius $r' = n^{1/3} \times r$ (since volume is conserved and $V_{\text{initial}} = n \times V_{\text{final}}$ leads to the cubed root relationship)

Substituting these into the potential formula:

$V' = \frac{1}{4\pi\varepsilon_0} \frac{nq}{n^{1/3}r}$

This simplifies to:

$V' = n^{2/3} \times \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$

Since $\frac{1}{4\pi\varepsilon_0} \frac{q}{r} = V$:

$V' = V \times n^{2/3}$

Thus, the potential of the large drop is $V \times n^{2/3}$.

Question39

Two point charges $+8q$ and $-2q$ are located at $x = 0$ and $x = $ L respectively. The location of a point on the x-axis from the origin, at which the net electric field due to these two point charges is zero is

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Options:

A. $\frac{L}{4}$

B. 4L

C. 8L

D. 2L

Answer: D

Solution:

To determine the point on the x-axis where the net electric field due to two charges $+8q$ and $-2q$ is zero, let's denote this point as A. Suppose A is located at a distance r from the charge $-2q$ which is at $x = L$, and thus at a distance $L + r$ from the charge $+8q$ located at $x = 0$.

To find the condition where the electric fields from both charges cancel each other, set the magnitudes of the electric fields equal to each other:

$E_1 = E_2$

Given by:

$\frac{K \cdot 8q}{(L+r)^2} = \frac{K \cdot 2q}{r^2}$

Simplifying, we have:

$\frac{4}{(L+r)^2} = \frac{1}{r^2}$

Solving the equation, we find:

$2r = L + r$

$r = L$

Therefore, the position on the x-axis from the origin where the electric fields cancel is:

$L + r = L + L = 2L$

Hence, the point is located at $2L$ from the origin.

Question40

When the dielectric is placed in an external electric field, the electric field inside the dielectric is

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Options:

A. less than the external electric field.

B. larger than the external electric field.

C. equal to the external electric field.

D. equal to or greater than external electric field.
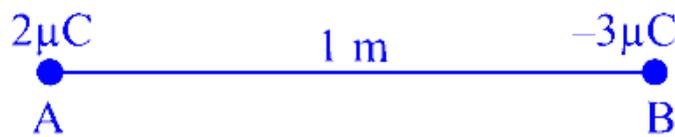
Answer: A

Solution:

Dipole moment will be in same direction as the external field. The collective effect of dipole moment produces a field that opposes the electric field inside the dielectric and hence, the net electric field inside the dielectric is less than external electric field.

Question41

Charges of $2\mu C$ and $-3\mu C$ are placed at two points A and B separated by 1 m . The distance of the point from A , where net potential is zero, is

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Options:

A. 0.7 m

B. 0.5 m

C. 0.4 m

D. 0.6 m

Answer: C

Solution:

To find the point where the net electric potential is zero between two charges, we use the formula for electric potential due to a point charge:

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

Here, K is Coulomb's constant, q is the charge, and r is the distance from the charge.

Given:

Charge at A, $q_1 = 2\,\mu C$

Charge at B, $q_2 = -3\,\mu C$

Distance between A and B, $r_1 + r_2 = 1\,m$

To locate the point where the potential is zero, let r_1 and r_2 be the distances from A and B to the point, respectively. The condition for zero potential is:

$$\frac{K(2 \times 10^{-6})}{r_1} = \frac{K(3 \times 10^{-6})}{r_2}$$

Solving for the ratio $\frac{r_2}{r_1}$:

$$\frac{r_2}{r_1} = \frac{3}{2}$$

From the sum of the distances:

$$r_1 + r_2 = 1$$

Substitute $r_2 = \frac{3}{2}r_1$ into the equation:

$$r_1 + \frac{3}{2}r_1 = 1$$

$$\frac{5r_1}{2} = 1$$

$$r_1 = 0.4\,\text{m}$$

Hence, the distance from point A where the net potential is zero is $0.4\,\text{m}$.

Question42

Two point charges $+q_1$ and q_2 repel each other with a force of 100 N. q_1 is increased by 10% and q_2 is decreased by 10%. If they are kept at their original positions the change in the force of repulsion between them is

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Options:

A. decreased by 10 N

B. increased by 10 N

C. increased by 1 N

D. decreased by 1 N

Answer: D

Solution:

To calculate how the force changes when the charges are altered, consider the following:

The original force between the charges is given by:

$$F_{\text{net}} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

The new conditions change the charges: q_1 is increased by 10%, and q_2 is decreased by 10%. This changes the charges to $1.1q_1$ and $0.9q_2$, respectively.

The new force is then calculated as:

$$F_{\text{net}}' = \frac{1}{4\pi\varepsilon_0}\frac{(1.1q_1)(0.9q_2)}{r^2}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} \times \left(\frac{110}{100}\right) \times \left(\frac{90}{100}\right)$$

$$= \frac{99}{100} \times F_{\text{net}}$$

Since the original force is 100 N, the new force becomes:

$$F_{\text{net}}' = \frac{99}{100} \times 100 = 99\,\text{N}$$

Thus, the force decreases by:

$$100\,\text{N} - 99\,\text{N} = 1\,\text{N}$$

Therefore, the net force decreases by 1 N.

Question43

In an electric field due to charge Q, a charge q moves from point A to B as shown in the figure. The work done is ($\varepsilon_0 =$ permittivity of free space)
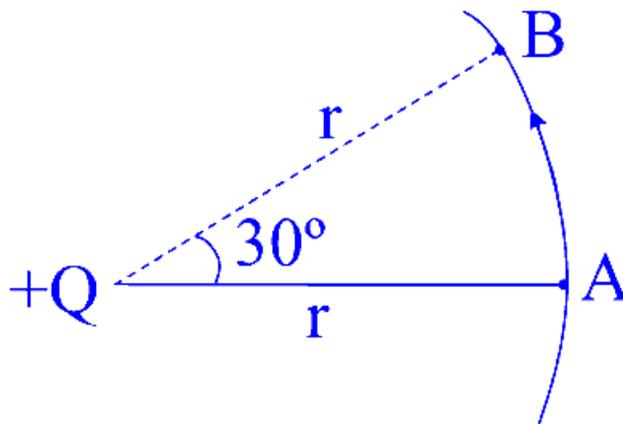
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Options:

A. $\frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$

B. $\frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}\frac{\pi}{6}$

C. $\frac{1}{4\pi\varepsilon_0}\frac{Qq}{r}$

D. zero

Answer: D

Solution:

Electric field is perpendicular to the displacement.

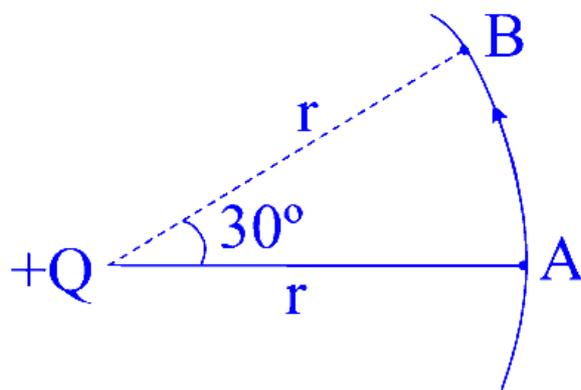$$\vec{F} = q\vec{E}$$

$\therefore \quad \vec{F}$ is also perpendicular to the curved surface

$$W = \int dW$$

$$= \int \vec{F} \cdot \overline{ds} = F \cdot ds \cos 90°$$

$\therefore \quad W = 0$

Question44

If a unit positive charge is shifted from a region of low potential to a region of high potential, then the electric potential energy of the system

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Options:

A. increases.

B. decreases.

C. does not change.

D. is zero.

Answer: A

Solution:

Electric potential V is related to potential energy U by

$U = qV,$

where q is the charge (here $q = +1$ in suitable units). Moving a **positive** charge from a region of **lower** potential to a region of **higher** potential increases V, and hence **increases** the electric potential energy U.

Answer : (A) increases.

Question45

Two point charges $+8q$ and $-2q$ are located at $\mathrm{X} = 0$ (origin) and $\mathrm{X} = \mathrm{L}$ respectively. The net electric field due to these two charges is zero at point P on X-axis. The location of point P from the origin is

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Options:

A. $\frac{L}{4}$

B. 2L

C. 4L

D. 8L

Answer: B

Solution:

Let's work through the problem step by step.

Identify the charges and their positions:

A charge of $+8q$ is at the origin ($x = 0$).

A charge of $-2q$ is at $x = L$.

Determine the region where the net electric field could be zero:

If we look between the charges (i.e., $0 < x < L$), the electric fields due to both charges will point in the same direction along the x-axis. Hence, they cannot cancel.

For a point to the right of both charges (i.e., $x > L$), the field due to the positive charge points to the right (away from it), while the field from the negative charge points to the left (toward it). This setup allows for cancellation.

Write expressions for the electric fields at a point x (where $x > L$):

The electric field due to $+8q$ at a distance x is:

$E_1 = k\frac{8q}{x^2}$ (pointing right).

The electric field due to $-2q$ at a distance $(x - L)$ is:

$E_2 = k\frac{2q}{(x-L)^2}$ (pointing left, because the field due to a negative charge is towards the charge).

Set up the condition for net electric field being zero:

Since the two fields are in opposite directions, they cancel when their magnitudes are equal:

$k\frac{8q}{x^2} = k\frac{2q}{(x-L)^2}$

Simplify the equation:

Cancel k and q from both sides:

$\frac{8}{x^2} = \frac{2}{(x-L)^2}$

Cross-multiply:

$8(x-L)^2 = 2x^2$

Divide both sides by 2:

$4(x-L)^2 = x^2$

Solve for x:

Take the square root of both sides (note that since $x > L$, $x - L$ is positive):

$x = 2(x-L)$

Distribute and solve:

$x = 2x - 2L$

$2L = 2x - x$

$x = 2L$

Conclusion:

The point at which the net electric field is zero is $x = 2L$ from the origin.

Therefore, the correct answer is Option B: $2L$.

Question46

Consider a long uniformly charged cylinder having constant volume charge density ' λ ' and radius ' R '. A Gaussian surface is in the form of a cylinder of radius ' r ' such that vertical axis of both the cylinders coincide. For a point inside the cylinder $(r < R)$, electric field is directly proportional to

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Options:

A. r^{-1}

B. r

C. r^2

D. r^{-2}

Answer: B

Solution:

To determine how the electric field varies with the radial distance inside the cylinder, we can use Gauss's law. Here's the step-by-step reasoning:

Gaussian Surface:

We choose a cylindrical Gaussian surface of radius r (with $r < R$) and length L, aligned coaxially with the charged cylinder.

Electric Flux Through the Gaussian Surface:

The electric field $\vec{E}$ points radially outward.

The flux through the curved side is given by the product of the electric field and the lateral surface area:

Flux $= E \cdot (2\pi r L)$

The end caps do not contribute because the electric field is parallel to those surfaces.

Charge Enclosed by the Gaussian Surface:

If the cylinder has a constant volume charge density (commonly denoted by ρ), the charge inside the Gaussian surface is:

$Q_{\text{enc}} = \rho \cdot$ Volume of the Gaussian cylinder $= \rho \cdot (\pi r^2 L)$

(Note: Sometimes λ is used to denote linear charge density, but here we assume the cylinder is uniformly charged in volume and use ρ.)

Applying Gauss's Law:

Gauss's law states:

$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\epsilon_0}$

Substituting the above expressions:

$E \cdot (2\pi r L) = \frac{\rho \cdot (\pi r^2 L)}{\epsilon_0}$

Solving for the Electric Field E:

Cancel common factors π and L on both sides:

$E \cdot (2r) = \frac{\rho \cdot r^2}{\epsilon_0}$

Rearranging gives:

$E = \frac{\rho\, r}{2\epsilon_0}$

This shows that the electric field inside the cylinder is directly proportional to r.

Thus, for a point inside the cylinder ($r < R$), the electric field is directly proportional to r.

The correct answer is Option B: r.

Question47

An electric dipole will have minimum potential energy when it subtends an angle

$$
\begin{bmatrix} \cos 0^\circ = 1 \\ \sin 0^\circ = 0 \end{bmatrix} \begin{bmatrix} \cos 90^\circ = 0 \\ \cos \pi = -1 \end{bmatrix}
$$

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Options:

A. π with direction of field.

B. $\frac{\pi}{2}$ with direction of field.

C. $\frac{3\pi}{2}$ with direction of field.

D. zero with direction of field.

Answer: D

Solution:

The potential energy (U) of an electric dipole in an external uniform electric field ($\mathbf{E}$) is given by the expression:

$U = -\mathbf{p} \cdot \mathbf{E} = -pE \cos \theta$

where:

$\mathbf{p}$ is the electric dipole moment,

E is the magnitude of the electric field,

θ is the angle between the dipole moment $\mathbf{p}$ and the electric field $\mathbf{E}$.

The potential energy is minimized when $\cos \theta$ is maximized, which occurs when $\cos \theta = 1$. This happens when $\theta = 0^\circ$, meaning the dipole moment is aligned with the electric field.

Therefore, the electric dipole will have minimum potential energy when it subtends an angle of zero with the direction of the field.

The correct option is: D) zero with the direction of the field.

Question48

A particle ' A ' has charge ' $+q$ ' and a particle ' B ' has charge ' $+4q$ '. Each has same mass ' m '. When they are allowed to fall from rest through the same potential, the ratio of their speeds will become (particle A to particle B)

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Options:

A. 2 : 1

B. 1 : 2

C. 1 : 4

D. 4 : 1

Answer: B

Solution:

When a charged particle is placed in an electric field, it experiences an electric force. Consider the following for particles A and B:

Electric Force and Acceleration

For particle A:

$F_A = qE$

$F_A = m_A a_A$

$\therefore \quad a_A = \frac{qE}{m}$

For particle B:

$F_B = 4qE$

$F_B = m_B a_B$

$a_B = \frac{4qE}{m}$

From this, it follows that:

$a_A = \frac{a_B}{4}$ .... (i)

Relation of Speeds

Since both particles start from rest and fall through the same distance, we can use the equations of motion:

For particle A:

$V_A^2 = 0 + 2a_A x$

For particle B:

$V_B^2 = 0 + 2a_B x$

Taking the ratio of their speeds:

$\left(\frac{V_A}{V_B} \right)^2 = \frac{a_A}{a_B}$

Using the relationship from (i):

$\left(\frac{V_A}{V_B} \right)^2 = \frac{a_B}{4 \times a_B} = \frac{1}{4}$

Therefore, the ratio of their speeds is:

$\frac{V_A}{V_B} = \frac{1}{2}$

In summary, the ratio of the speeds of particles A to B is 1 : 2.

Question49

A sphere ' A ' of radius ' R ' has a charge ' Q ' on it. The field at point B outside the sphere is ' E '. Now another sphere of radius ' $2R$ ' having a charge ' $-2Q$ ' is placed at B. The total field at the point midway between A and B due to both the spheres is

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Options:

A. E

B. 3E

C. 12E

D. 15E

Answer: C

Solution:
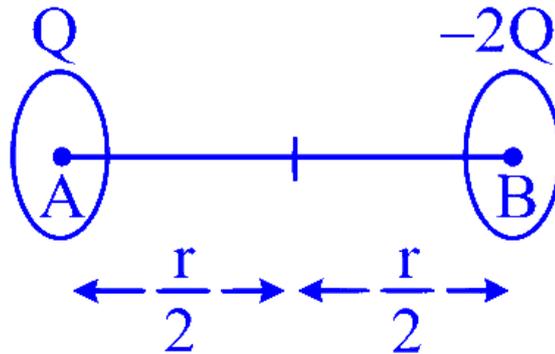
The field at point ' B ' due to sphere of charge ' Q ' will be,
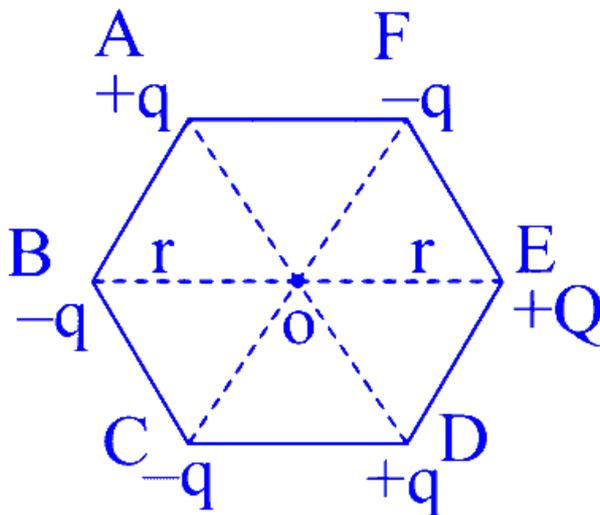
$E = \frac{KQ}{r^2}$

Electric field at mid-way between points ' A ' and ' B ' will be,

$$E' = \frac{KQ}{\left(\frac{r}{2}\right)^2} + \frac{K(2Q)}{\left(\frac{r}{2}\right)^2}$$
$$= \frac{4KQ}{r^2} + \frac{8KQ}{r^2}$$
$$E' = \frac{12KQ}{r^2} = 12E$$

Question50

The point charges $+q, -q, -q, +q, +Q$ and -q are placed at the vertices of a regular hexagon ABCDEF as shown in figure. The electric field at the centre of hexagon ' O ' due to the five charges at A, B, C, D and F is thrice the electric field at centre ' O ' due to charge +Q at E alone. The value of Q is

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Options:

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

B. $\frac{+q}{5}$

C. $\frac{+q}{6}$

D. $+6q$

Answer: A

Solution:

Electric field at ' O ' due to charge ' Q ' is given by, $E = \frac{kQ}{r^2}$

Electric field at ' O ' due to charges +q at A and D are equal and opposite and hence they will cancel each other. Similarly electric field at ' O ' due to charges -q at F and C will also cancel each other.

Electric field at ' O ' due to charge $-q$ at B is given by,

$E' = \frac{kq}{r^2}$

Now, $E' = 3E$

$\therefore \quad \frac{kq}{r^2} = \frac{3kQ}{r^2} \Rightarrow Q = \frac{q}{3}$

Question51

A small particle carrying a negative charge of 1.6×10^{-19} C is suspended in equilibrium between two horizontal metal plates 8 cm apart having a potential difference of 980 V across them. The mass of the particle is $\left[g = 9.8 \ \mathrm{m/s^2}\right]$

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Options:

A. 2×10^{-16} kg

B. 2.2×10^{-16} kg

C. 20×10^{-16} kg

D. 4×10^{-16} kg

Answer: A

Solution:

First, find the electric field E between the plates using the formula:

$E = \frac{V}{d}$,

where

$V = 980$ V is the potential difference,

$d = 8 \ \mathrm{cm} = 0.08 \ \mathrm{m}$ is the separation between the plates.

Substituting the values:

$E = \frac{980}{0.08} = 12250 \ \mathrm{V/m}$.

The charged particle experiences an electric force given by:

$F_e = qE$,

where

$q = 1.6 \times 10^{-19} \ \mathrm{C}$ is the charge of the particle.

Therefore,

$F_e = \left(1.6 \times 10^{-19}\right) \times 12250 = 1.96 \times 10^{-15} \ \mathrm{N}$.

Since the particle is suspended in equilibrium, the upward electric force balances the downward gravitational force. The gravitational force is:

$F_g = mg,$

where

$g = 9.8 \, \text{m/s}^2$ is the acceleration due to gravity,

m is the mass of the particle.

Setting the forces equal:

$qE = mg.$

Solve for the mass m:

$m = \frac{qE}{g} = \frac{1.96 \times 10^{-15}}{9.8} \approx 2 \times 10^{-16} \, \text{kg}.$

Thus, the correct option is Option A:

$2 \times 10^{-16} \, \text{kg}.$

Question52

Charges $3Q$, q **and Q are placed along x -axis at positions** $x = 0, x = \frac{1}{3}$ **and** $x = 1$ **respectively. When the force on charge Q is zero, the value of** q **is**

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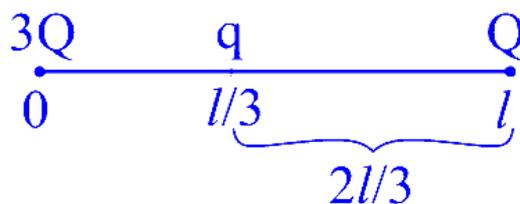
Options:

A. $\frac{Q}{3}$

B. $-\frac{Q}{3}$

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

D. $-\frac{4}{3}Q$

Answer: D

Solution:

Force F_1 due to charge $3Q$ on Q will be,

$F_1 = \frac{1}{4\pi\varepsilon_0} \frac{3Q^2}{l^2}$

Force F_2 due to charge q on charge Q will be,

$F_2 = \frac{1}{4\pi\varepsilon_0} \frac{Qq}{\left(\frac{2l}{3}\right)^2}$

$\therefore \quad F_2 = \frac{1}{4\pi\varepsilon_0} \frac{9Qq}{4l^2}$

For the force on charge Q to be zero,

$F_1 + F_2 = 0$ or $F_1 = -F_2$

$\therefore \quad \frac{3Q^2}{l^2} = -\frac{9Qq}{4l^2}$

$\therefore \quad Q = -\frac{3q}{4}$

$\therefore \quad q = -\frac{4}{3}Q$

Question53

If a unit charge is taken from one point to another point over an equipotential surface, then

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Options:

A. work is done on the charge.

B. work is done by the charge.

C. work done on the charge is constantly increasing.

D. work done to move a charge is zero.

Answer: D

Solution:

When a charge is moved from one point to another, the work done by the electric force is given by

$W = q\Delta V$

where:

q is the charge,

ΔV is the difference in electric potential between the two points.

On an equipotential surface, all points have the same potential. This means that

$\Delta V = 0$.

Thus, for a unit charge (where $q = 1$),

$W = 1 \times 0 = 0$.

So, no work is required to move a unit charge along an equipotential surface. This corresponds to Option D:

work done to move a charge is zero.

Question54

Two point charges $q_1 = 6\mu C$ **and** $q_2 = 4\mu C$ **are kept at points** A **and** B **in air where** $AB = 10$ cm**. What is the increase in potential energy of the system when** q_2 **is moved towards** q_1 **by 2 cm ?**

$$\left(\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ SI units} \right)$$

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Options:

A. 0.27 J

B. 0.54 J

C. 0.81 J

D. 54 J

Answer: B

Solution:

The potential energy between two charges is defined by the formula:

$U = \frac{Kq_1q_2}{r}$

Calculating the Increase in Potential Energy:

Initial Potential Energy (U_i):

The initial distance between the charges is $d = 10\,\text{cm} = 0.1\,\text{m}$.

Initial potential energy $U_i = \frac{Kq_1q_2}{d}$

Final Potential Energy (U_f):

The charge q_2 is moved towards q_1 by $x = 2\,\text{cm} = 0.02\,\text{m}$.

The new separation becomes $d - x = 0.1\,\text{m} - 0.02\,\text{m} = 0.08\,\text{m}$.

Final potential energy $U_f = \frac{Kq_1q_2}{d-x}$

Increase in Potential Energy (ΔU):

The increase in potential energy is given by the difference:

$$\Delta U = U_f - U_i = Kq_1q_2 \left(\frac{1}{d-x} - \frac{1}{d} \right)$$

$$\Delta U = \frac{Kq_1q_2x}{d(d-x)}$$

Substituting Given Values:

$K = 9 \times 10^9 \, \text{N m}^2/\text{C}^2$

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

$q_2 = 4 \, \mu\text{C} = 4 \times 10^{-6} \, \text{C}$

$x = 0.02 \, \text{m}$

$d = 0.1 \, \text{m}$

Performing the calculation:

$$\Delta U = \frac{(9 \times 10^9) \times (6 \times 10^{-6}) \times (4 \times 10^{-6}) \times 0.02}{0.1 \times 0.08}$$

Simplifying:

$$\Delta U = \frac{4.32 \times 10^{-3}}{0.008} = 0.54 \, \text{J}$$

Therefore, the increase in potential energy of the system is $0.54 \, \text{J}$.

Question55

Two point charges $(A$ and $B) + 4q$ and $-4q$ are placed along a line separated by a distance I '. Force acting between them is F. If 25% of charge from point A is transferred to that at point B , the force between the charges now becomes

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Options:

A. $\frac{3}{4}$ F

B. $\frac{4}{3}$ F

C. $\frac{9}{16}$ F

D. $\frac{16}{9}$ F

Answer: C

Solution:

When the charges $+4q$ and $-4q$ are placed along a line separated by a distance r, the initial force between them is given by:

$F = \frac{-16q^2}{4\pi\varepsilon_0 r^2}$ ..... (i)

If 25% of the charge from point A is transferred to point B, the charges change as follows:

Charge at point A becomes:

$q_1 = +4q - 0.25(+4q) = +3q$

Charge at point B becomes:

$q_2 = -4q + 0.25(+4q) = -3q$

Thus, the new force between points A and B is:

$F' = \frac{(3q) \times (-3q)}{4\pi\varepsilon_0 r^2} = \frac{-9q^2}{4\pi\varepsilon_0 r^2}$

By multiplying and dividing by 16 to compare with the initial force F, we get:

$F' = \frac{9}{16} \times \left(\frac{-16q^2}{4\pi\varepsilon_0 r^2} \right) = \frac{9}{16} F$ [From (i)]

Question56

The electric potential at a point on the axis of an electric dipole is proportional to [r = distance between centre of the electric dipole and the point]

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Options:

A. $\frac{1}{r}$

B. $\frac{1}{r^2}$

C. r

D. $\frac{1}{r^3}$

Answer: B

Solution:

For an electric dipole, the potential at a point in space is given by the equation:

$V = \frac{1}{4\pi\varepsilon_0} \frac{\mathbf{p} \cdot \hat{r}}{r^2}$

where:

p is the dipole moment,

$\hat{r}$ is the unit vector pointing from the center of the dipole to the point of interest, and

r is the distance between the center of the dipole and that point.

On the axis of the dipole, the dipole moment and the unit vector point in the same direction. This means that $\mathbf{p} \cdot \hat{r} = p$, and the potential simplifies to:

$V = \frac{1}{4\pi\varepsilon_0} \frac{p}{r^2}$

Thus, the electric potential is proportional to $\frac{1}{r^2}$.

To summarize in a few steps:

The general dipole potential is $V = \frac{1}{4\pi\varepsilon_0} \frac{\mathbf{p}\cdot\hat{r}}{r^2}$.

On the axis, $\mathbf{p} \cdot \hat{r} = p$.

So, the potential on the axis becomes $V = \frac{1}{4\pi\varepsilon_0} \frac{p}{r^2}$.

Therefore, the potential is proportional to $\frac{1}{r^2}$.

The correct answer is Option B: $\frac{1}{r^2}$.

Question57

Four electric charges $+q, +q, -q$ and -q are placed in order at the corners of a square of side 2 L. The electric potential at point midway between the two positive charges is

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Options:

A. $\frac{1}{4\pi E_0} \frac{2q}{L} \left(1 + \frac{1}{\sqrt{5}}\right)$

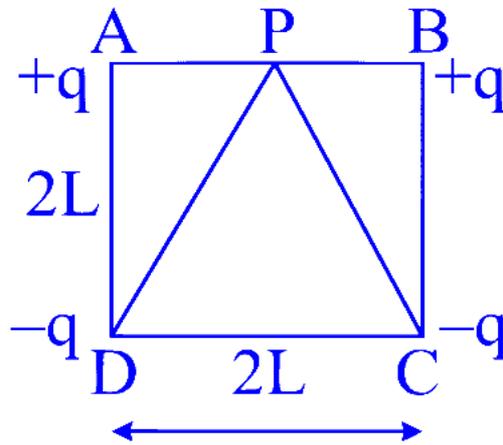B. $\frac{1}{4\pi E_0} \frac{2q}{L} \left(1 - \frac{1}{\sqrt{5}}\right)$

C. $\frac{1}{4\pi E_0} \frac{2q}{L}\left(1 - \sqrt{5}\right)$

D. $\frac{1}{4\pi E_0} \frac{2q}{L}\left(1 + \sqrt{5}\right)$

Answer: B

Solution:

$DP^2 = (2\,L)^2 + L^2 = 4\,L^2 + L^2 = 5\,L^2$

$\therefore \quad DP = \sqrt{5}\,L = CP$

$AP = BP = L$

$\therefore \quad$ Potential at point P due to the four charges,

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{L} + \frac{q}{L} - \frac{q}{\sqrt{5}L} - \frac{q}{\sqrt{5}L}\right)$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{2q}{L} - \frac{2q}{\sqrt{5}L}\right)$$

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q}{L}\left(1 - \frac{1}{\sqrt{5}}\right)$$

Question58

Two point charges +10 q and -4 q are located at $x = 0$ and $x = L$ respectively. What is the location of a point on the x-axis from the origin, which the net electric field due to these two point charges is zero?($r = $ required distance$)$

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Options:

A. $r = \dfrac{\sqrt{2}}{\sqrt{5}-\sqrt{2}}$ right to pt. B

B. $r = \dfrac{\sqrt{2}}{\sqrt{5}-\sqrt{2}}$ left to pt.A

C. $r = \dfrac{\sqrt{2}}{\sqrt{5}+\sqrt{2}}$ right to pt.B

D. $r = \dfrac{\sqrt{2}}{\sqrt{5}+\sqrt{2}}$ left to pt.A

Answer: A

Solution:

Let ' Q ' be the point at a distance r from $-4q$ and $(L + r)$ from 10q. wherein net electric field is zero.

$E_1 = E_2$

$\dfrac{K(10q)}{(L+r)^2} = \dfrac{K(4q)}{r^2}$

$\dfrac{\sqrt{10}}{L+r} = \dfrac{2}{r}$

$\dfrac{\sqrt{5} \times \sqrt{2}}{L+r} = \dfrac{\sqrt{2} \times \sqrt{2}}{r} = \dfrac{2}{r}$

$\sqrt{5} \times \sqrt{2} \times r = 2(L + r)$

$\sqrt{5} \times \sqrt{2} \times r = \sqrt{2} \times \sqrt{2}(L + r)$

$\sqrt{5}r = \sqrt{2}L + \sqrt{2}r$

$\sqrt{5} - \sqrt{2}r = \sqrt{2}L$

$r = \dfrac{\sqrt{2}}{\sqrt{5} - \sqrt{2}}$

If B is position of charge $-4q$ then point Q is $r = \dfrac{\sqrt{2}}{\sqrt{5}-\sqrt{2}}$ to the right of B

Question59

The van de Graaff Generator is not based on

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Options:

A. the phenomenon of Corona Discharge in X-ray tube.

B. the application of electric field and magnetic field which are perpendicular to each other.

C. the property that charge given to a hollow conductor is transferred to its outer surface and distributed uniformly over it.

D. the fact that a charge is continuously supplied to an isolated metallic conductor, the potential of the conductor goes on increasing.

Answer: B

Solution:

The van de Graaff Generator is not based on:

Option B: the application of electric field and magnetic field which are perpendicular to each other.

The van de Graaff Generator operates primarily on the principle of transferring electric charge to a hollow metal sphere and is not related to the perpendicular interaction of electric and magnetic fields, which is more relevant to devices like the cyclotron.

Question60

The electric flux over a sphere of radius ' r ' is ' ϕ '. If the radius of the sphere is doubled without changing the charge, the flux will be

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Options:

A. 4ϕ

B. 2ϕ

C. ϕ

D. $\frac{\phi}{2}$

Answer: C

Solution:

Using Gauss's Law, the electric flux through a closed surface is given by:

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

where q is the charge enclosed by the surface, and ε_0 is the permittivity of free space.

From this expression, we see that the electric flux ϕ is directly proportional to the charge q, and is independent of the size or shape of the Gaussian surface itself.

Thus, if the radius of the sphere is doubled and the charge q remains the same, the electric flux will remain unchanged. Therefore, the new flux ϕ_2 is equal to the original flux ϕ:

$\phi_2 = \phi$

Question61

If the electric flux entering and leaving an enclosed surface is ϕ_1 and ϕ_2 then charge enclosed in the surface is ($\varepsilon_0 = $ permittivity of free space)

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Options:

A. $\frac{\phi_2 - \phi_1}{\varepsilon_0}$

B. $\frac{\phi_2 + \phi_1}{\varepsilon_0}$

C. $\frac{\phi_1 - \phi_2}{\varepsilon_0}$

D. $\varepsilon_0 (\phi_2 - \phi_1)$

Answer: D

Solution:

Gauss's law tells us that the net electric flux through a closed surface is related to the charge enclosed by the surface. Specifically, Gauss's law is:

$$\oint_S \mathbf{E} \cdot d\mathbf{A} = \frac{Q_{\text{enc}}}{\varepsilon_0}$$

Here's how to apply this to the problem:

The net electric flux through the surface is the algebraic sum of the flux leaving the surface and the flux entering the surface. If you take ϕ_2 as the flux exiting the surface and ϕ_1 as the flux entering, then the net flux is:

$$\Phi_{\text{net}} = \phi_2 - \phi_1$$

By substituting this into Gauss's law, we have:

$$\phi_2 - \phi_1 = \frac{Q_{\text{enc}}}{\varepsilon_0}$$

Solving for the enclosed charge Q_{enc}, we multiply both sides by ε_0:

$$Q_{\text{enc}} = \varepsilon_0(\phi_2 - \phi_1)$$

Thus, the correct answer is:

Option D: $\varepsilon_0 (\phi_2 - \phi_1)$

Question62

Two surfaces A and B are enclosing the charges as shown below. The total normal electric induction (T.N.E.I) through the surfaces A and B are respectively.
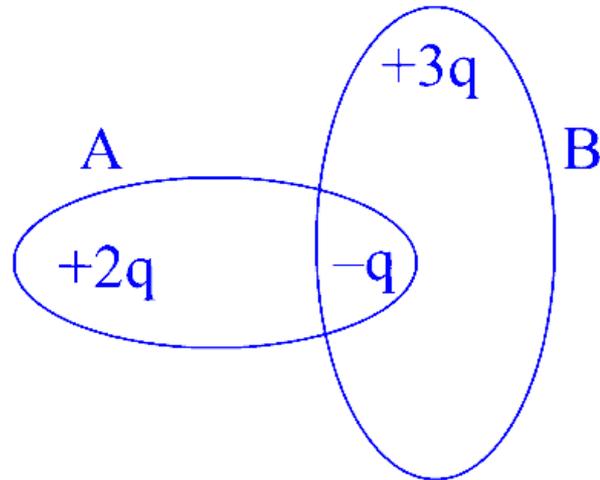
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Options:

A. $+2q$ and $+2q$

B. $+q$ and $+3q$

C. $+q$ and $+2q$

D. $+2q$ and $+3q$

Answer: C

Solution:

Total normal electric induction is given by,

T.N.E.I. $= \sum q_{enclosed}$

$\therefore$ T.N.E.I. for $A = (+2q - q) = +q$

T.N.E.I. for $B = (+3q - q) = +2q$

Question63

A spherical rubber balloon carries a charge, uniformly distributed over the surface. As the balloon is blown up and increases in size, the total electric flux coming out the surface

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Options:

A. becomes zero

B. decreases

C. increases

D. remains unchanged

Answer: D

Solution:

According to Gauss's law, the net electric flux through any closed surface is given by

$$\Phi_E = \frac{q_{enc}}{\varepsilon_0}$$

where:

Φ_E is the electric flux,

q_{enc} is the total enclosed charge, and

ε_0 is the permittivity of free space.

In our case, the balloon carries a total charge Q which is uniformly distributed over its surface. When you blow up the balloon, its size increases, but the total charge Q remains the same.
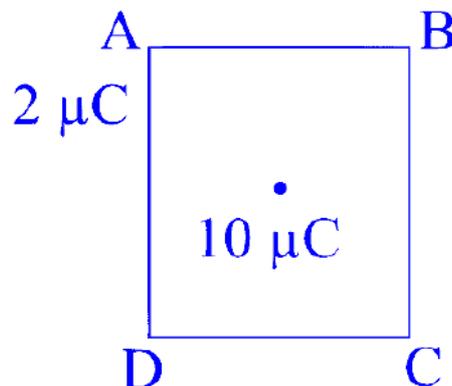
Because the net flux depends only on the total enclosed charge and not on the size or shape of the surface, the total electric flux will remain unchanged.

Thus, the correct answer is:

Option D: remains unchanged.

Question64

If a $10\mu C$ charge exists at the centre of a square, the work done in moving a $2\mu C$ point charge from corner A to corner B of a square ABCD is

Options:

A. Zero

B. 5

C. 2

D. 20

Answer: A

Solution:

Due to the $10\mu C$ change, potential at all the four corners will be the same

$\therefore$ work done in moving $2\mu C$ change from point A to B will be zero.

Question65

If the electric flux entering and leaving an enclosed surface are ϕ_1 and ϕ_2 respectively, the electric charge inside the surface will be

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Options:

A. $\frac{\phi_2 - \phi_1}{\varepsilon_0}$

B. $\frac{\phi_1 + \phi_2}{\varepsilon_0}$

C. $\varepsilon_0 \left(\phi_1 - \phi_2 \right)$

D. $\varepsilon_0 \left(\phi_2 - \phi_1 \right)$

Answer: D

Solution:

We can solve this using Gauss's Law, which states that:

$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{q_{\text{enc}}}{\varepsilon_0}$

Here's a step-by-step explanation:

The flux leaving the surface contributes positively with a value of ϕ_2, while the flux entering the surface contributes negatively with a value of ϕ_1. Thus, the net electric flux is:

$\phi_{\text{net}} = \phi_2 - \phi_1$

Applying Gauss's Law:

$\phi_{\text{net}} = \frac{q_{\text{enc}}}{\varepsilon_0}$

Substituting for the net flux:

$\phi_2 - \phi_1 = \frac{q_{\text{enc}}}{\varepsilon_0}$

Solving for the enclosed charge q_{enc} :

$q_{\text{enc}} = \varepsilon_0 \left(\phi_2 - \phi_1 \right)$

Thus, the correct answer is:

Option D

$\varepsilon_0(\phi_2 - \phi_1)$

Question66

An electron of mass ' m ' and charge ' q ' is accelerated from rest in a uniform electric field of intensity ' E '. The velocity acquired by it as it travels a distance ' l ' is ' v '. The ratio $\frac{q}{m}$ in terms of E, l and v is

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Options:

A. $\frac{v_2}{2El}$

B. $\frac{v_2 l}{2E}$

C. $\frac{2E}{v^2 l}$

D. $\frac{v_2 l}{E}$

Answer: A

Solution:

When an electron with mass 'm' and charge 'q' is accelerated from rest in a uniform electric field with intensity 'E', it attains a velocity 'v' while traveling a distance 'l'. We need to find the expression for the ratio $\frac{q}{m}$ in terms of E, l, and v.

First, we use the relationship between force and acceleration:

$F = ma$ and $F = qE$

Thus, we equate these expressions:

$qE = ma$

So, the acceleration a is given by:

$a = \frac{qE}{m}$ ...(i)

Next, we apply the equation of motion for constant acceleration:

$v^2 = u^2 + 2aL$

Since the electron starts from rest, $u = 0$. Therefore, the equation simplifies to:

$v^2 = 2aL$

Solving for a, we get:

$a = \frac{v^2}{2L}$ ...(ii)

By equating expressions from (i) and (ii):
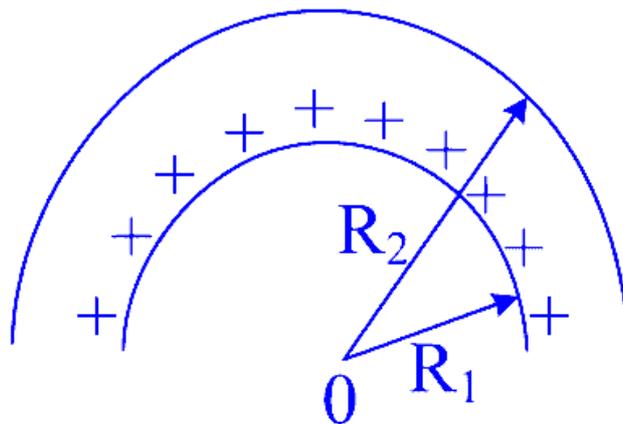
$\frac{qE}{m} = \frac{v^2}{2L}$

Rearranging for $\frac{q}{m}$, we find:

$\frac{q}{m} = \frac{v^2}{2EL} = \frac{v^2}{2E\ell}$ (since $L = \ell$)

Question67

The electric potential at the centre of two concentric half rings of radii R_1 and R_2, having same linear charge density ' λ ' is ($\varepsilon_0 = $ permittivity of free space)

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A. $\dfrac{2\lambda}{\varepsilon_0}$

B. $\dfrac{\lambda}{2\varepsilon_0}$

C. $\dfrac{\lambda}{4\varepsilon_0}$

D. $\dfrac{\lambda}{\varepsilon_0}$

Answer: B

Solution:

$$V_1 = \frac{1}{4\pi\varepsilon_0} \times \frac{\lambda\,(\pi R_1)}{R_1}$$
$$V_2 = \frac{1}{4\pi\varepsilon_0} \times \frac{\lambda\,(\pi R_2)}{R_2}$$
$$V_{net} = V_1 + V_2 = \frac{1}{4\pi\varepsilon_0} \times \pi\lambda \times 2 = \frac{\lambda}{2\varepsilon_0}$$

Question68

A metallic sphere ' A ' isolated from ground is charged to $+50\mu C$. This sphere is brought in contact with other isolated metallic sphere ' B ' of half the radius of sphere ' A '. Then the charge on the two isolated spheres A \& B are in the ratio

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Options:

A. $1 : 2$

B. $2 : 1$

C. $4 : 1$

D. $1 : 1$

Answer: B

Solution:

When sphere A is brought into contact with sphere B, charge will transfer between them until their electrical potentials are equal. The relationship between charge and potential for a sphere is given by:

$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$

For both spheres A and B to have the same potential:

$V_A = V_B$

Thus,

$\frac{1}{4\pi\varepsilon_0} \frac{q_A}{r_A} = \frac{1}{4\pi\varepsilon_0} \frac{q_B}{r_B}$

This simplifies to:

$\frac{q_A}{q_B} = \frac{r_A}{r_B}$

Given that sphere B has half the radius of sphere A:

$r_B = \frac{r_A}{2}$

Substitute this into the equation:

$\frac{q_A}{q_B} = \frac{r_A}{\frac{r_A}{2}} = \frac{2}{1}$

Hence, the charges on the spheres A and B are in the ratio 2 : 1.

Question69

A regular hexagon of side 10 cm has a charge $1\mu C$ at each of its vertices. The potential at the centre of hexagon is $\left[\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ SI unit} \right]$
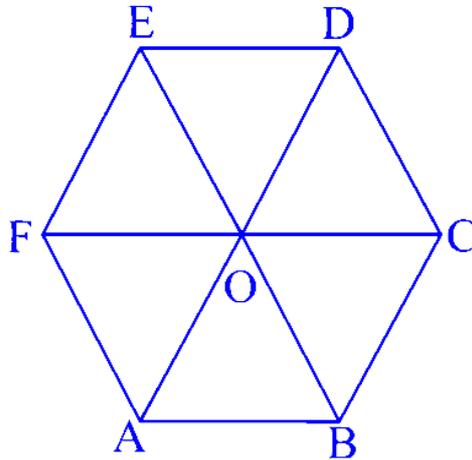
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Options:

A. 1.8×10^5 volt

B. 3.6×10^5 volt

C. 5.4×10^5 volt

D. 7.2×10^5 volt

Answer: C

Solution:

Potential at the centre of hexagon

Potential at

$$V_0 = V_A + V_B + V_C + V_D + V_E + V_F$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{OA} + \frac{q}{OB} + \frac{q}{OC} + \frac{q}{OD} + \frac{q}{OE} + \frac{q}{OF}\right]$$

For a hexagon, distance from centre to vertices is equal to length of side.

$$\therefore \quad OA = OB = OC = OD = OE = OF = 10\text{ cm}$$
$$= 0.1\text{ m}$$
$$\therefore \quad V_0 = \frac{1}{4\pi\varepsilon_0}\frac{q}{0.1}(6)$$
$$= 9 \times 10^9 \times \frac{(1 \times 10^{-6})6}{0.1}$$
$$= 5.4 \times 10^5 \text{ volt}$$

Question70

Two charged particles each having charge ' q ' and mass ' m ' are held at rest while their separation is ' r '. The speed of the particles when their separation is ' $\frac{r}{2}$ ' will be ($\varepsilon_0 = $ permittivity of the medium)

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Options:

A. $\frac{q}{4\pi\varepsilon_0 \text{mr}}$

B. $\frac{q}{2\pi\varepsilon_0 \text{mr}}$

C. $\dfrac{q}{\sqrt{4\pi\varepsilon_0 mr}}$

D. $\dfrac{q^2}{4\pi\varepsilon_0 mr}$

Answer: C

Solution:

To determine the speed of two charged particles when their separation changes, we use the principle of conservation of energy. Consider the following steps:

Initially, the two charged particles, each with charge q and mass m, are at rest and separated by a distance r. The initial kinetic energy (K.E.) of the system is zero because the particles are not moving. The initial potential energy (P.E.) is given by the electrostatic potential energy formula:

Initial P.E. $= \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{q^2}{r}$

When the particles move closer such that their separation is reduced to $\dfrac{r}{2}$, they gain kinetic energy. The final kinetic energy (assuming that both particles gain the same speed v) can be expressed as:

Final K.E. $= 2 \times \dfrac{1}{2}mv^2 = mv^2$

The final potential energy when the separation is $\dfrac{r}{2}$ is:

Final P.E. $= \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{q^2}{r/2} = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{2q^2}{r}$

According to the conservation of energy principle:

$(\text{Initial K.E.} + \text{Initial P.E.}) = (\text{Final K.E.} + \text{Final P.E.})$

Substituting the expressions for the initial and final energies:

$\dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{q^2}{r} = mv^2 + \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{2q^2}{r}$

Rearranging terms to solve for mv^2:

$mv^2 = \dfrac{1}{4\pi\varepsilon_0}\left(\dfrac{2q^2}{r} - \dfrac{q^2}{r}\right) = \dfrac{q^2}{4\pi\varepsilon_0} \cdot \dfrac{1}{r}$

Then:

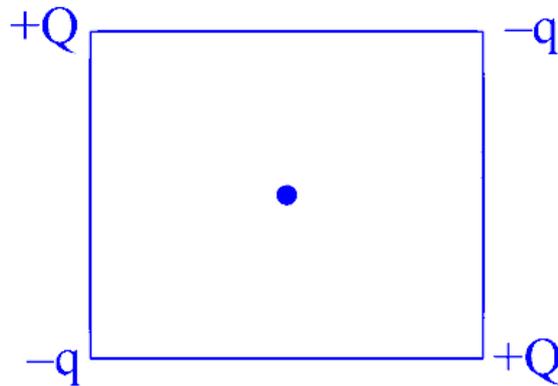$mv^2 = \dfrac{q^2}{4\pi\varepsilon_0} \cdot \dfrac{1}{r}$

Solving for v:

$v = \dfrac{q}{\sqrt{4\pi\varepsilon_0 mr}}$

Thus, the speed of the particles when their separation is reduced to $\dfrac{r}{2}$ is given by:

$v = \dfrac{q}{\sqrt{4\pi\varepsilon_0 mr}}$

Question71

A charge $+Q$ is placed at each of the diagonally opposite corners of a square. A charge -q is placed at each of the other diagonally opposite corners as shown. If the net electrical force on $+Q$ is zero, then $\frac{+Q}{-q}$ is equal to
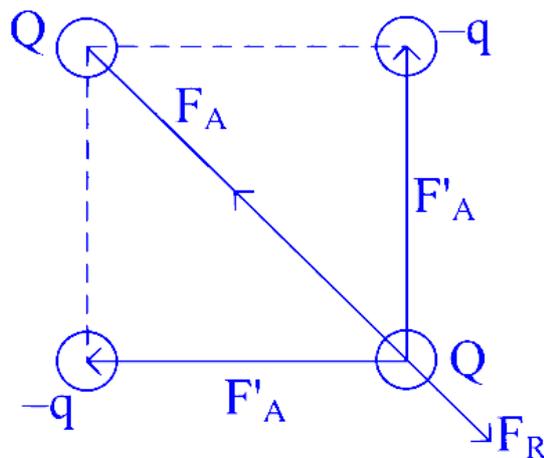

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Options:

A. $+1$

B. $+2\sqrt{2}$

C. $\frac{+1}{\sqrt{2}}$

D. $-2\sqrt{2}$

Answer: B

Solution:

From the diagram,
$$(F_A)^2 = (F_R)^2 \Rightarrow 2(F'_A)^2 = F_R^2$$
$$\therefore \quad \sqrt{2}\,(F'_A) = F_R$$
$$\therefore \quad \frac{1}{4\pi\varepsilon_0} \frac{\sqrt{2}Q(-q)}{a^2} = \frac{1}{4\pi\varepsilon_0} \frac{Q^2}{2a^2}$$
$$\therefore \quad Q = -2\sqrt{2}q$$
$$\therefore \quad \frac{Q}{q} = \frac{-2\sqrt{2}}{1}$$
$$\frac{Q}{-q} = 2\sqrt{2}$$

Question72

Two equal point charges ' q ' each exert a force ' F ' on each other, when they are placed distance ' x ' apart in air. When the same charges are placed distance ' y ' apart in a medium of dielectric constant ' k ', they exert the same force. The ratio of distance ' y ' to ' x ' is equal to

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Options:

A. $\frac{1}{\sqrt{k}}$

B. $\sqrt{k}$

C. $\frac{\sqrt{k}}{2}$

D. $\frac{2}{\sqrt{k}}$

Answer: A

Solution:

When two equal point charges, each of magnitude q, exert a force F on each other when placed distance x apart in air, the force is given by:

$$F_1 = \frac{1}{4\pi\varepsilon_0} \frac{q^2}{x^2}$$

Here, ε_0 is the permittivity of free space.

When these charges are placed distance y apart in a medium with a dielectric constant k, they exert the same force F:

$$F_2 = \frac{1}{4\pi\varepsilon_0 k} \frac{q^2}{y^2}$$

Since the forces F_1 and F_2 are equal, we have:

$$\frac{1}{4\pi\varepsilon_0}\frac{q^2}{x^2} = \frac{1}{4\pi\varepsilon_0 k}\frac{q^2}{y^2}$$

Simplifying the equation:

$$k\frac{y^2}{x^2} = 1$$

From this, we determine the ratio of distance y to x:

$$\frac{y}{x} = \frac{1}{\sqrt{k}}$$

Thus, the ratio of distance y to x in the medium is $\frac{1}{\sqrt{k}}$.

Question73

Three charges $2q$, $-q$ and $-q$ are located at the vertices of an equilateral triangle. At the centre of the triangle

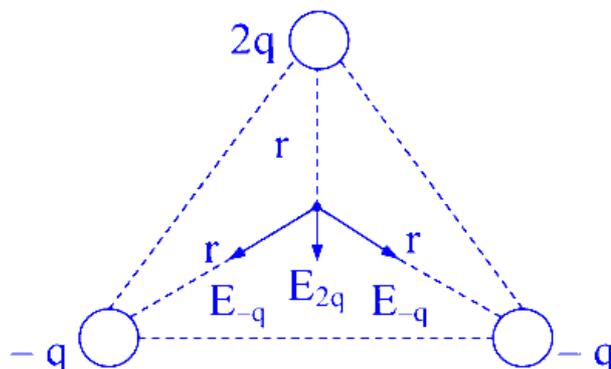**MHT CET 2024 3rd May Morning Shift**

Options:

A. the field is zero but potential is non-zero.

B. the field is non-zero but potential is zero.

C. both field and potential are zero.

D. both field and potential are non-zero.

Answer: B

Solution:

From charge configuration, at the centre electric field is non-zero. Potential at the centre due to $2q$ charge $V_{2q} = \frac{2q}{r}$

and potential due to $-q$ charge

$V_{-q} = -\frac{q}{r} (r = $ distance of centre point $)$

$\therefore$ total potential $V = V_{2q} + V_{-q} + V_{-q} = 0$

Question74

An electric dipole of moment $\overrightarrow{p}$ is lying along a uniform electric field $\overrightarrow{E}$. The work done in rotating the dipole through $\frac{\pi^c}{3}$ is

$$\left[\sin 30° = \cos 60° = 0 \cdot 5, \cos 30° = \sin 60° = \sqrt{3}/2 \right]$$

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Options:

A. 3 pE

B. $\sqrt{2}$pE

C. pE

D. $\frac{pE}{2}$

Answer: D

Solution:

To find the work done in rotating an electric dipole in a uniform electric field, use the formula:

$W = -\Delta U = -(U_f - U_i),$

where U denotes the potential energy of the dipole in the electric field, which is given by:

$U = -\overrightarrow{p} \cdot \overrightarrow{E} = -pE \cos \theta,$

with θ being the angle between the dipole moment $\overrightarrow{p}$ and the electric field $\overrightarrow{E}$.

Initially, the dipole is aligned with the field, so $\theta_i = 0$, and

$U_i = -pE \cos 0 = -pE.$

After rotating through an angle of $\frac{\pi}{3}$, $\theta_f = \frac{\pi}{3}$, and

$U_f = -pE \cos\left(\frac{\pi}{3}\right) = -pE \cdot \frac{1}{2}.$

The change in potential energy, ΔU, is then:

$\Delta U = U_f - U_i = \left(-pE \cdot \frac{1}{2}\right) - (-pE) = -pE \cdot \frac{1}{2} + pE = \frac{pE}{2}.$

Therefore, the work done is:

$W = -\Delta U = -\left(\frac{pE}{2}\right) = \frac{pE}{2}.$

The correct answer is Option D:

$\frac{pE}{2}.$

Question75

Which of the following statement is correct?

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Options:

A. Electric lines of force originate from a -vely charged object and terminate on a +vely charged object.

B. The electric line of force do not pass through an insulator but can pass through a conductor.

C. The electric line of force do not intersect each other.

D. Electric intensity is small in a region where the lines of force are crowded.

Answer: C

Solution:

Option C is correct: The electric lines of force do not intersect each other.

Electric field lines, also known as electric lines of force, have several important properties that help us understand electric fields:

Origin and Termination: Electric field lines originate from positive charges and terminate on negative charges. This means Option A is incorrect because it mistakenly reverses this behavior.

Passage Through Materials: Electric field lines can pass through insulators, which are materials where the electric charges do not easily move. However, electric fields cannot pass through perfect conductors because charges within the conductor will rearrange to cancel the field inside. Option B is incorrect because it reverses the behavior and misunderstand the role of conductors vs. insulators.

Non-Intersection: Electric field lines never intersect each other. If they did, it would imply that there are two directions of the electric field at the point of intersection, which is physically impossible. Hence, Option C is the correct statement.

Intensity and Crowding: The electric field intensity is stronger in regions where the lines of force are crowded and weaker where they are spread out. Therefore, Option D is incorrect as it states the opposite.

These principles are foundational to understanding how electric fields behave in different contexts and environments.

Question76

Four point charges each +q is placed on the circumference of a circle of diameter 2 d in such a way that they form a square. The potential at the centre is proportional to

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Options:

A. $\dfrac{q^2}{d^2}$

B. $\dfrac{q}{d}$

C. $\dfrac{d}{q}$

D. $\dfrac{d^2}{q^2}$

Answer: B

Solution:

Four point charges, each with a charge of $+q$, are positioned on the circumference of a circle with a diameter of $2d$, arranged to form a square. To determine the potential at the circle's center, consider the following:

Since the charges are equally distributed on the circle's circumference, the distance from each charge to the center is:

$r = \dfrac{\text{Diameter}}{2} = \dfrac{2d}{2} = d$

The potential at the center from each charge can be determined using the formula for the potential due to a point charge, $V = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r}$. Therefore, the total potential at the center due to all four charges is:

$$\begin{aligned} V_{\text{total}} \ &= \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{d} + \frac{q}{d} + \frac{q}{d} + \frac{q}{d}\right) \\ &= \frac{1}{4\pi\varepsilon_0}\cdot\frac{4q}{d} \\ &= 4K\left(\frac{q}{d}\right) \end{aligned}$$

where $K = \dfrac{1}{4\pi\varepsilon_0}$.

Thus, the potential at the center is proportional to $\frac{q}{d}$.

Question77

90 J of work is done to move an electric charge of magnitude 3 C from a place A , where potential is -10 V to another place B , where potential is ' V_1 ' volt. The value of V_1 is

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Options:

A. 10 V

B. 20 V

C. 30 V

D. -40 V

Answer: B

Solution:

The work done to move a charge in an electric field is related to the change in electric potential by the equation:

$W = q\Delta V$

where:

$W = 90\,\text{J}$ (work done),

$q = 3\,\text{C}$ (charge),

$\Delta V = V_1 - (-10\,\text{V}) = V_1 + 10\,\text{V}$ (change in electric potential).

We can solve for V_1 using the formula:

$90 = 3(V_1 + 10)$

Divide both sides by 3:

$30 = V_1 + 10$

Subtract 10 from both sides:

$V_1 = 20\,\text{V}$

Thus, the value of V_1 is 20 V, corresponding to Option B.

Question78

Three charges are placed at the vertices of an equilateral triangle as shown in the figure. For what value of charge ' Q ', the electrostatic potential energy of the system is zero?
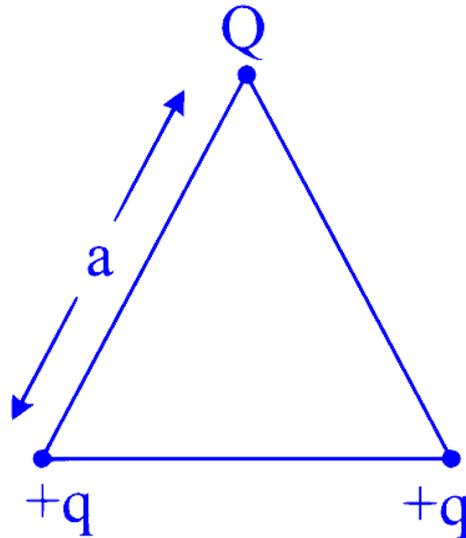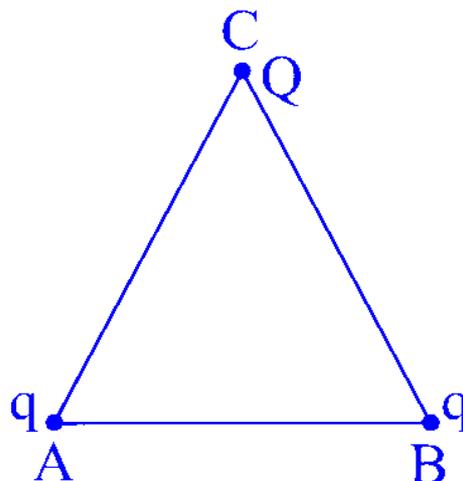

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Options:

A. $-q$

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

C. $-2q$

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

Answer: D

Solution:

Potential energy $U = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{a}$

∴ Potential energy at A due to $B = \frac{q^2}{4\pi\varepsilon_0 a}$

Potential energy at B due to $C = \frac{Qq}{4\pi\varepsilon_0 a}$

Potential energy at C due to A $= \frac{Qq}{4\pi\varepsilon_0 a}$

∴ Total P.E $= \frac{q}{4\pi\varepsilon_0 a}(q + Q + Q) = 0$
∴ $2Q + q = 0 \quad \Rightarrow Q = -\frac{q}{2}$

Question79

A uniformly charged conducting sphere of diameter 14 cm has surface charge density of $40\mu\text{Cm}^{-2}$. The total electric flux leaving the surface of the sphere is nearly (Permittivity of free space $= 8.85 \times 10^{-12}$ SI unit)

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Options:

A. 40 kWb

B. 140 kWb

C. 240 kWb

D. 280 kWb

Answer: D

Solution:

Electric flux $\phi = \dfrac{q}{\varepsilon_0} = \dfrac{4\pi r^2 \sigma}{\varepsilon_0}$

$$= \frac{4 \times 3.14 \times \left(7 \times 10^{-2}\right)^2 \times 40 \times 10^{-6}}{8.85 \times 10^{-12}}$$

$$= \frac{4 \times 3.14 \times 49 \times 10^{-4} \times 4 \times 10^{-5}}{8.85 \times 10^{-12}}$$

$$= \frac{4 \times 3.14 \times 49 \times 4 \times 10^3}{8.85}$$

$$= 278 \times 10^3 \approx 280 \times 10^3 \text{ Wb}$$

$$= 280 \text{ kWb}$$

Question80

The electrostatic potential inside a charged spherical ball is given by $V = ar^2 + b$ where ' r ' is the distance from its centre and ' a ' and ' b ' are constants. The volume charge density of the ball is [ε_0 = permittivity of free space]

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Options:

A. $-24\pi a\varepsilon_0 r$

B. $-6a\varepsilon_0 r$

C. $-24\pi a\varepsilon_0$

D. $-6a\varepsilon_0$

Answer: D

Solution:

Given: $V = ar^2 + b$

$$E = -\frac{dV}{dr}$$
$$= -\frac{d}{dr}(ar^2 + b)$$
$$E = -2ar \quad \text{... (i)}$$

By Gauss' law,

$$\vec{E} \cdot \vec{S} = \frac{q}{\varepsilon_0}$$
$$4\pi r^2 E = \frac{q}{\varepsilon_0} \quad \text{.... (ii)}$$

Total charge (q) enclosed $= \frac{4p}{3}\pi r^3$ ... (ρ = charge density of ball)

From (i) and (ii)

$$4\pi r^2 \times (-2ar) = \frac{4\rho}{3\varepsilon_0}\pi r^3$$
$$-2a = \frac{\rho}{3\varepsilon_0}$$
$$\rho = -6a\varepsilon_0$$

Question81

A charge 17.7×10^{-4} C is distributed uniformly over a large sheet of area 200 m^2. The electric field intensity at a distance 20 cm from it in air will be $\left[\varepsilon_0 = 8.85 \times 10^{-12} \text{C}^2/\text{Nm}^2\right]$

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Options:

A. 5×10^5 N/C

B. 6×10^5 N/C

C. 7×10^5 N/C

D. 8×10^5 N/C

Answer: A

Solution:

The surface charge density is given by,

$\sigma = \frac{q}{A} = \frac{17.7 \times 10^{-4}}{200} = 8.85 \times 10^{-6} \text{C/m}^2$

The electric field intensity at a distance of 20 cm in air is,

$E = \frac{\sigma}{2\varepsilon_0} = \frac{8.85 \times 10^{-6}}{2 \times 8.85 \times 10^{-12}} = 5 \times 10^5$ N/C

Hence, option (A).

Question82

If E_a and E_q represent the electric field intensity due to a short dipole at a point on its axial line and on the equatorial line at the same distance 'r' from the centre of the dipole, then

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Options:

A. $E_a = E_q$

B. $E_a = \frac{1}{2}E_q$

C. $E_a = \frac{1}{\sqrt{2}}E_q$

D. $E_a = 2E_q$

Answer: D

Solution:

To solve this problem, we need to understand the electric field intensity due to a short dipole at two specific points: on the axial line and on the equatorial line.

For a short dipole, the expressions for the electric field intensity are as follows:

1. On the axial line (line extending along the dipole axis):

$E_a = \frac{1}{4\pi\epsilon_0} \cdot \frac{2p}{r^3}$

where p is the dipole moment, r is the distance from the center of the dipole, and ϵ_0 is the permittivity of free space.

2. On the equatorial line (line perpendicular to the dipole axis at the center):

$E_q = \frac{1}{4\pi\epsilon_0} \cdot \frac{p}{r^3}$

Notice the difference in the coefficients. The electric field on the axial line is twice as strong as that on the equatorial line at the same distance r.

Thus, the relationship between E_a and E_q can be derived:

Given:

$E_a = 2E_q$

Therefore, the correct option is:

Option D
$E_a = 2E_q$

Question83

The electric field intensity on the surface of a solid charged sphere of radius 'r' and volume charge density 'ρ' is (ε_0 = permittivity of free space)

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Options:

A. $\dfrac{\rho r}{3\varepsilon_0}$

B. $\dfrac{\rho}{4\pi\varepsilon_0 r}$

C. zero

D. $\dfrac{5\rho r}{6\varepsilon_0}$

Solution:

According to Gauss' theorem,

$\phi = \mathrm{E} \cdot \mathrm{A} = \dfrac{q_{enc}}{\varepsilon_0}$

But, $q_{enc} = \rho \times$ volume

$\therefore \quad q_{enc} = \rho\left(\dfrac{4}{3}\pi r^3\right)$

And area is $A = 4\pi r^2$

$\therefore \quad E\left(4\pi r^2\right) = \dfrac{\rho\left(\dfrac{4}{3}\pi r^3\right)}{\varepsilon_0}$

$\therefore \quad E = \dfrac{\rho r}{3\varepsilon_0}$

Question84

A uniformly charged semicircular arc of radius 'r' has linear charge density 'λ'. The electric field at its centre is ($\varepsilon_0 =$ permittivity of free space)

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Options:

A. $\dfrac{\lambda}{4\varepsilon_0}$

B. $\dfrac{2\varepsilon_0}{\lambda}$

C. $\dfrac{\lambda}{4\varepsilon_0 r}$

D. $\dfrac{2\pi\varepsilon_0}{\lambda}$

Solution:

$$\lambda = \frac{q}{l}$$

$$\therefore \quad q = \lambda \times l = \lambda \times \pi r$$

$\therefore$ The electric field at its centre is,

$$E = \frac{q}{4\pi\varepsilon_0 r^2} = \frac{\lambda\pi r}{4\pi\varepsilon_0 r^2}$$

$$\therefore \quad E = \frac{\lambda}{4\varepsilon_0 r}$$

Question85

A conducting sphere of radius 0.1 m has uniform charge density $1.8\mu C/m^2$ on its surface. The electric field in free space at radial distance 0.2 m from a point on the surface is ($\varepsilon_0 =$ permittivity of free space)

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Options:

A. $\frac{6\times10^{-6}}{\varepsilon_0} Vm^{-1}$

B. $\frac{6\times10^{-8}}{\varepsilon_0} Vm^{-1}$

C. $\frac{2\times10^{-7}}{\varepsilon_0} Vm^{-1}$

D. $\frac{1\times10^{-7}}{\varepsilon_0} Vm^{-1}$

Answer: C

Solution:

To find the electric field at a distance of 0.2 m from the surface of the conducting sphere, we can use Gauss's Law. For a spherical charge distribution, the electric field at an external point is the same as if all the charge were concentrated at the center of the sphere.

First, we calculate the total charge Q on the sphere. The charge density σ is the charge per unit area, so multiplying it by the surface area A gives us the total charge Q.

The surface area of a sphere is given by:

$A = 4\pi r^2$

Where r is the radius of the sphere. Plugging in the given radius of 0.1 m,

$A = 4\pi(0.1 \text{ m})^2 = 0.04\pi \text{ m}^2$

The charge density σ is given as $1.8\mu C/m^2$, which is $1.8 \times 10^{-6} C/m^2$. Now compute the total charge Q:

$Q = \sigma \cdot A = (1.8 \times 10^{-6} C/m^2)(0.04\pi \text{ m}^2)$

$Q = (1.8 \times 10^{-6}) \cdot (0.04\pi)\text{C} = 7.2 \times 10^{-8}\pi\text{C}$

Gauss's Law states that the electric field E multiplied by the surface area of an imaginary sphere A' that encloses the charge is equal to the total charge Q enclosed divided by the permittivity ε_0:

$E \cdot A' = \frac{Q}{\varepsilon_0}$

For a radial distance of 0.2 m from the surface, the actual radial distance from the center of the sphere will be the sum of the sphere's radius (0.1 m) and the distance from the surface (0.2 m), giving us:

$R = 0.1\,\text{m} + 0.2\,\text{m} = 0.3\,\text{m}$

The area of the Gaussian surface A' is now:

$A' = 4\pi(0.3\,\text{m})^2 = 0.36\pi\,\text{m}^2$

Plugging the values back into the equation we have:

$E = \frac{7.2 \times 10^{-8}\pi\ \text{C}}{\varepsilon_0 \cdot 0.36\pi\ \text{m}^2}$

$E = \frac{7.2 \times 10^{-8}}{0.36\varepsilon_0}$

$E = \frac{7.2}{0.36} \times \frac{10^{-8}}{\varepsilon_0}$

$E = 20 \times \frac{10^{-8}}{\varepsilon_0}\text{Vm}^{-1}$

$E = 2 \times \frac{10^{-7}}{\varepsilon_0}\text{Vm}^{-1}$

Now, the value obtained is that the electric field E at a radial distance of 0.2 m from the sphere's surface is equal to:

$E = \frac{2 \times 10^{-7}}{\varepsilon_0}\text{Vm}^{-1}$

This matches Option C.

Question86

The work done in rotating a dipole placed parallel to the electric field through $180°$ is W. So, the work done in rotating it through $60°$ is
$\left(\cos 0° = 1, \cos 60° = \frac{1}{2}, \cos 180° = -1\right)$

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Options:

A. $4W$

B. 3 W

C. $W/2$

D. $W/4$

Answer: D

Solution:

∵ Work done in rotating dipole by θ angle from equilibrium,

$W = pE[1 - \cos\theta]$ ..... (i)
$\Rightarrow \quad W = pE\,[1 - \cos 180°]$
$\Rightarrow \quad W = pE[1 + 1] = 2pE$
or $\quad pE = \dfrac{W}{2}$ ..... (ii)
and $\quad W' = pE\,(1 - \cos 60°]$
$\Rightarrow \quad W' = pE\left[1 - \dfrac{1}{2}\right] = \dfrac{pE}{2}$
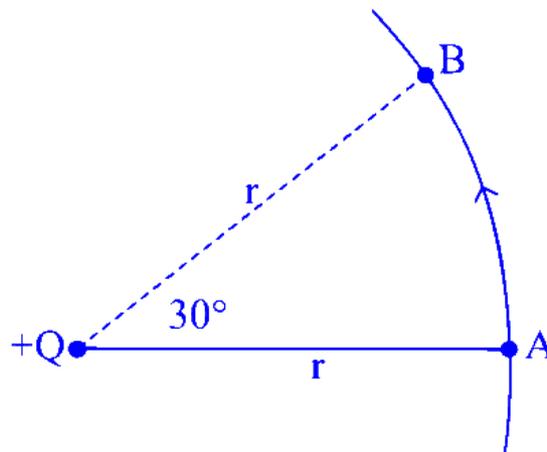$\Rightarrow \quad W' = \dfrac{pE}{2}$ ..... (iii)

From Eq. (ii) put the value of pE in Eq. (iii), we get

$\Rightarrow \quad W' = \frac{W}{2\times 2} = \frac{W}{4} \Rightarrow W' = \frac{W}{4}$

Question87

In the electric field due to a charge Q, a charge q moves from point A to B. The work done is ($\varepsilon_0 = $ permittivity of vacuum)

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Options:

A. $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Qq}{r^2}$

B. $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Qq}{r} \times \dfrac{\pi}{6}$

C. $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Qq}{r}$

D. Zero

Answer: D

Solution:

The electric field due to a single charge has point symmetry, or single charged forms spherical equipotential surface.

The work done in moving a charge on this spherical surface is always zero.

Question88

Which of the following statements is 'WRONG' for the conductors?

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Options:

A. In static situation, the interior of conductor can have no charge.

B. The net electrostatic field is zero in the interior of a conductor.

C. The electrostatic field just outside the surface of charged conductor must be tangential to the surface at any point.

D. The electrostatic potential is constant within and on the surface of a conductor.

Answer: C

Solution:

The electric field just outside the surface of the conductor is perpendicular to the surface which is a property of conductors in electrostatic equilibrium.

Question89

A charged spherical conductor of radius 'R' is connected momentarily to another uncharged spherical conductor of radius 'r' by means of a thin conducting wire, then the ratio of the surface charge density of the first to the second conductor is

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Options:

A. $R : r^2$

B. $R : r$

C. $r : R$

D. $1 : 1$

Solution:

$V_1 = V_2$ ($\because$ both the conductors have the same potential as they are connected)

$\Rightarrow \dfrac{q_1}{R} = \dfrac{q_2}{r}$

$\sigma = \dfrac{q}{4\pi R^2}$

$\therefore$ The ratio of their charge densities is:

$\Rightarrow \dfrac{\sigma_1}{\sigma_2} = \dfrac{\frac{q_1}{R^2}}{\frac{q_2}{r^2}}$

$\therefore \quad \dfrac{\sigma_1}{\sigma_2} = \dfrac{r}{R}$

Question90

If the magnitude of intensity of electric field at a distance 'r_1' on an axial line and at a distance 'r_2' on an equatorial line due to a given short dipole are equal, then $r_1 : r_2$, is

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Options:

A. $\sqrt[3]{2} : 1$

B. $\sqrt{2} : 1$

C. $1 : 2$

D. $1 : \sqrt[3]{2}$

Solution:

$$E_{\text{axial}} = E_{\text{equatorial}} \quad \Rightarrow k\frac{2p}{r_1^3} = \frac{kp}{r_2^3}$$

$$\Rightarrow \frac{r_1}{r_2} = \frac{2^{1/3}}{1} = \sqrt[3]{2} : 1$$

Question91

Three charges each of value $+q$ are placed at the corners of an isosceles triangle ABC of sides AB and AC each equal to 2a. The mid points of AB and AC are D and E respectively. The work done in taking a charge Q from D to E is ($\varepsilon_0 = $ permittivity of free space)

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Options:

A. Zero

B. $\frac{3qQ}{4\pi\varepsilon_0 a}$

C. $\frac{qQ}{8\pi\varepsilon_0 a}$

D. $\frac{3qQ}{8\pi\varepsilon_0 a}$

Answer: A

Solution:

Given $AB = AC = 2a$

$V_D = V_E$ ($\because$ D and E are mid-points)

$\therefore$ The work done in taking a charge q from D to E is

$W = q\Delta V = q(V_D - V_E)$

$\therefore \quad W = 0$ (Equipotential surfaces)

Question92

Select the correct statement from the following.

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Options:

A. Gravitational force is stronger than electrostatic force

B. Gravitational as well as electrostatic force always attractive.

C. Gravitational as well as electrostatic force always act along the line joining the two objects.

D. Inverse square law $\left(\text{F} \propto \frac{1}{\text{r}^2}\right)$ is not obeyed by electrostatic force.

Answer: C

Solution:

The correct option is:

Option C: Gravitational as well as electrostatic force always act along the line joining the two objects.

Explanation:

Option A is incorrect because gravitational force is actually much weaker than the electrostatic force. The gravitational force between two particles is given by Newton's law of gravitation:

$$F_{\text{gravity}} = G\frac{m_1 m_2}{r^2}$$

where G is the gravitational constant, m_1 and m_2 are the masses of the particles, and r is the distance between their centers. On the other hand, the electrostatic force is given by Coulomb's law:

$$F_{\text{electrostatic}} = k\frac{|q_1 q_2|}{r^2}$$

where k is Coulomb's constant, and q_1 and q_2 are the electric charges of the particles. The electrostatic force is much stronger than the gravitational force because the gravitational constant G is a much smaller number than Coulomb's constant k.

Option B is incorrect because the electrostatic force can be either attractive or repulsive, depending on whether the charges are opposite (attractive) or like charges (repulsive). However, the gravitational force is always attractive, as it always acts to pull masses together.

Option C is correct. Both gravitational and electrostatic forces act along the straight line joining the centers of the two masses or charges, respectively. This line is known as the line of action for these forces.

Option D is incorrect because the electrostatic force does indeed obey an inverse square law, just like the gravitational force. Both forces diminish in strength with the square of the distance between the two objects, as is reflected in the equations for both forces (Newton's law of gravitation and Coulomb's law).

Question93

Two point charges '$q1$' and '$q2$' are separated by a distance 'd'. What is the increase in potential energy of the system when '$q2$' is moved towards '$q1$' by a distance 'x' ? $(x < d)(\frac{1}{4\pi\varepsilon_0} = K$, constant)

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Options:

A. $-\dfrac{Kq_1q_2x}{d(d-x)}$

B. $-\dfrac{Kq_1q_2}{d(d-x)}$

C. $\dfrac{Kq_1q_{2x}}{\left(d^2-x^2\right)}$

D. $\dfrac{Kq_1q_2x}{(d^2-x^2)}$

Solution:

The potential energy between two charges is given as $U = \dfrac{kq_1q_2}{r}$

Initial potential energy is $U_f = \dfrac{kq_1q_2}{r}$

When charge q_2 moves towards the q_1 the separation between the charges becomes $d - x$

The final potential energy is $U_f = \dfrac{kq_1q_2}{(d-x)}$

The increase in potential energy is

$\therefore \quad \Delta U = U_f - U_f$

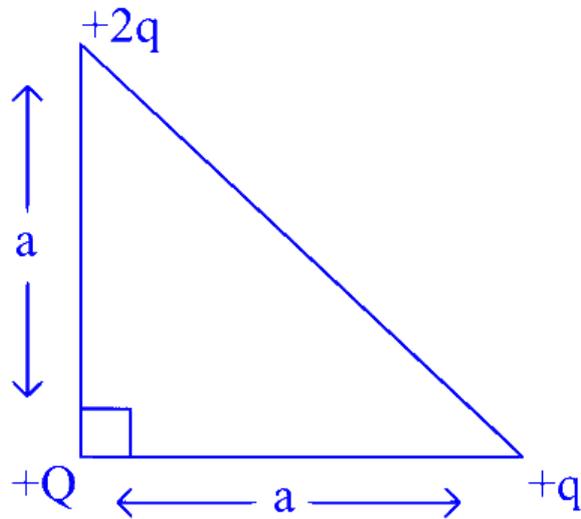$\therefore \quad \Delta U = \dfrac{kq_1q_2}{d} - \dfrac{k_1q_2}{(d-x)}$

$\therefore \quad \Delta U = kq_1q_2\left(\dfrac{1}{d} - \dfrac{1}{d-x}\right)$

$\therefore \quad \Delta U = \dfrac{-kq_1q_2x}{d(d-x)}$

Question94

Three point charges $+Q$, $+2q$ and $+q$ are placed at the vertices of a right angled isosceles triangle. The net electrostatic potential energy of the configuration is zero, if Q is equal to

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Options:

A. $-\dfrac{\sqrt{2}}{3}q$

B. $+\dfrac{\sqrt{2}}{3}q$

C. $-\dfrac{3}{\sqrt{2}}q$

D. $+\dfrac{3}{\sqrt{2}}q$

Answer: A

Solution:

Net electrostatic potential energy of the system is,

$$U = \frac{1}{4\pi\varepsilon_0}\left(\frac{Qq}{a} + \frac{2Qq}{a} + \frac{2qq}{\sqrt{2}a}\right) = 0$$

$$Q + 2Q + \frac{2q}{\sqrt{2}} = 0$$

$$3Q + \sqrt{2}q = 0$$

$$\therefore \quad Q = \frac{-\sqrt{2}q}{3}$$

Question95

Two electric dipoles of moment P **and** 27P **are placed on a line with their centres** 24 cm **apart. Their dipole moments are in opposite direction. At which**

point the electric field will be zero between the dipoles from the centre of dipole of moment P?
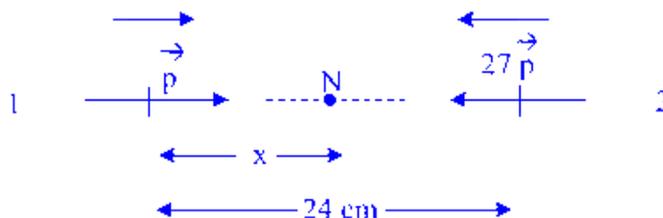
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Options:

A. 6 cm

B. 8 cm

C. 10 cm

D. 12 cm

Answer: A

Solution:

Dipole of moment p is at a distance x from N

At N,|E. F. due to dipole 1| = |E. F. due to dipole 2|

$$\therefore \quad \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{x^3} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2(27p)}{(24-x)^3}$$

$$\therefore \quad \frac{1}{x^3} = \frac{27}{(24-x)^3} \Rightarrow x = 6 \text{ cm.}$$

Question96

An electron of mass 'm' and charge 'q' is accelerated from rest in a uniform electric field of strength 'E'. The velocity acquired by the electron, when it travels a distance 'L', is

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Options:

A. $\sqrt{\dfrac{2q\ m}{mL}}$

B. $\sqrt{\dfrac{2qEL}{m}}$

C. $\sqrt{\dfrac{2Em}{qL}}$

D. $\sqrt{\dfrac{qE}{mL}}$

Answer: B

Solution:

We know

$F = ma$ and $F = qE$

$qE = ma$

$\therefore \quad \dfrac{qE}{m} = a$

According to equation of motion,

$v^2 - u^2 = 2aL$

$v^2 - 0^2 = 2aL$

$v^2 = 2aL$

$v = \sqrt{2aL}$

$\therefore \quad v = \sqrt{\dfrac{2qEL}{m}}$

Question97

Two positively charged identical spheres separated by a distance 'd' exert some force (F) on each other when they are kept in air. If both the spheres are immersed in a liquid of dielectric constant 5 , the force experienced by each is (All other parameters are unchanged.)

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Options:

A. 5 F

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

C. $\frac{F}{4}$

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

Answer: D

Solution:

The ratio of force when the medium is changed will be:

$\frac{F_1}{F_2} = \frac{1}{k}$

Here, $k = 5$,

Therefore, the force experience by each will be $\frac{F}{5}$.

Question98

Two charges of equal magnitude 'q' are placed in air at a distance '$2r$' apart and third charge '$-2q$' is placed at mid point. The potential energy of the system is ($\varepsilon_0 =$ permittivity of free space)

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Options:

A. $-\frac{q^2}{8\pi\varepsilon_0 r}$

B. $-\frac{3q^2}{8\pi\varepsilon_0 r}$

C. $-\frac{5q^2}{8\pi\varepsilon_0 r}$

D. $-\frac{7q^2}{8\pi\varepsilon_0 r}$

Answer: D

Solution:

Potential energy of 'n' point charges,

$U = \frac{1}{4\pi\varepsilon_0} \sum_{\text{all pairs}} \frac{q_j q_k}{r_{jk}}$

For 3 point charges,

$$\therefore \quad U = -\frac{q(2q)}{4\pi\varepsilon_0 r} - \frac{q(2q)}{4\pi\varepsilon_0 r} + \frac{q(q)}{4\pi\varepsilon_0(2r)}$$

$$U = -\frac{2q^2}{4\pi\varepsilon_0 r} - \frac{2q^2}{4\pi\varepsilon_0 r} + \frac{q^2}{4\pi\varepsilon_0(2r)}$$

$$U = -\frac{4q^2}{8\pi\varepsilon_0 r} - \frac{4q^2}{8\pi\varepsilon_0 r} + \frac{q^2}{8\pi\varepsilon_0 r}$$

$$U = -\frac{7q^2}{8\pi\varepsilon_0 r}$$

Question99

An electron moving with velocity 1.6×10^7 m/s has wavelength of $0.4\overset{o}{A}$. The required accelerating voltage for the electron motion is [charge on electron $= 1.6 \times 10^{-19}$ C, mass of electron $= 9 \times 10^{-31}$ kg]

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Options:

A. 7.2×10^3 V

B. 7.2×10^2 V

C. 7.2 V

D. 7.2×10^{-2} V

Answer: B

Solution:

When an electron is accelerated through a voltage its kinetic energy is converted into electric potential energy:

$$K = U$$
$$\frac{1}{2}mv^2 = eV$$
$$\therefore \quad V = \frac{mv^2}{2e}$$
$$V = \frac{\left(9 \times 10^{-31}\right)\left(1.6 \times 10^7\right)^2}{2 \times 1.6 \times 10^{-19}} = 7.2 \times 10^2 \text{ V}$$

Question100

Three point charges $+q, +2q$ and $+Q$ are placed at the three vertices of an equilateral triangle. If the potential energy of the system of three charges is zero, the value of Q in terms of q is

Options:

A. $Q = -\frac{2q}{3}$

B. $Q = -\frac{1}{3}q$

C. $Q = \frac{3q}{2}$

D. $Q = \frac{q}{2}$

Answer: A

Solution:

Potential energy due to +q and +2q,

$U_1 = \frac{K_q(2q)}{r}$

∴   Potential energy due to +q and +Q,

$U_2 = \frac{KqQ}{r}$

∴   Potential energy due to $+Q$ and $+2q$,

$U_3 = \frac{KQ(2q)}{r}$

Given: Potential energy of system $= 0$

∴ $U_1 + U_2 + U_3 = 0$
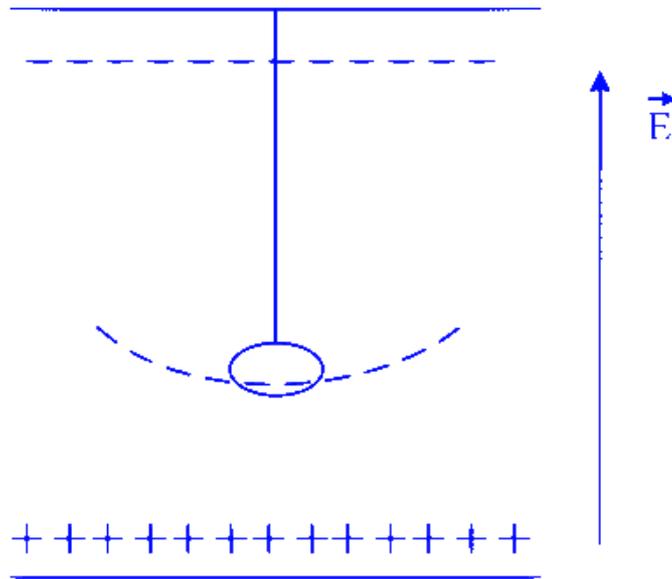$$\frac{Kq(2q)}{r} + \frac{KqQ}{r} + \frac{KQ(2q)}{r} = 0$$
$2q + Q + 2Q = 0$
$3Q = -2q$
$Q = \frac{-2}{3}q$

Question101

The bob of a simple pendulum of length 'L' has a mass 'm' and charge 'q'. The pendulum is suspended between the plates of a charged parallel plate capacitor. The direction of electric field is shown in figure. The period of oscillations of the simple pendulum is (acceleration due to gravity $g > qE/m$)

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Options:

A. $2\pi\sqrt{\dfrac{L}{g}}$

B. $2\pi\left[\dfrac{L}{\frac{qE}{m}-g}\right]^{\frac{1}{2}}$

C. $2\pi\left[\dfrac{L}{g-\frac{qE}{m}}\right]^{\frac{1}{2}}$

D. $2\pi\left[\dfrac{L}{g+\frac{qE}{m}}\right]^{\frac{1}{2}}$

Answer: C

Solution:

Electric force, $F_{\text{electric}} = qE$

The effective force,

$mg_{\text{eff}} = mg - F_{\text{electric}}$

$g_{\text{eff}} = g - \dfrac{qE}{m}$

The period of oscillation for a simple pendulum,

$T = 2\pi\sqrt{\dfrac{L}{g}}$

Time period when pendulum is suspended between the plates,

$$T = 2\pi\sqrt{\frac{L}{g_{\text{eff}}}}$$

$$T = 2\pi\left[\frac{L}{g - \frac{qE}{m}}\right]^{\frac{1}{2}}$$

Question102

Assume that an electric field $E = 30x^2\hat{i}$ exists in space. If 'V_0' is the potential at the origin and 'V_A' is the potential at $x = 2$ m, then the potential difference $(V_A - V_0)$ is

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Options:

A. -80 J

B. -120 J

C. 80 J

D. 120 J

Answer: A

Solution:

$dV = \vec{E} \cdot dx$

$\int_{V_0}^{V_A} dV = -\int_0^2 30x^2 dx$

$V_A - V_0 = -\left[10x^3\right]_0^2 = -80J$

Question103

An electric dipole consisting of two opposite charges of 2×10^{-6}C separated by a distance of 3 cm placed in an electric field of 2×10^5 N/C then the maximum torque acting on dipole is

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Options:

A. 12×10^{-1} N − m

B. 24×10^{-3} N − m

C. 12×10^{-3} N − m

D. 24×10^{-1} N − m

Answer: C

Solution:

Dipole moment $p = q \times 2l = 2 \times 10^{-6} \times 3 \times 10^{-2}$
$$= 6 \times 10^{-8} \mathrm{Cm}$$
$$\therefore \quad \tau_{\max} = \rho E \sin \theta = pE \sin 90°$$
$$= 6 \times 10^{-8} \times 2 \times 10^5 \times 1$$
$$= 12 \times 10^{-3} \mathrm{Nm}$$

Question104

When a charge of 3 C is placed in uniform electric field, it experiences a force of 3000 N. Within this field, potential difference between two points separated by a distance of 1 cm is

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Options:

A. 10 V

B. 90 V

C. 1000 V

D. 3000 V

Answer: A

Solution:

Electric force, $F = qE$ and potential difference, $V = Ed$

$$\therefore \quad V = \frac{Fd}{q} = \frac{3000 \times 10^{-2}}{3} = 10 \text{ V}$$

[Note: Framing of question is modified to arrive at the correct answer.]

Question105

The charges $2q, -q, -q$ are located at the vertices of an equilateral triangle. At the circumcentre of the triangle

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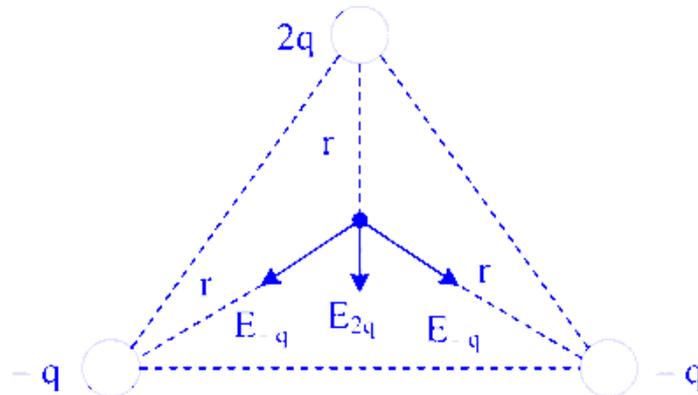
Options:

A. the field is zero but potential is not zero.

B. the field is non-zero but the potential is zero.

C. both, field and potential are zero.

D. both. field and potential are non-zero.

Answer: B

Solution:

From charge configuration, at the centre electric field is non-zero.

Potential at the centre due to $2q$ charge $V_{2q} = \frac{2q}{r}$ and potential due to $-q$ charge

$V_{-q} = -\frac{q}{r}$ ($r =$ distance of centre point)

$\therefore$ total potential $V = V_{2q} + V_{-q} + V_{-q} = 0$

Question106

A solid metallic sphere has a charge $+3Q$. Concentric with this sphere is a conducting spherical shell having charge $-Q$. The radius of the sphere is 'A' and that of the spherical shell is 'B'. $(B > A)$. The electric field at a distance ' R' $(A < R < B)$ from the centre is ($\varepsilon_0 =$ permittivity of vacuum)

Options:

A. $\dfrac{Q}{2\pi\varepsilon_0 R}$

B. $\dfrac{3Q}{2\pi\varepsilon_0 R}$

C. $\dfrac{3Q}{4\pi\varepsilon_0 R^2}$

D. $\dfrac{4Q}{2\pi\varepsilon_0 R^2}$

Answer: C

Solution:

We know the electric field inside a shell is zero. So, we only consider the electric field due to the solid sphere.

$\therefore$ Using $E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r^2}$, we get

$E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{(3Q)}{R^2}$

Question107

If the radius of the spherical gaussian surface is increased then the electric flux due to a point charge enclosed by the surface

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Options:

A. increases

B. remains unchanged

C. decreases

D. zero

Answer: B

Solution:

If the radius of the spherical Gaussian surface is increased, then the electric flux due to a point charge enclosed by the surface remains constant.

Flux depends only on the enclosed charge. It does not depend upon the size or shape of the Gaussian surface.

Question108

Three equal charges 'q_1', ''q_2' and 'q_3' are placed on the three corners of a square of side 'a'. If the force between q_1 and q_2 is 'F_{12}' and that between q_1 and q_3 is 'F_{13}', then the ratio of magnitudes $\left(\dfrac{F_{12}}{F_{13}} \right)$ is
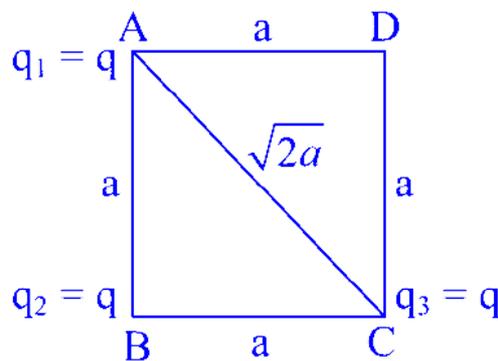
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Options:

A. $\frac{1}{2}$

B. $\sqrt{2}$

C. $\frac{1}{\sqrt{2}}$

D. 2

Answer: D

Solution:

Three equal charges are kept at the corners A, B, C of a square ABCD.

$\therefore$ The force between q_1 and q_2 is F_{12}

and $F_{12} = \dfrac{1}{4\pi\varepsilon_0} \dfrac{q \times q}{a^2} = \dfrac{1}{4\pi\varepsilon_0} \dfrac{q^2}{a^2}$

and the force between q_1 and q_3 at A and C is

$F_{13} = \dfrac{1}{4\pi\varepsilon_0} \dfrac{q^2}{2a^2}$

$\therefore \dfrac{F_{12}}{F_{13}} = \dfrac{q^2}{a^2} \times \dfrac{2a^2}{q^2} = 2$ (in magnitude)

Question109

Three charges each of $+1\mu C$ are placed at the corners of an equilateral triangle. If the repulsive force between any two charges is F, then the net force on either charge will be [$\cos 60° = 0.5$]

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Options:

A. 2F

B. 3F

C. $\sqrt{2}$ F

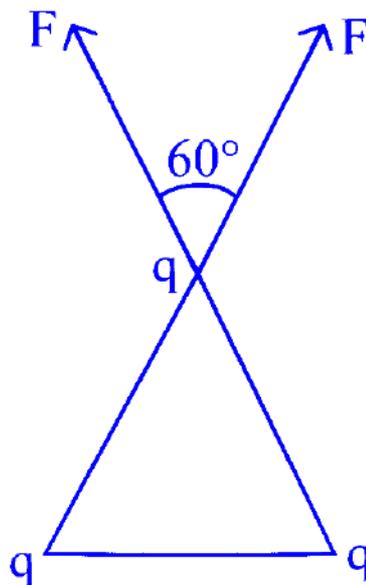D. $\sqrt{3}$ F

Answer: D

Solution:

The force on any charge due to each of the other two charges has magnitude F.

The angle between the two forces is $60°$.

Hence the resultant force is given by

$R = \sqrt{F^2 + F^2 + 2F^2 \cos 60°} = \sqrt{3}F$

Question110

Four electric charges $+q, +q, -q$ and $-q$ are placed in order at the corners of a square of side $2\,\mathrm{L}$. The electric potential at point midway between the two positive charges is

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Options:

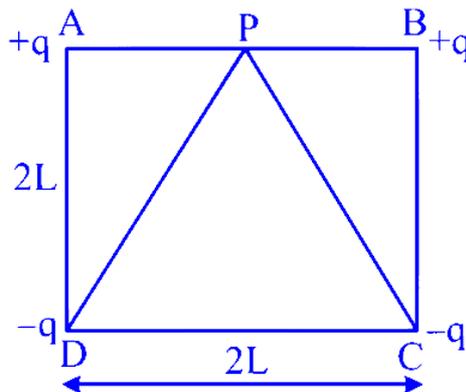A. $\frac{1}{4\pi\epsilon_0}\frac{2q}{L}\left(1-\sqrt{5}\right)$

B. zero

C. $\frac{1}{4\pi\epsilon_0}\frac{2q}{L}\left(1+\frac{1}{\sqrt{5}}\right)$

D. $\frac{1}{4\pi\epsilon_0}\frac{2q}{L}\left(1-\frac{1}{\sqrt{5}}\right)$

Answer: D

Solution:

$$DP^2 = (2\,\mathrm{L})^2 + L^2 = 4\,\mathrm{L}^2 + L^2 = 5\,\mathrm{L}^2$$
$$\therefore \quad DP = \sqrt{5}\,L = CP$$
$$AP = BP = L$$

$\therefore$ Potential at point P due to the four charges

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{L} + \frac{q}{L} - \frac{q}{\sqrt{5}\,L} - \frac{q}{\sqrt{5}\,L}\right)$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{2q}{L} - \frac{2q}{\sqrt{5}\,L}\right)$$

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q}{L}\left(1 - \frac{1}{\sqrt{5}}\right)$$

Question111

The electric field intensity on the surface of a charged solid sphere of radius 'r' and volume charge dentiy 'ρ' is given by (ϵ_0 = permittivity of free space)

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Options:

A. zero

B. $\frac{\sigma\pi}{3\epsilon_0}$

C. $\frac{1}{4\pi\epsilon_0}\frac{\sigma}{r}$

D. $\frac{5\pi}{6\epsilon_0}$

Answer: B

Solution:

The electric field intensity on the surface is given by

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} \quad \text{.... (1)}$$
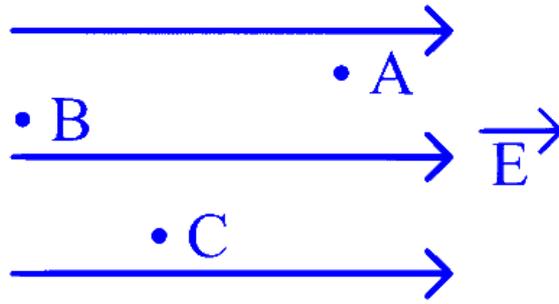
But $q = \frac{4}{3}\pi r^3\rho$

Putting this value of q in Eq.(1) and simplifying we get

$E = \frac{\rho r}{3\varepsilon_0}$

Question112

Let A, B and C be the three points in a uniform electric field $(\overrightarrow{E})$ as shown. The electric potential is

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Options:

A. maximum at point C

B. maximum at point A

C. maximum at point B

D. same at all points A, B and C

Answer: C

Solution:

The electric potential decreases in the direction of the field. Hence field is maximum at B.

Question113

Two positive ions, each carrying a charge 'q' are separated by a distance 'd'. If 'F' is the force of repulsion between the ions, the number of electrons from each ion will be (ε = charge on ε_k = permittivity of free space)

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Options:

A. $\sqrt{\dfrac{4\pi\varepsilon_0 \, \mathrm{d}^2}{e^2}}$

B. $\sqrt{\dfrac{4\pi\varepsilon_0 \mathrm{Fd}}{e^2}}$

C. $\sqrt{\frac{4\pi\varepsilon_0 Fd^2}{e}}$

D. $\sqrt{\frac{4\pi\varepsilon_0 Fd^2}{e^2}}$

Answer: D

Solution:

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{d^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(ne)^2}{d^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{n^2 e^2}{d^2}$$

$$\therefore n = \sqrt{\frac{4\pi\varepsilon_0 Fd^2}{e^2}}$$

Question114

Three charges $-q, Q$ and $-q$ are placed at equal distances on a straight line. If the total potential energy of the system of three charges is zero then the ratio $\frac{Q}{q}$ is
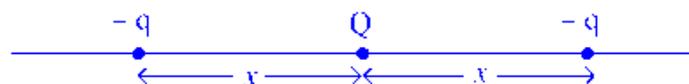
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Options:

A. 1 : 2

B. 1 : 1

C. 1 : 4

D. 1 : 3

Answer: C

Solution:

Potential energy of the system is zero.

$$\therefore \frac{1}{4\pi\varepsilon_0}\left(\frac{-q\cdot Q}{x} + \frac{-q\cdot Q+}{x} + \frac{(-q)(-q)}{2x}\right) = 0$$

$$\therefore -2qQ + \frac{q^2}{2} = 0$$

or $-2Q + \frac{q^2}{2x} = 0 \quad \therefore 2Q = \frac{q}{2}$ or $\frac{Q}{q} = \frac{1}{4}$

Question115

Two point charges $+3\mu C$ and $+8\mu C$ repel each other with a force of 40 N. If a charge of $-5\mu C$ is added to each of them, then force between them will become

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Options:

A. -10 N

B. 10 N

C. 20 N

D. -20 N

Answer: A

Solution:

Redistribution of charges takes place.

Charge $q_1 = 3\mu C$ and Charge $q_2 = 8\mu C$

When third charge $q_3 = -5\mu C$ is added to each, then new charges on q_1 and q_2 will be

$q_1 = 3 - 5 = -2\mu C$

and $\quad q_2 = 8 - 5 = 3\mu C$

Now,

Case I $\quad 40 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{3\times 8}{r^2}$

Case II $\quad F = \frac{1}{4\pi\varepsilon_0} \times \frac{(-2\times 3)}{r^2}$

$$\therefore \frac{F}{40} = \frac{-2 \times 3}{3 \times 8} \Rightarrow F = -10N$$

Question116

In hydrogen atom an electron revolves around a proton (in nucleus) at a distance 'r' m. the intensity of electric field due to the proton at distance 'r' is $5 \times 10^{11} \mathrm{NC}^{-1}$, the magnitude of force between the electron and proton is [charge on electron $= 1.6 \times 10^{-19}$C]

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Options:

A. 4×10^8 N

B. 8×10^8 N

C. 4×10^{-8} N

D. 8×10^{-8} N

Answer: D

Solution:

To find the magnitude of the force between the electron and proton, we can use the relationship between the electric field and the force on a charge. The force **F** on a charge **q** in an electric field **E** is given by:

$\mathbf{F} = q\mathbf{E}$

Here, the electric field intensity due to the proton at distance r is given as:

$E = 5 \times 10^{11} \mathrm{NC}^{-1}$

The charge on the electron is:

$q = 1.6 \times 10^{-19}$C

Substituting these values into the equation for the force:

$\mathbf{F} = (1.6 \times 10^{-19}\mathrm{C}) \times (5 \times 10^{11}\mathrm{NC}^{-1})$

$\mathbf{F} = 8 \times 10^{-8}\mathrm{N}$

Therefore, the magnitude of the force between the electron and proton is:

Option D: $8 \times 10^{-8}\mathrm{N}$

Question117

Two charged metallic spheres are joined by a very thin metal wire. If the radius of the larger sphere is four times that of the smaller sphere, the electric field near the larger sphere is

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Options:

A. twice that near the smaller sphere

B. quarter of that near the smaller sphere

C. same as that near the smaller sphere

D. half of that near smaller sphere

Answer: B

Solution:

When two charged metallic spheres are joined by a very thin metal wire, they come to the same electric potential because the wire itself is a conductor and will ensure that the potential difference between the two spheres becomes zero. Let's denote the radii of the smaller and larger spheres as R_s and R_L, respectively. According to the problem, the radius of the larger sphere is four times that of the smaller sphere:

$$R_L = 4R_s$$

When the spheres reach electrostatic equilibrium, they share the same electric potential. The electric potential V on the surface of a sphere is given by:

$$V = \frac{q}{4\pi\epsilon_0 R}$$

where q is the charge on the sphere, ϵ_0 is the permittivity of free space, and R is the radius of the sphere.

Let the charges on the smaller and larger spheres be q_s and q_L. Since the spheres are at the same potential, we have:

$$\frac{q_s}{4\pi\epsilon_0 R_s} = \frac{q_L}{4\pi\epsilon_0 R_L}$$

Eliminating the constants and solving for the charges, we get:

$$\frac{q_s}{R_s} = \frac{q_L}{R_L}$$

Since $R_L = 4R_s$, we can substitute and rearrange to find:

$$q_L = 4q_s$$

Now, the electric field E near the surface of a sphere is given by:

$$E = \frac{q}{4\pi\epsilon_0 R^2}$$

For the smaller sphere, the electric field near its surface is:

$$E_s = \frac{q_s}{4\pi\epsilon_0 R_s^2}$$

For the larger sphere, substituting $q_L = 4q_s$ and $R_L = 4R_s$ into the electric field equation gives:

$$E_L = \frac{4q_s}{4\pi\epsilon_0 (4R_s)^2}$$

Simplifying, we get:

$$E_L = \frac{4q_s}{4\pi\epsilon_0 \cdot 16R_s^2} = \frac{q_s}{16\pi\epsilon_0 R_s^2}$$

$$E_L = \frac{E_s}{4}$$

Therefore, the electric field near the larger sphere is a quarter of that near the smaller sphere.

The correct answer is:

Option B: Quarter of that near the smaller sphere

Question118

A charged spherical conductor has radius 'r'. The potential difference between its surface and 3 point at a distance '$3r$' from the centre is 'v' The electric intensity at a distance '$3r$' from the centre of the conductor is

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Options:

A. $\frac{v}{8r}$

B. $\frac{v}{2r}$

C. $\frac{v}{4r}$

D. $\frac{v}{6r}$

Answer: D

Solution:

To determine the electric intensity at a distance $3r$ from the center of the charged spherical conductor, we first need to understand the relationship between potential difference and electric field.

The potential due to a charged spherical conductor at a distance r from its center is given by:

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

where Q is the charge on the conductor and ϵ_0 is the permittivity of free space.

The potential at the surface of the conductor (radius r) is:

$$V_1 = \frac{Q}{4\pi\epsilon_0 r}$$

The potential at a distance $3r$ from the center is:

$$V_2 = \frac{Q}{4\pi\epsilon_0 \cdot 3r} = \frac{Q}{12\pi\epsilon_0 r}$$

The potential difference between the surface and the point at a distance $3r$ (given as v) is:

$$v = V_1 - V_2 = \frac{Q}{4\pi\epsilon_0 r} - \frac{Q}{12\pi\epsilon_0 r}$$

Simplifying the difference, we get:

$$v = \frac{Q}{4\pi\epsilon_0 r}\left(1 - \frac{1}{3}\right) = \frac{Q}{4\pi\epsilon_0 r} \cdot \frac{2}{3} = \frac{Q}{6\pi\epsilon_0 r}$$

The electric field intensity at a distance $3r$ from the center is given by:

$$E = \frac{Q}{4\pi\epsilon_0 \cdot (3r)^2} = \frac{Q}{36\pi\epsilon_0 r^2}$$

From the potential difference equation, we can express Q in terms of v and substitute it back:

$$Q = \frac{6\pi\epsilon_0 r v}{1}$$

Thus, the electric field intensity at a distance $3r$ is:

$$E = \frac{\frac{6\pi\epsilon_0 r v}{1}}{36\pi\epsilon_0 r^2} = \frac{6v}{36r} = \frac{v}{6r}$$

Hence, the electric intensity at a distance $3r$ from the center of the conductor is:

Option D: $\frac{v}{6r}$

Question119

Two spherical conductors of radii 4 cm and 5 cm are charged to the same potential. If 'σ_1' and 'σ_2' be the respective values of the surface density of charge on the two conductors then the ratio $\sigma_1 : \sigma_2$ is

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Options:

A. $5 : 4$

B. $3 : 2$

C. $4 : 3$

D. $2 : 1$

Answer: A

Solution:

When two spherical conductors are charged to the same potential, the relationship between the potential (V), surface charge density (σ), and radius (R) of the conductor can be utilized to find the ratio of the surface charge densities σ_1 and σ_2. The electric potential on the surface of a charged spherical conductor is given by:

$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{R}$$

Where:

- V is the potential,
- Q is the total charge,
- R is the radius of the sphere,
- ϵ_0 is the permittivity of free space.

The surface charge density (σ) is defined as the charge per unit area, so:

$$\sigma = \frac{Q}{4\pi R^2}$$

Combining these expressions, we can express the potential in terms of the surface charge density as follows:

$$V = \frac{\sigma R}{\epsilon_0}$$

Given that the two spheres are charged to the same potential ($V_1 = V_2 = V$), and the radii are $R_1 = 4\,\text{cm}$ and $R_2 = 5\,\text{cm}$, we can set up the equality:

$$\frac{\sigma_1 R_1}{\epsilon_0} = \frac{\sigma_2 R_2}{\epsilon_0}$$

Upon simplifying, ϵ_0 cancels out on both sides, allowing us to solve for the ratio of σ_1 to σ_2 directly:

$$\sigma_1 R_1 = \sigma_2 R_2$$

Thus,

$$\frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

Plugging in the given radii values:

$$\frac{\sigma_1}{\sigma_2} = \frac{5}{4}$$

This corresponds to the ratio of surface charge densities:

$$\sigma_1 : \sigma_2 = 5 : 4$$

Therefore, the correct answer is:

Option A 5 : 4

Question120

An electron of mass 'm' and charge 'q' is accelerated from rest in a uniform electric field of strength 'E'. The velocity acquired by the electron when it travels a distance 'L' is

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Options:

A. $\sqrt{\dfrac{2qE}{mL}}$

B. $\sqrt{\dfrac{2Em}{qL}}$

C. $\sqrt{\dfrac{2qEL}{m}}$

D. $\times\sqrt{\dfrac{qE}{mL}}$

Answer: C

Solution:

The correct option for the velocity acquired by an electron when it travels a distance 'L' in a uniform electric field of strength 'E' is found by considering the work done by the electric field on the electron and equating it to the kinetic energy gained by the electron.

The work done by the electric field on the electron is given by the product of the force (F) exerted by the electric field on the electron, and the distance (L) over which this force acts. The force exerted by the electric field on a charge is given by $F = qE$, where q is the charge of the electron, and E is the strength of the electric field. Therefore, the work done (W) by the electric field can be expressed as:

$W = F \cdot L = qEL$

According to the principle of conservation of energy, the work done by the electric field is converted into kinetic energy (K) of the electron. The kinetic energy of an object with mass m and velocity v is given by $K = \frac{1}{2}mv^2$. Therefore, we equate the work done to the kinetic energy to find the velocity:

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

Solving this equation for v to find the velocity of the electron after traversing the distance L yields:

$v = \sqrt{\dfrac{2qEL}{m}}$

Hence, the correct answer is

Option C: $\sqrt{\dfrac{2qEL}{m}}$

Question121

Two particles A and B having same mass have charge $+q$ and $+4q$ respectively. When they are allowed to fall from rest through same electric potential difference, the ratio of their speeds 'V_A' to 'V_B' will become

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Options:

A. $1 : 2$

B. 2 : 1

C. 1 : 4

D. 4 : 1

Answer: A

Solution:

To find the ratio of the speeds V_A to V$_B$ of two particles A and B after falling through the same electric potential difference, we should consider the work done by the electric field on each particle due to the potential difference. This work done will convert into kinetic energy for each particle assuming they start from rest.

The work done on a charge by an electric potential difference V is given by the formula:

$W = qV$

where

- W is the work done or energy gained,
- q is the charge of the particle, and
- V is the electric potential difference.

Since the initial kinetic energy of both particles is zero (as they are initially at rest), the entire work done on each will convert into its kinetic energy. The kinetic energy (K) of a particle is given by:

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

where

- m is the mass of the particle, and
- v is its speed.

Thus, for particle A with charge $+q$,

$qV = \frac{1}{2}mV_A^2$

And for particle B with charge $+4q$,

$4qV = \frac{1}{2}mV_B^2$

Now, to find the ratio of their speeds, V_A to V_B, we can set up a ratio using the above equations. Dividing the equation for particle A by the equation for particle B,

$\frac{qV}{4qV} = \frac{\frac{1}{2}mV_A^2}{\frac{1}{2}mV_B^2}$

Simplifying the equation gives,

$\frac{1}{4} = \frac{V_A^2}{V_B^2}$

Taking the square root of both sides,

$\frac{V_A}{V_B} = \frac{1}{2}$

This means the ratio of their speeds $V_A : V_B$ is 1 : 2.

Therefore, the correct answer is:

Option A: 1 : 2.

Question122

A point charge Q is placed at the centre of the line joining two equal point charges $+q$ and $+q$. The value of Q if the system of the charges is in equilibrium, is

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Options:

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

B. $-\frac{9}{4}$
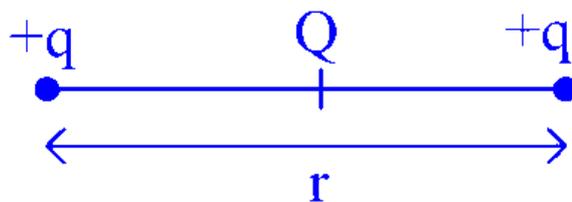
C. $\frac{+q}{4}$

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

Answer: B

Solution:

The forces on charge Q due to the other two charges will be equal and opposite and hence it will be in equilibrium.

Force on +q due to the other two charges should also be equal and opposite. Their magnitudes will be equal if

$$\frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{qQ}{\left(\frac{r}{2}\right)^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{4qQ}{r^2}$$

$$\therefore q = 4Q \quad \text{or } Q = \frac{q}{4}$$

$\therefore q = 4Q$

or $Q = \frac{q}{4}$

Q and q should have opposite signs so that the two forces are opposite in direction.

$\therefore Q = -\frac{q}{4}$

Question123

When a piece of polythene is rubbed with wool, a negative charge of 4×10^{-7}C is developed on the polythene. The number of electrons transferred from wool to polythene is $[e = 1.6 \times 10^{-19}$C$]$

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Options:

A. 1.5×10^{12}

B. 3.5×10^{13}

C. 2.5×10^{13}

D. 2.5×10^{12}

Answer: D

Solution:

$q = 4 \times 10^{-7}$

$q = Ne$

$N = \frac{q}{e} = \frac{4 \times 10^{-7}}{1.6 \times 10^{-19}} = 2.5 \times 10^{12}$

Question124

A hollow metal sphere has a radius 'r'. The potential difference between a point on its surface and at a point at a distance '3r' from its centre is 'V'. The electric intensity at the distance '3r' from the centre of the sphere will be :

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Options:

A. $\frac{V}{3r}$

B. $3Vr$

C. $\frac{V}{r}$

D. $\frac{V}{6r}$

Answer: D

Solution:

Given a hollow metal sphere with a radius r, if it is charged, the electric field E outside the sphere behaves just as if all the charge were concentrated at the center.

From the properties of spherical conductors, the potential V at a distance r from the center due to a point charge Q is given by :

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

where k is Coulomb's constant.

Now, let the potential at the surface of the sphere be V_1 and the potential at a distance $3r$ be V_2.

Given :

$$V_2 - V_1 = V$$

$$\frac{kQ}{3r} - \frac{kQ}{r} = V$$

$$\frac{kQ(1-3)}{3r} = V$$

$$\frac{-2kQ}{3r} = V$$

$$Q = \frac{-3rV}{2k} \text{ ... (i)}$$

The electric field E at a distance $3r$ from the center of the sphere is given by:

$$E = \frac{kQ}{(3r)^2}$$

Using equation (i),

$$E = \frac{k \times (-3rV/2k)}{(3r)^2}$$

$$E = \frac{-3rV}{2 \times 9r^2}$$

$$E = \frac{-V}{6r}$$

Question125

'F' is the force between the two identical charged particles placed at a distance 'Y' from each other. If the distance between the charges is reduced to half the previous distance then force between them becomes

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Options:

A. $\frac{F}{4}$

B. 4 F

C. 2 F

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

Answer: B

Solution:

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2}$$
$$\therefore \quad \frac{F_2}{F_1} = \left(\frac{r_1}{r_2}\right)^2 = (2)^2 = 4$$
$$\therefore \quad F_2 = 4 F_1$$

Question126

A uniformly charged semicircular arc of radius 'r' has linear charge density (λ), is the electric field at its centre? ($\in_0=$ permittivity of free space)

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Options:

A. $\frac{\lambda}{4\epsilon_0 r}$

B. $\frac{2\pi\epsilon_0}{\lambda}$

C. $\frac{\lambda}{4\epsilon_0}$
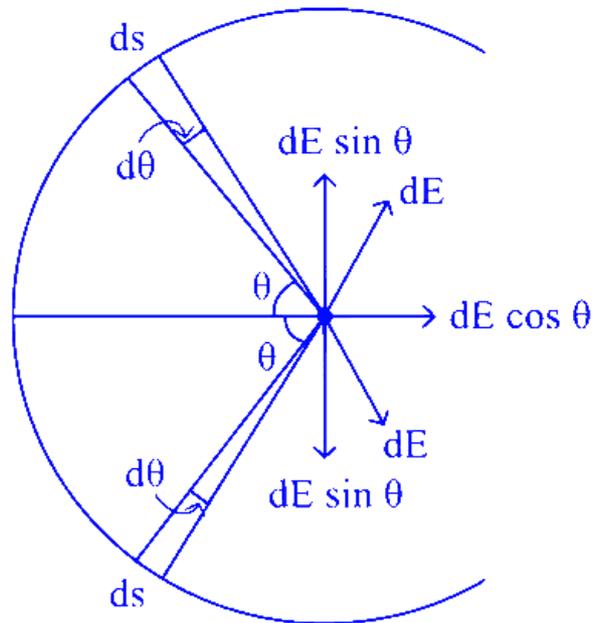
D. $\frac{2\epsilon_0}{\lambda}$

Answer: A

Solution:

The electric field at the centre due to a small element ds of the ring is given by

$$dE = \frac{1}{4\pi\epsilon_0}\frac{\lambda ds}{r^2}$$

The field can be resolved along X and Y directions as shown in the figure.Similarly field due to symmetrically situated another element can also be resolved along X and Y directions. The X-components are in the same direction and get added while the Y-components are in opposite directions and cancel each other. Hence, the total field due to the range is

$$\text{E} = \int dE \cos\theta$$
$$\therefore \text{E} = \int \frac{1}{4\pi\epsilon_0} \frac{\lambda ds}{r^2} \cos\theta$$
$$= \int \frac{1}{4\pi\epsilon_0} \frac{\lambda d\theta \cos\theta}{r^2} \quad = \frac{1}{4\pi\epsilon_0} \frac{\lambda}{r} \int_{-\pi/2}^{\pi/2} \cos\theta d\theta$$
$$= \frac{1}{4\pi\epsilon_0} \frac{\lambda}{r} [\sin\theta]_{0\pi/2}^{\pi/2} = \frac{1}{4\pi\epsilon_0} \frac{\lambda}{r} [1 - (-1)]$$
$$= \frac{1}{4\pi\epsilon_0} \frac{\lambda}{r} 2 \quad = \frac{\lambda}{2\pi\epsilon_0 r}$$

Question127

A hollow charged metal sphere has radius 'R'. If the potential difference between its surface and a point at a distance '5 R' from the centre is V, then magnitude of electric field Intensity at a distance '5R' from the centre of sphere is

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Options:

A. $\frac{V}{2R}$

B. $\frac{V}{20R}$

C. 10VR

D. 20VR

Answer: B

Solution:

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{R} - \frac{1}{4\pi\epsilon_0}\frac{q}{5R}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{q}{R}\left(1 - \frac{1}{5}\right)$$

$$= \frac{1}{4\pi\epsilon_0}\frac{q}{R}\frac{4}{5}$$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{25R^2}$$

$$\therefore \frac{E}{V} = \frac{1}{20R} \text{ or } E = \frac{V}{20R}$$

Question128

An electric dipole having dipole moment $P = q \times 2\ell$ is placed in a uniform electric field 'E'. The dipole moment is along the direction of the field. The force acting on it and its potential energy are respectively

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Options:

A. qE and minimum

B. qE and maximum

C. 2qE and minimum

D. zero and minimum

Answer: D

Solution:

A dipole has two equal and opposite charges. In a uniform electric field, the two charges will experience equal and opposite force, hence net force will be zero.

The potential energy of an electric dipole is given by

$$U = -pE\cos\theta$$

where θ is the angle between the dipole moment and the electric field. The potential energy will be minimum when $\cos\theta$ is maximum.

For $\theta = 0°$, $\cos\theta$ has maximum value equal to 1.

$\therefore U = -pE$ when $\theta = 0°$.

Question129

A uniformly charged half ring of a radius ' R ' has linear charge density 'σ'. The electric potential at the centre of the half ring is ($\epsilon_0 = $ permittivity of free space)

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Options:

A. $\frac{\sigma}{6\epsilon_0}$

B. $\frac{\sigma}{2\epsilon_0}$

C. $\frac{\sigma}{\epsilon_0}$

D. $\frac{\sigma}{4\epsilon_0}$

Answer: D

Solution:

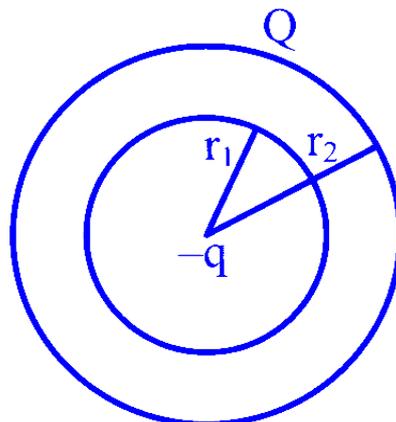If q is the charge on the ring, then the potential at the centre is given by

$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{R}$

But $q = \sigma \times \pi R$

$\therefore V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\rho\pi R}{R} = \frac{\sigma}{4\varepsilon_0}$

Question130

A spherical conducting shell of inner radius 'r_1' and outer radius 'r_2' has a charge 'Q'. A charge $-q$ is placed at the centre of the shell. The surface charge density on the inner and outer surface of the shell will be

Options:

A. $\frac{q}{4\pi r_1^2}$ and $\frac{Q-q}{4\pi r_2^2}$

B. $\frac{q}{4\pi r_1^2}$ and $\frac{Q}{4\pi r_2^2}$

C. $\frac{-q}{4\pi r_1^2}$ and $\frac{Q+q}{4\pi r_2^2}$

D. zero and $\frac{Q-q}{4\pi r_2^2}$

Answer: A

Solution:

Due to charge $-q$ at the centre of the shell, a charge q will be induced on the inner surface and $-q$ on the outer surface. The charge on outer surface will become $Q - q$. Hence, surface change densities will be $\frac{q}{4\pi r_1^2}$ and $\frac{Q-q}{4\pi r_2^2}$

Question131

A charge of magnitude '2e' and mass '4m' is moving in an electric field $\overrightarrow{E}$. The acceleration imparted to the above charge is

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Options:

A. $\frac{2m}{3Ee}$

B. $\frac{Ee}{2m}$

C. $\frac{2Ee}{3m}$

D. $\frac{3m}{2Ee}$

Answer: B

Solution:

Force, F = Charge × Electric field = 2eE

Acceleration $= \frac{\text{Force}}{\text{Mass}} = \frac{2eE}{4m} = \frac{eE}{2m}$

Question132

Van de Graaff generator produces

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Options:

A. high voltage and high current

B. high voltage and low current

C. low voltage and low current

D. low voltage and high current

Answer: B

Solution:

The Van de Graaff generator is specifically designed to produce a very high voltage while only providing a very low current. Here's a brief explanation of why:

The generator uses a moving belt to transport electrical charge to a large, hollow metal sphere.

This accumulation of charge creates a high electric potential (voltage) on the sphere.

However, due to its design, the amount of current (the flow of charge per unit time) is very limited.

So, the correct answer is:

Option B: high voltage and low current.

Question133

A spherical rubber balloon carries a charge, uniformly distributed over the surface. As the balloon is blown up and increases in size, the total electric flux coming out of the surface

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Options:

A. increases

B. remains unchanged

C. becomes zero

D. decreases

Answer: B

Solution:

A spherical rubber balloon carries a charge uniformly distributed over its surface. As the balloon is inflated and its size increases, the total electric flux emanating from the surface does not change.

The electric field intensity due to a point charge placed at the center of a sphere with radius r is given by:

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

As the balloon expands, the charge enclosed by the Gaussian surface doesn't change. Therefore, the electric field intensity E remains the same. The electric flux ϕ is defined by the relationship:

$\phi = E \cdot dS$

Since the electric field E remains constant, the electric flux ϕ remains unchanged.

Question134

Surface density of charge on a charged conducting sphere of radius R in terms of electric field intensity E at a distance r in free space is ($r > R, \varepsilon_0 =$ permittivity of free space)

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Options:

A. $\varepsilon_0 E \left(\frac{R}{r}\right)^2$

B. $\varepsilon_0 E \frac{R}{r}$

C. $\varepsilon_0 E \left(\frac{r}{R} \right)^2$

D. $\varepsilon_0 E \frac{r}{R}$

Answer: C

Solution:

The electric field intensity at a distance r from the conducting sphere is

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

The surface charge density of sphere is

$\sigma = \frac{Q}{4\pi R^2}$ ..... (ii)

Dividing Eqs. (ii) by (i), we get

$\frac{\sigma}{E} = \frac{Q}{4\pi R^2} \times \frac{4\pi\varepsilon_0 r^2}{Q} = \varepsilon_0 \left(\frac{r}{R} \right)^2$

or $\sigma = \varepsilon_0 E \left(\frac{r}{R} \right)^2$

Question135

In case of dimensions of electric field and electric dipole moment the power of mass is reswpectively,

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Options:

A. 1, 1

B. 1, 0

C. 0, 1

D. 0, 0

Answer: B

Solution:

To determine the dimensions of the electric field and the electric dipole moment concerning the power of mass, let's analyze each one:

Electric Field:

The expression for the electric field E is given by:

$E = \frac{F}{q}$

Where F is the force and q is the electric charge.

The dimensions of force F are:

$[F] = [\mathrm{MLT}^{-2}]$

The dimensions of charge q are:

$[q] = [AT]$

Therefore, the dimensions of the electric field E are:

$[E] = \frac{[\mathrm{MLT}^{-2}]}{[AT]} = [\mathrm{MLT}^{-3}\mathrm{A}^{-1}]$

This shows that the power of mass in the dimensions of the electric field is 1.

Electric Dipole Moment:

The electric dipole moment m is defined as $m = 1 \times A$, where I is the current and A is the area.

The dimensions are given by:

$[m] = [AL^2] = [M^0 L^2 T^0 A]$

This indicates that the power of mass in the dimensions of the electric dipole moment is 0.

In summary, for the electric field, the power of mass is 1, and for the electric dipole moment, it is 0.

Question136

A charged conductor produces an electric field of intensity 10^3 V/m just outside its surface in vacuum. Then, it produces the electric field of intensity E just outside its surface, when it is placed in a medium of dielectric constant 4. The value of E will be

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Options:

A. 400 V/m

B. 450 V/m

C. 250 V/m

D. 150 V/m

Answer: C

Solution:

Given that a charged conductor produces an electric field intensity of 10^3 V/m just outside its surface in a vacuum, we need to determine the electric field E when the conductor is placed in a medium with a dielectric constant of 4.

The electric field in a medium with a dielectric constant K is given by:

$E = \frac{E_0}{K}$

Substituting the given values:

$E = \frac{10^3}{4} = 250 \, \text{V/m}$

Thus, the electric field intensity just outside the surface of the conductor when placed in the medium is $250 \, \text{V/m}$.

Question137

Which of the following is the dimensional formula for electric polarisation?

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Options:

A. $\left[M^P L^{-2} T^1 I^1\right]$

B. $\left[M^{-1} L^{-2} T^1 I^{-1}\right]$

C. $\left[M^P L^{-1} T^{-1} I^1\right]$

D. $\left[M^1 L^{-2} T^1 I^1\right]$

Answer: A

Solution:

Electric polarisation (P) is given by

$P = \varepsilon_0 \chi E$

where, E is electric field and χ is electric susceptibility and it is dimensionless quantity,

Dimensional formula of $P =$ Dimensional formula of $(\varepsilon_0) \times$ Dimensional formula of E

$= \left[M^{-1} L^{-3} T^4 I^2\right] \left[MLT^{-3} I^{-1}\right] = \left[M^0 L^{-2} T^1 I^1\right]$
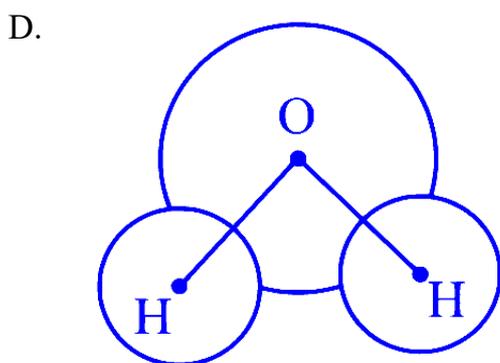

Question138

Which of the following molecules is a polar molecule?

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Options:

A.

B.

C.

D.
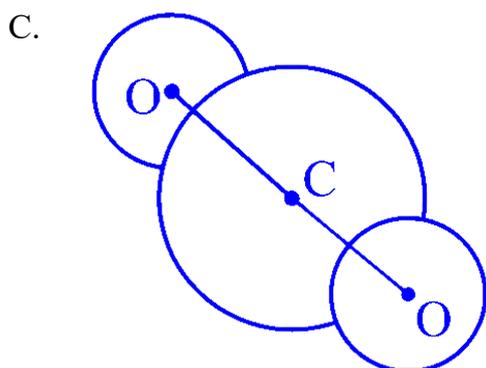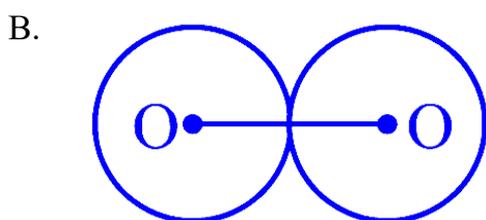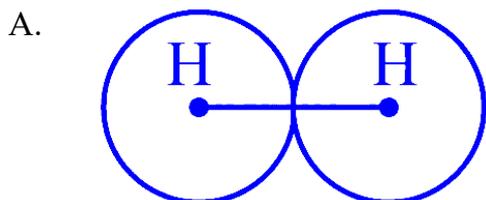
Answer: D

Solution:

A polar molecule is a molecule containing polar bonds, where the sum of all the bonds dipole moment is not zero. In case of H_2O, the bonds are inclined at an angle, so the net dipole moment is non-zero. Hence, H_2O is a polar molecule while in all other cases the dipole moment are balanced, so the net moment is zero.