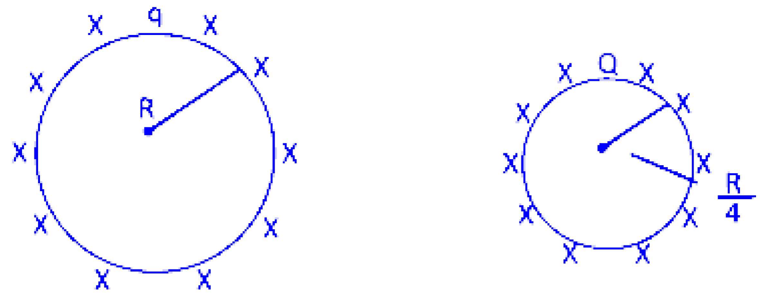
Electrostatics

Question1

A metallic sphere of radius R carrying a charge q is kept at certain distance from another metallic sphere of radius $\mathrm{R}/4$ carrying a charge Q . What is the electric flux at any point inside the metallic sphere of radius R due to the sphere of radius $\mathrm{R}/4$?



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Options:

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

B. Zero

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

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

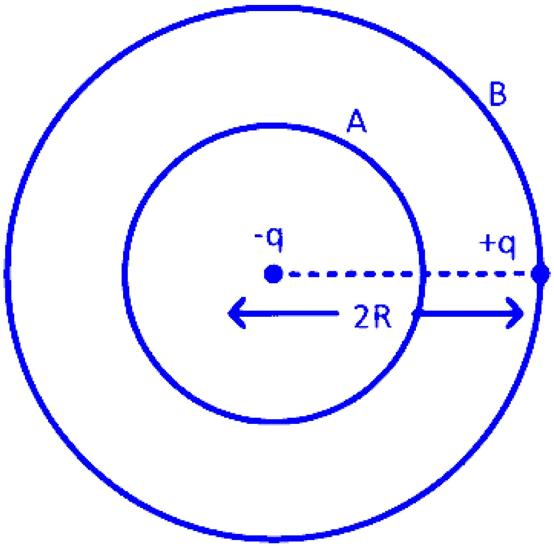
Answer: B

Solution:

Since spheres are electrostatically shielded from each other, $\phi=0$.

Question2

You are given a dipole of charge $+q$ and $-q$ separated by a distance $2R$. A sphere ' A ' of radius ' R ' passes through the centre of the dipole as shown below and another sphere ' B ' of radius ' $2R$ ' passes through the charge +q . Then the electric flux through the sphere A is



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Options:

A. q$/\varepsilon_0$

B. Zero

C. $2q/\varepsilon_0$

D. $-q/\varepsilon_0$

Answer: D

Solution:

To determine the electric flux through sphere 'A', we can apply Gauss's Law, which states that the electric flux ϕ through a closed surface is equal to the charge Q_{enc} enclosed by that surface divided by the permittivity of free space ε_0.

For sphere 'A', which passes through the center of the dipole, the enclosed charge is only the negative charge $-q$, since the positive charge $+q$ lies outside of sphere 'A'.

Thus, the electric flux through sphere 'A' is calculated as:

$\phi_{\text{sphere}} \quad A = \frac{-q}{\varepsilon_0}$

This result indicates that sphere 'A' encloses a net negative charge, contributing to a negative flux value.

Question3

A potential at a point A is -3 V and that at another point B is 5 V . What is the work done in carrying a charge of 5 m C from B to A ?

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Options:

A. -0.04 J

B. -0.4 J

C. -4 J

D. -40 J

Answer: A

Solution:

To determine the work done in moving a charge from point B to point A, we use the formula:

$W_{\text{ext}} = q\Delta V$

Where:

q is the charge being moved, given as $5\,\text{mC}$ or $5 \times 10^{-3}\,\text{C}$.

ΔV is the change in electric potential between the two points: $V_f - V_i$.

Given:

Potential at point A, $V_A = -3\text{ V}$

Potential at point B, $V_B = 5\text{ V}$

Substitute these values into the formula:

$\mathrm{W}_{\text{ext}} = 5 \times 10^{-3}(V_A - V_B)$

$= 5 \times 10^{-3}(-3 - 5)$

$= 5 \times 10^{-3} \times (-8)$

$= -40 \times 10^{-3}\text{ J}$

$= -0.04\text{ J}$

Thus, the work done in carrying the charge from point B to point A is -0.04 J.

Question4

Charges are uniformly spread on the surface of a conducting sphere. The electric field from the centre of sphere to a point outside the sphere varies with distance r from the centre as

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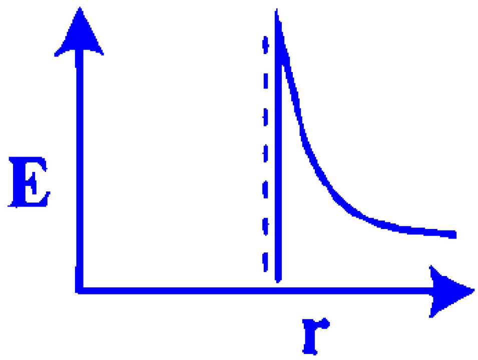
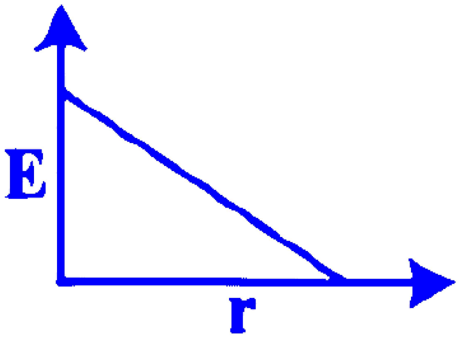
Options:

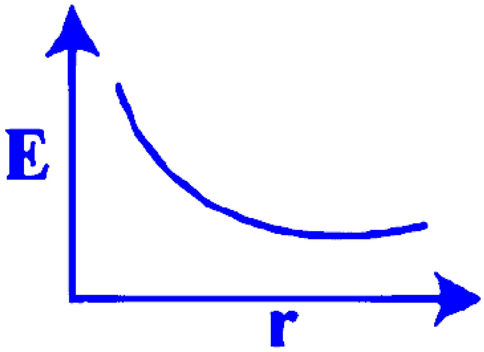
A.



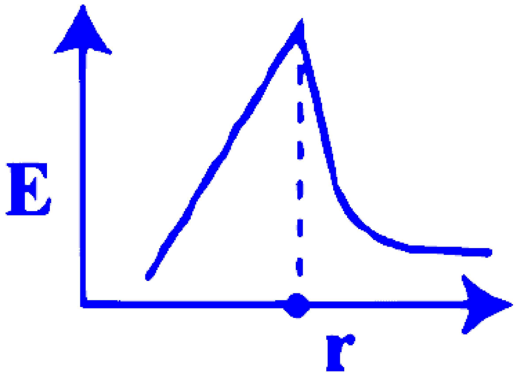
B.



C.



D.



Answer: A

Solution:

For a conducting sphere with uniform surface charge distribution:

Inside the sphere ($r < R$): The electric field $E = 0$. This is because the electric field within a conductor in electrostatic equilibrium is zero.

Outside the sphere ($r \geq R$): The electric field behaves like that of a point charge. It can be represented by the equation $E = \frac{kQ}{r^2}$, where k is Coulomb's constant, Q is the total charge on the sphere, and r is the distance from the center of the sphere.

Thus, the graph depicting the electric field as a function of distance r should show a flat line at $E = 0$ for $r < R$ and then a curve following the inverse square law $E = \frac{kQ}{r^2}$ for $r \geq R$.

Question5

Match Column-I with Column - II related to an electric dipole of dipole moment $\vec{p}$ that is placed in a uniform electric field $\vec{E}$.

Column - I Angle between $\vec{p}$ and $\vec{E}$	Column - II Potential energy of the dipole
a) 180° b) 120° c) 90°	i) -pE ii) pE iii) $\frac{1}{2}$pE iv) Zero

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Options:

A. $a - i, b - ii, c - iii$

B. a - ii, b - iii, c - i

C. $a - ii, b - i, c - iv$

D. a - ii, b - iii, c - iv

Answer: D

Solution:

The potential energy (PE) of an electric dipole in a uniform electric field is given by the formula:

$\text{PE} = -\vec{p} \cdot \vec{E} = -pE\cos\theta$

Let's evaluate the potential energy for different angles:

(a) $\theta = 180^\circ$**:**

$\text{PE} = -pE\cos 180^\circ = pE$

This corresponds to option (ii) in Column-II.

(b) $\theta = 120^\circ$**:**

$\text{PE} = -pE\cos 120^\circ = -pE\left(\frac{-1}{2}\right) = \frac{pE}{2}$

This corresponds to option (iii) in Column-II.

(c) $\theta = 90^\circ$**:**

$\text{PE} = -pE\cos 90^\circ = 0$

This corresponds to option (iv) in Column-II.

Thus, the correct matching is:

$a \rightarrow$ (ii)

$b \rightarrow$ (iii)

$c \rightarrow$ (iv)

Question6

Which of the following statements is not true?

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Options:

A. Work done to move a charge on an equipotential surface is not zero

B. Equipotential surfaces are the surfaces where the potential is constant

C. Equipotential surfaces for a uniform electric field are parallel and equidistant from each other

D. Electric field is always perpendicular to an equipotential surfaces.

Answer: A

Solution:

The false statement is Option A.

Reasoning:

By definition, on an equipotential surface the potential V is the same everywhere, so any two points have $\Delta V = 0$.

The work done in moving a charge q through a potential difference ΔV is

$W = q\,\Delta V = q \times 0 = 0.$

Hence it's incorrect to say the work is "not zero."

The other options are all true:

B: Equipotentials are surfaces of constant V.

C: In a uniform field, equipotentials are equally spaced parallel planes.

D: $\mathbf{E}$ is always perpendicular to equipotential surfaces.

Question7

Which of the following is a correct statement?

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Options:

A. Gauss's law is true for any open surface

B. Gauss's law is not applicable when charges are not symmetrically distributed over a closed surface.

C. Gauss's law does not hold good for a charge situated outside the Gaussian surface.

D. Gauss's law is true for any closed surface

Answer: D

Solution:

The only correct statement is Option D.

Reasoning:

Gauss's law in integral form reads

$\Phi_E = \oint_S \mathbf{E} \cdot d\mathbf{A} = \frac{Q_{\text{enclosed}}}{\varepsilon_0},$

where the surface integral is taken over a **closed** surface S.

It holds **for any** closed surface, regardless of its shape or how the enclosed charge is distributed.

Open surfaces (Option A) aren't allowed because the "enclosed" concept only makes sense for closed surfaces.

Symmetry is not required for the **validity** of Gauss's law—it only makes field calculations easier (so Option B is false).

Charges outside the surface contribute zero net flux, but Gauss's law itself still applies (so Option C is false).

Hence:

Option D is correct.

Question8

A body has a charge of $-3.2\mu\text{C}$. The number of excess electrons will be

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Options:

A. 5.12×10^{25}

B. 5×10^{12}

C. 2×10^{13}

D. 5.12×10^{13}

Answer: C

Solution:

Charge on body, $q = -3.2\mu\text{C} = -3.2 \times 10^{-6}\text{C}$

$\therefore$ Number of excess electrons,

$$n = \frac{q}{e} = \frac{-3.2 \times 10^{-6}}{-1.6 \times 10^{-19}}$$
$$= 2 \times 10^{13}$$

Question9

A point charge A of $+10 \mu \mathrm{C}$ and another point charge B of $+20 \mu \mathrm{C}$ are kept 1 m apart in free space. The electrostatic force on A due to B is F_1 and the electrostatic force on B due to A is $\mathbf{F}_2$. Then

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Options:

A. $\mathrm{F}_1=-2 \mathrm{~F}_2$

B. $\mathrm{F}_1=-\mathrm{F}_2$

C. $2 \mathrm{F}_1=-\mathrm{F}_2$

D. $\mathrm{F}_1=\mathrm{F}_2$

Answer: B

Solution:

Electrostatic force on each charges placed at certain distance is equal in magnitude but opposite in direction.

Question10

A uniform electric field $E=3 \times 10^5 \mathrm{NC}^{-1}$ is acting along the positive Y-axis. The electric flux through a rectangle of area $10 \mathrm{~cm} \times 30 \mathrm{~cm}$ whose plane is parallel to the ZX -plane is

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Options:

A. $12 \times 10^3 \mathrm{Vm}$

B. 9×10^3Vm

C. 15×10^3Vm

D. 18×10^3Vm

Answer: B

Solution:

Given, $\mathbf{E} = 3 \times 10^5 \hat{\mathbf{j}} \mathrm{NC}^{-1}$

$$A = 10 \text{ cm} \times 30 \text{ cm} = 3 \times 10^{-2} \text{ m}^2$$

$$\therefore \quad \mathbf{A} = 3 \times 10^{-2} \hat{\mathbf{j}} \text{ m}^2 \quad \text{(For ZX-plane)}$$

$$\therefore \text{ Electric flux, } \phi = \mathbf{E} \cdot \mathbf{A}$$

$$= 3 \times 10^5 \hat{\mathbf{j}} \times 3 \times 10^{-2} \hat{\mathbf{j}}$$

$$= 9 \times 10^3 \text{ V} - \text{m}$$

Question11

The total electric flux through a closed spherical surface of radius r enclosing an electric dipole of dipole moment $2aq$ is (Give $\varepsilon_0 =$ permittivity of free space)

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Options:

A. zero

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

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

D. $\frac{8\pi r^2 q}{\varepsilon_0}$

Answer: A

Solution:

The total electric flux through a closed surface is given by Gauss's Law, which states that:

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

Where Φ is the electric flux, Q_{enc} is the total charge enclosed by the surface, and ε_0 is the permittivity of free space.

In the case of an electric dipole, the dipole consists of two equal and opposite charges separated by some distance. Therefore, the net charge Q_{enc} enclosed by the spherical surface is zero, because the positive and negative charges cancel each other out.

Thus, the total electric flux through the closed spherical surface enclosing an electric dipole is:

$\Phi = \frac{0}{\varepsilon_0} = 0$

Therefore, the correct option is:

Option A: zero

Question12

Under electrostatic conditien of a charged conductor, which among the following statements is true?

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Options:

A. The electric field on the suriacie of a charged conductor is $\frac{\sigma}{2\varepsilon_0}$, where σ is the surface charge density.

B. The electric potential inside a charged conductor is always zero.

C. Any excess charge resides on the surface of the conductor.

D. The net electric filed is tangential to the surface of the conductor.

Answer: C

Solution:

Since, there is no electric field inside the conductor, hence according to Coulomb's law, the mutual repulsion of like charges demands that the charges be as for apart as possible. Hence, on the surface of the conductor, the net electric charge resides entirely on its surface. Electric field on the surface of a charged conductor is σ/ε_0. Electric potential inside a charged conductor is constant (non-zero). The net electric field lines is perpendicular to the surface of the conductor.

Question13

A cube of side 1 cm contains 100 molecules each having an induced dipole moment of $0.2 \times 10^{-6} \mathrm{C}-\mathrm{m}$ in an external electric field of $4 \mathrm{NC}^{-1}$. The electric susceptibility of the materials is .... $\mathrm{C}^2 \mathrm{N}^{-1} \mathrm{~m}^{-2}$

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Options:

A. 50

B. 5

C. 0.5

D. 0.05

Answer: B

Solution:

Induced dipole moment, $p=0.2 \times 10^{-5} \mathrm{C}$

Number of molecules, $n=100$ molecule/ cm^3

$$= 100 \times 10^6 \text { molecule } / \mathrm{m}^3$$
$$E = 4 \mathrm{~N} / \mathrm{C}$$

$\therefore$ Electric susceptibility,

$$\chi_e=\frac{p}{E} \times n=\frac{0.2 \times 10^{-6} \times 100 \times 10^6}{4}$$
$$=5 \mathrm{C}^2 \mathrm{~N}^{-1} \mathrm{~m}^{-2}$$

Question14

A positively charged glass rod is brought near uncharged metal sphere, which is mounted on an insulated stand. If the glass rod is

removed, the net charge on the metal sphere is

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Options:

A. negative charge

B. zero

C. 1.6×10^{-19}C

D. positive charge

Answer: B

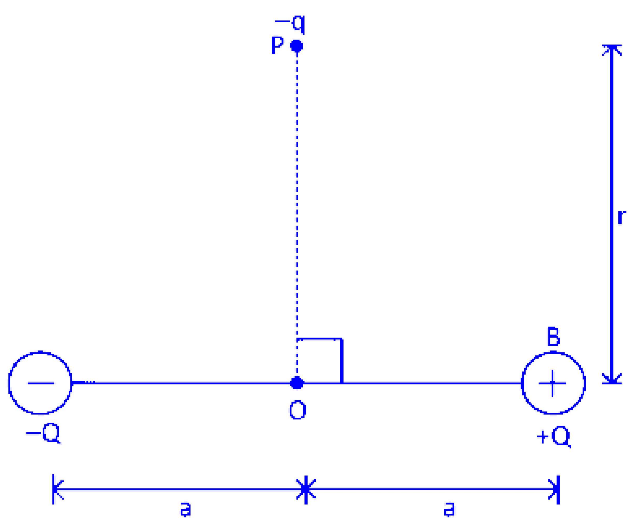
Solution:

If the metal sphere is connected to insulated mount, then net flow due to induction of charges is zero and hence even after, the net charge on the metal sphere will be zero.

Question15

In the situation shown in the diagram, magnitude, if $q << |Q|$ and $r >>> a$. The net force on the free charge $-q$ and net torque on it about O at the instant shown are respectively.

($p = 2aQ$ is the dipole moment)



Options:

A. $\frac{1}{4\pi\varepsilon_0}\frac{pq}{r^3}\hat{\mathbf{i}}, -\frac{1}{4\pi\varepsilon_0}\frac{pq}{r^2}\hat{\mathbf{k}}$

B. $\frac{1}{4\pi\varepsilon_0}\frac{pq}{r^2}\hat{\mathbf{k}}, \frac{1}{4\pi\varepsilon_0}\frac{pq}{r^3}\hat{\mathbf{i}}$

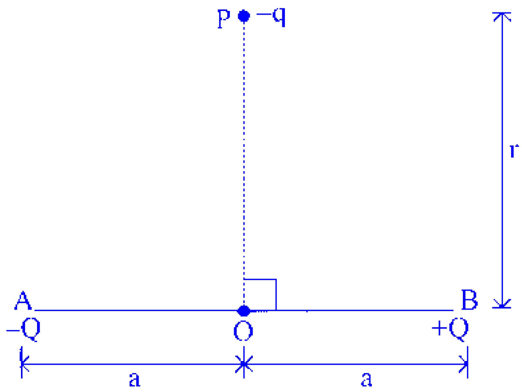
C. $-\frac{1}{4\pi\varepsilon_0}\frac{pq}{r^2}\hat{\mathbf{k}}, -\frac{1}{4\pi\varepsilon_0}\frac{pq}{r^3}\hat{\mathbf{i}}$

D. $\frac{1}{4\pi\varepsilon_0}\frac{pq}{r^3}\hat{\mathbf{i}}, +\frac{1}{4\pi\varepsilon_0}\frac{pq}{r^2}\hat{\mathbf{k}}$

Answer: D

Solution:

Net force due to dipole on equatorial line, $F_{eq} = E.q$



$= \frac{K\mathbf{p}}{r^3}\hat{\mathbf{i}}q = \frac{1}{4\pi\varepsilon_0}\frac{pq}{r^3}\hat{\mathbf{i}}$

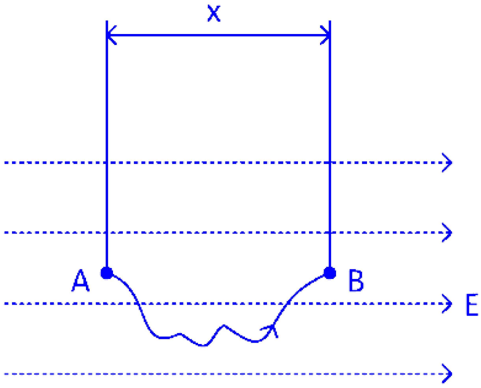
Net torque; $\tau = F \times r_{\perp}$

$= \frac{1}{4}\pi\frac{pq}{r^3}\hat{\mathbf{i}} \times r(\hat{\mathbf{j}}) = \frac{1}{4\pi\varepsilon_0}\frac{pq}{r^2}\hat{\mathbf{k}}$

Hence, option (d) is correct.

Question16

A uniform electric field vector E exists along horizontal direction as shown. The electric potential at A is V_A. A small point charge q is slowly taken from A to B along the curved path as shown. The potential energy of the charge when it is at point B is



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Options:

A. $q[V_A - Ex]$

B. $q[V_A + Ex]$

C. $q[Ex - V_A]$

D. qEx

Answer: A

Solution:

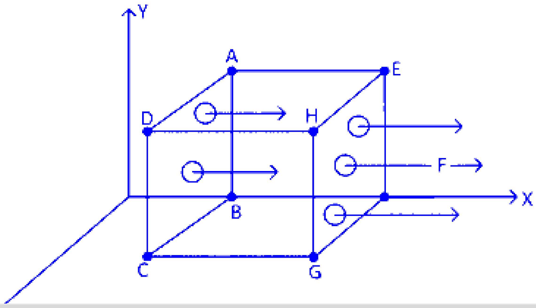
Potential energy at B = Potential difference $\times$ Charge + Energy spent by moving charge from A to B

$= V_A \times q - q \cdot E \cdot x = q(V_A - Ex)$

Question17

A cubical Gaussian surface has side of length $a = 10$ cm. Electric field lines are parallel to X-axis as shown in figure. The magnitudes of electric fields through surfaces $ABCD$ and $EFGH$ are $6\ \mathrm{kNC}^{-1}$ and $9\ \mathrm{kNC}^{-1}$ respectively. Then, the total charge enclosed by the cube is

[Take, $\varepsilon_0 = 9 \times 10^{-12}\ \mathrm{Fm}^{-1}$]



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Options:

A. -0.27 nC

B. 1.35 nC

C. -1.35 nC

D. 0.27 nC

Answer: D

Solution:

Total flux $\phi_E = E \cdot ds$

$$
\begin{aligned}
&= 9\text{k} - 6\text{k} \times \left(10^{-2} \times 10\right)^2 \\
&= 3 \times 10^3 \times 10^{-2} = 30\ \text{NC}^{-1}\ \text{m}^2
\end{aligned}
$$

According to Gauss' law, $\frac{q}{\varepsilon_0} = \phi_E$

$$
\begin{aligned}
\Rightarrow q_{\text{enclosed}} \quad &= 3 \times \varepsilon_0 \\
&= 30 \times 9 \times 10^{-12}\text{C} = 270 \times 10^{-9} \times 10^{-3} \\
&= 0.27 \times 10^{-9}\text{C} = 0.27\ \text{nC}
\end{aligned}
$$

Question18

Electric field at a distance r from an infinitely long uniformly charged straight conductor, having linear charge density λ is E_1. Another uniformly charged conductor having same linear charge density λ is bent into a semicircle of radius r. The electric field at its centre is E_2. Then

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Options:

A. $E_2 = \pi r E_1$

B. $E_2 = \frac{E_1}{r}$

C. $E_1 = E_2$

D. $E_1 = \pi r E_2$

Answer: C

Solution:

Electric field due to infinitely charged long wire, $E_1 = \frac{2k\lambda}{r}$.

Electric field at the centre of semicircular ring,

$E_2 = \frac{2k\lambda}{r}$

Therefore, $E_1 = E_2$

Question19

A tiny spherical oil drop carrying a net charge q is balanced in still air, with a vertical uniform electric field of strength $\frac{81}{7}\pi \times 10^5$ V/m. When the field is switched OFF, the drop is observed to fall with terminal velocity 2×10^{-3} ms^{-1}. Here $g = 9.8$ m/s^2, viscosity of air is 1.8×10^{-5}Ns/m^2 and density of oil is 900 kg m^{-3}. The magnitude of q is

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Options:

A. 8×10^{-19}C

B. 1.6×10^{-19}C

C. 3.2×10^{-19}C

D. 0.8×10^{-19}C

Answer: A

Solution:

Given, $E=\frac{81\pi}{7}\times 10^5\ \mathrm{V/m}$

Terminal velocity , $v=2\times 10^{-3}\ \mathrm{m/s}$

$g=9.8\ \mathrm{m/s^2}$

Viscosity, $\eta=1.8\times 10^{-5}\ \mathrm{N-s/m^2}$

Density, $\rho=900\ \mathrm{kg/m^3}$

Since, $qE=mg$ ..... (i)

In the absence of electric field,

$$mg=6\pi\eta rv$$
$$\Rightarrow\quad qE=6\pi\eta rv \text{ [from Eq. (i)]}$$
$$\Rightarrow\quad r=\frac{qE}{6\pi\eta v}\quad \text{.... (ii)}$$

From Eq. (i), we get

$m=\frac{qE}{g}$

$$\Rightarrow \frac{4}{3}\pi r^3 d=\frac{qE}{g}\Rightarrow \frac{4}{3}\pi\left(\frac{qE}{6\pi\eta v}\right)^3 d=\frac{qE}{g}$$
$$\Rightarrow\quad q=\sqrt{\frac{3\times 6^3\pi^2\eta^3v^3}{4E^2g}}$$
$$=\sqrt{\frac{3\times 6^3\times(314)^2\times\left(1.8\times 10^{-5}\right)^3\times\left(2\times 10^{-3}\right)^3}{4\times\left(\frac{81\pi}{7}\times 10^5\right)^2\times 9.8}}$$
$$=8\times 10^{-19}\mathrm{C}$$

Question20

Four charges $+q_1+2q_1+q$ and $-2q$ are placed at the corners of a square $ABCD$ respectively. The force on a unit positive charge kept at the centre O is

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Options:

A. along the diagonal BD

B. along the diagonal AC

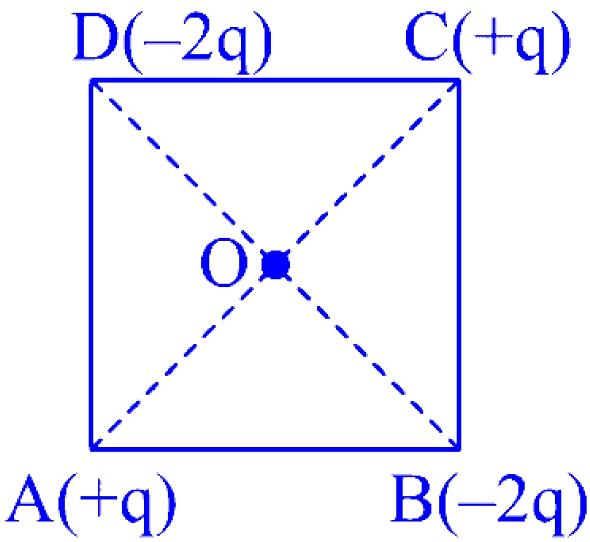
C. perpendicular to AD

D. zero

Answer: A

Solution:

The given situation is shown below



Since, charges kept at point A and C are in same magnitude and same nature (i.e. both positive), hence net force due these two charges on unit charge at centre O will be zero.

Force due to charge $(+2q)$ at unit positive charge at centre will be towards BO and also force due to charge $(-2q)$ at unit positive charge at centre will be towards OD.

Therefore, net force on the unit positive charge kept at centre O will be towards BD.

Question21

An electric dipole with dipole moment $4 \times 10^{-9} \mathrm{C-m}$ is aligned at 30° with the direction of a uniform electric field of magnitude $5 \times 10^{4} \mathrm{NC}^{-1}$, the magnitude of the torque acting on the dipole is

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Options:

A. $\sqrt{3} \times 10^{-4}\ \mathrm{N-m}$

B. $10^{-5}\ \mathrm{N-m}$

C. $10 \times 10^{-3}\ \mathrm{N-m}$

D. $10^{-4}\ \mathrm{N-m}$

Answer: D

Solution:

Given, for an electric dipole, dipole moment,

$p = 4 \times 10^{-9}\mathrm{C}$

$\theta = 30^{\circ}$

Magnitude of electric field, $E = 5 \times 10^4\ \mathrm{N/C}$

$\therefore$ Torque, $\tau = pE \sin\theta$

$= 4 \times 10^{-9} \times 5 \times 10^4 \sin 30^{\circ} = 10^{-4}\ \mathrm{N-m}$

Question22

A charged particle of mass m and charge q is released from rest in an uniform electric field E. Neglecting the effect of gravity, the kinetic energy of the charged particle after t seconds is

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Options:

A. $\frac{Eq^2m}{2t^2}$

B. $\frac{Eqm}{t}$

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

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

Answer: C

Solution:

According to given situation, force on charge particle in uniform electric field, $F = qE$ Acceleration of charge particle,

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

Velocity of charge particle after time t is given as

$v = u + at = 0 + \frac{qE}{m}t \Rightarrow v = \frac{qEt}{m}$

$\therefore$ Kinetic energy of the charged particle

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

Question23

The electric field and the potential of an electric dipole vary with distance r as

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Options:

A. $\frac{1}{r^2}$ and $\frac{1}{r}$

B. $\frac{1}{r^2}$ and $\frac{1}{r^3}$

C. $\frac{1}{r^3}$ and $\frac{1}{r^2}$

D. $\frac{1}{r}$ and $\frac{1}{r^2}$

Answer: C

Solution:

We know electric field and potential due to electric dipole on axial position is given as

$E=\frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$ and $V=\frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$

i.e. $E \propto \frac{1}{r^3}$ and $V \propto \frac{1}{r^2}$

Question24

Two tiny spheres carrying charges $1.8\mu\text{C}$ and $2.8\mu\text{C}$ are located at 40 cm apart. The potential at the mid - point of the line joining the two charges is

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Options:

A. 2.1×10^5 V

B. 3.6×10^5 V

C. 1.3×10^4 V

D. 3.8×10^4 V

Answer: A

Solution:

Charge on first sphere, $q_1=1.8\mu\text{C}=1.8\times 10^{-6}\text{C}$

Charge on second sphere, $q_2=2.8\mu\text{C}=2.8\times 10^{-6}\text{C}$

Distance between the two spheres, $r=40\text{ cm}$

Distance between mid-point and each sphere

$r_1=r_2=20\text{ cm}=0.2\text{ m}$

$\therefore$ Electric potential at mid-point due to both charged sphere

$$V = V_1 + V_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{r_1} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{r_2}$$
$$= 9 \times 10^9 \times \frac{1.8 \times 10^{-6}}{0.2} + 9 \times 10^9 \times \frac{2.8 \times 10^{-6}}{0.2}$$
$$= 9 \times 10^3(9 + 14) = 2.07 \times 10^5 \text{ V} \simeq 2.1 \times 10^5 \text{ V}$$

Question25

Electric field due to infinite, straight uniformly charged wire varies with distance r as

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Options:

A. r

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

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

D. r^2

Answer: B

Solution:

Electric field intensity due to infinity straight uniformly charged wire at some distance r is,

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

where, $\lambda =$ the surface charge density.

If λ, π and ε_0 are constants, then

$E \propto \frac{1}{r}$

Question26

A 2 g object, located in a region of uniform electric field $\mathrm{E}=\left(300 \mathrm{NC}^{-1}\right) \hat{\mathrm{i}}$ carries a charge Q. The object released from rest at $x=0$, has a kinetic energy of $0.12 \mathrm{~J}$ at $x=0.5 \mathrm{~m}$. Then, Q is

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Options:

A. $400 \mu \mathrm{C}$

B. $-400 \mu \mathrm{C}$

C. $800 \mu \mathrm{C}$

D. $-800 \mu \mathrm{C}$

Answer: C

Solution:

Given, $m=2 \mathrm{~g}=2 \times 10^{-3} \mathrm{~kg}$

$\mathbf{E}=\left(300 \mathrm{NC}^{-1}\right) \hat{\mathbf{i}}$

At, $x=0,(\mathrm{KE})_1=0$ and $x=0.5 \mathrm{~m},(\mathrm{KE})_2=0.12 \mathrm{~J}$

From work-energy theorem,

work done $=$ change in kinetic energy

$\Rightarrow$ Force $\times$ displacement $=\Delta \mathrm{KE}$

$$\begin{aligned} Q E \times d & =\mathrm{KE}_2-\mathrm{KE}_1 \\ \Rightarrow \quad Q \times 300 \times 0.5 & =0.12 \\ \text { or } \quad Q & =\frac{0.12}{300 \times 0.5}=800 \mu \mathrm{C} \end{aligned}$$

The charge Q is moving in the direction of electric field. Hence, it is positive.

Question27

Which of the following statements is false in the case of polar molecules?

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Options:

A. Centres of positive and negative charges are separated in the absence of external electric field.

B. Centres of positive and negative charges are separated in the presence of external electric field.

C. Do not possess permanent dipole moments.

D. Ionic molecule HCl is the example of polar molecule.

Answer: C

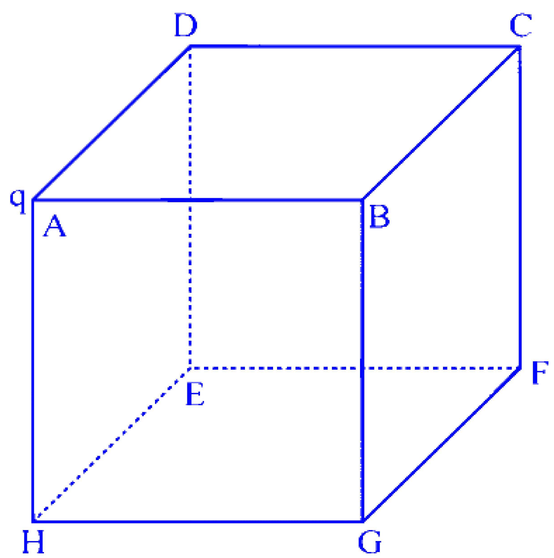
Solution:

Polar molecules are the molecules in which the centres of positive and negative charges are separated even there is no external field. Such molecules have a permanent dipole moment. e.g., HCl, H_2O, etc.

Thus, statement given in option (c) is false.

Question28

A point charge q is placed at the corner of a cube of side a as shown in the figure. What is the electric flux through the face $ABCD$?



KCET 2020

Options:

A. 0

B. $\frac{q}{24\varepsilon_0}$

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

D. $\frac{q}{72\varepsilon_0}$

Answer: B

Solution:

If charge is placed at the one corner of a cube, then it can be shared further by 8 cubes.

$\therefore$ Charge on one cube $= \frac{q}{8}$

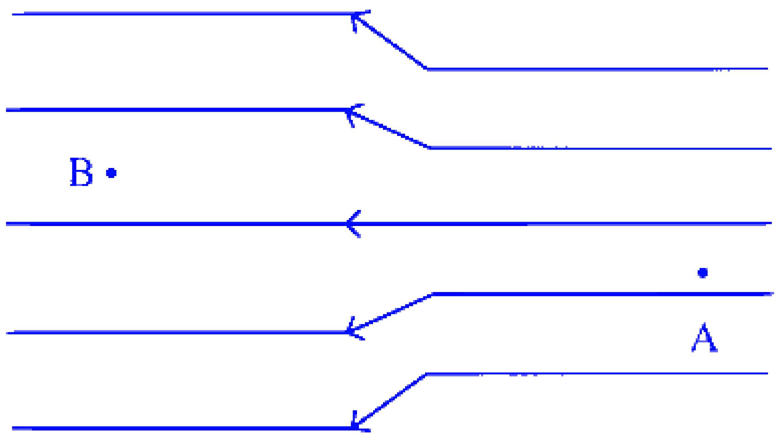
Now, in any given cube this charge will be touching 3 out of 9 of cube faces. So, the area vector of that side and the electric field vector will be perpendicular. So, flux through those 3 sides will be zero. However, equal amount of flux will flow from other 3 sides.

So, flux through one side $= \left(\frac{q/8}{3}\right) \cdot \frac{1}{\varepsilon_0} = \frac{q}{24\varepsilon_0}$

Hence, flux through one face $(ABCD) = \frac{q}{24\varepsilon_0}$

Question29

The electric field lines on the left have twice the separation on those on the right as shown in figure. If the magnitude of the field at A is $40 \mathrm{~Vm}^{-1}$, what is the force on $20 \mu \mathrm{C}$ charge kept at B ?



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Options:

A. $4 \times 10^{-4} \mathrm{~N}$

B. $8 \times 10^{-4} \mathrm{~N}$

C. $16 \times 10^{-4} \mathrm{~N}$

D. $1 \times 10^{-4} \mathrm{~N}$

Answer: A

Solution:

According to given figure,

Electric field at point $A, E_A=40 \mathrm{~Vm}^{-1}$

Since, electric field lines on the left have twice the separation on those on the right (at point B), hence electric field at point B

$E_B = \frac{E_A}{2} = \frac{40}{2}$
$E_B = 20 \mathrm{Vm}^{-1}$

Force on charge q kept at B is

$$F = qE_B$$

Given, $q = 20\mu\mathrm{C} = 20 \times 10^{-6}\mathrm{C}$

$$\Rightarrow \quad F = 20 \times 10^{-6} \times 20 = 4 \times 10^{-4}\,\mathrm{N}$$

Question30

An infinitely long thin straight wire has uniform charge density of $\frac{1}{4} \times 10^{-2}\,\mathrm{cm}^{-1}$. What is the magnitude of electric field at a distance $20\,\mathrm{cm}$ from the axis of the wire?

KCET 2020

Options:

A. $1.12 \times 10^8\,\mathrm{NC}^{-1}$

B. $4.5 \times 10^8\,\mathrm{NC}^{-1}$

C. $2.25 \times 10^8\,\mathrm{NC}^{-1}$

D. $9 \times 10^8\,\mathrm{NC}^{-1}$

Answer: A

Solution:

Given, charge density of uniformly long thin wire,

$$\lambda = \frac{1}{4} \times 10^{-2}\,\mathrm{cm}^{-1}$$
$$= \frac{1}{4} \times 10^{-2} \times 10^{2}\,\mathrm{m}^{-1} = \frac{1}{4}\,\mathrm{m}^{-1}$$
$$r = 20\,\mathrm{cm} = 0.2\,\mathrm{m}$$

Electric field at a distance r from the axis of wire is given as

$$E=\frac{\lambda}{2\pi\varepsilon_0 r}=\frac{2\lambda}{4\pi\varepsilon_0 r}$$
$$=\frac{9\times10^9\times2\times\frac{1}{4}}{0.2}$$
$$=2.25\times10^{10}\mathrm{NC}^{-1}$$

No given option is correct.

Question31

A dipole moment p and moment of inertia I is placed in a uniform electric field E. If it is displaced slightly from its stable equilibrium position, the period of oscillation of dipole is

KCET 2020

Options:

A. $\sqrt{\frac{pE}{I}}$

B. $2\pi\sqrt{\frac{I}{pE}}$

C. $\frac{1}{2\pi}\sqrt{\frac{pE}{I}}$

D. $\pi\sqrt{\frac{I}{pE}}$

Answer: B

Solution:

Torque on electric dipole placed in uniform electric field E,

$\tau=pE\sin\theta$ .... (i)

where, $p=$ electric dipole moment,

For small angle θ, $\sin\theta\approx\theta$

$\therefore$ From Eq. (i), we have

$\tau=pE\theta$ .... (ii)

but $\tau = I \times \alpha$ .... (iii)

where α is angular acceleration.

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

$I\alpha = pE\theta$

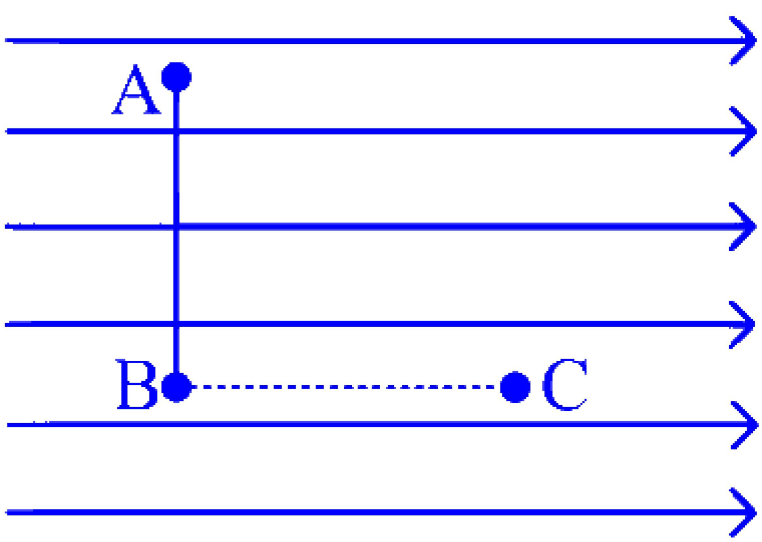
$\alpha = \frac{pE}{I} \cdot \theta \Rightarrow \frac{\theta}{\alpha} = \frac{I}{pE}$ ..... (iv)

$\therefore$ Time period for the oscillation of dipole,

$T = 2\pi\sqrt{\frac{\theta}{\alpha}} = 2\pi\sqrt{\frac{I}{pE}}$

Question32

Figure shows three points A, B and C in a region of uniform electric field $\mathbf{E}$. The line AB is perpendicular and BC is parallel to the field lines. Then, which of the following holds good ? (V_A, V_B and V_C represent the electric potential at points A, B and C, respectively)



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Options:

A. $V_A = V_B = V_C$

B. $V_A = V_B > V_C$

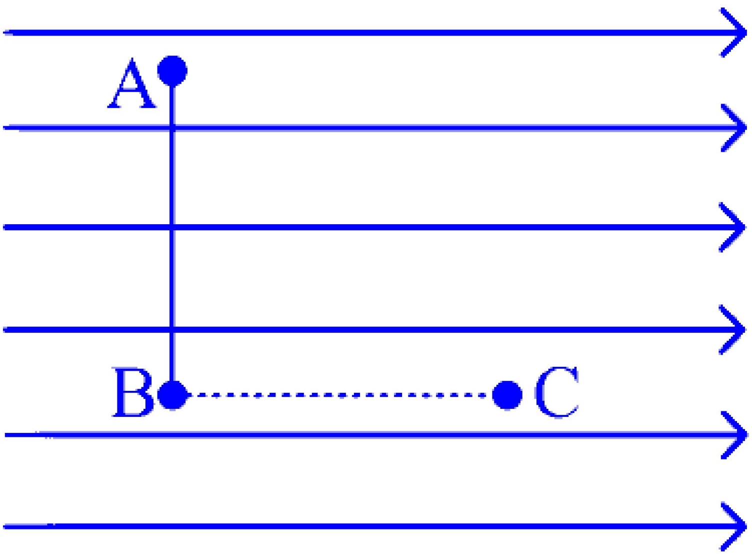
C. $V_A = V_B < V_C$

D. $V_A > V_B = V_C$

Answer: B

Solution:

According to given figure, line AB is perpendicular to direction of electric field lines. Hence, surface passing through line AB and perpendicular to electric field lines behaves like a equipotential surface, therefore



$V_A = V_B$ ..... (i)

Electric field and electric potential are related as

$E = -\frac{dV}{dx} \Rightarrow V = -\int E dx$

Which indicates that electric potential decreases in the direction of electric field, i.e.

$V_B > V_C$ ... (ii)

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

$V_A = V_B > V_C$

Question33

When a soap bubble is charged?

KCET 2020

Options:

A. Its radius increases

B. Its radius decreases

C. The radius remains the same

D. Its radius may increase or decrease

Answer: A

Solution:

When a soap bubble is charged, then the bubble expands because the charged particles uniformly distributed on it causes them to repel each other due to the electrostatic force. Hence, radius of soap bubble increases.

Question34

Two metal plates are separated by 2 cm. The potentials of the plates are -10 V and $+30 \text{ V}$. The electric field between the two plates is

KCET 2019

Options:

A. 500 V/m

B. 1000 V/m

C. 2000 V/m

D. 3000 V/m

Answer: C

Solution:

Distance between the metal plates

$\Delta x = 2 \text{ cm} = 2 \times 10^{-2} \text{ m}$

Potentials on first and second plate are -10 V and $+30 \text{ V}$

$\therefore$ Potential difference between the plates

$\Delta V = V_2 - V_1 = 30 - (-10) = 40 \text{ V}$

∴ Electric field between the plates

$|\mathrm{E}| = \frac{\Delta V}{\Delta x} = \frac{40}{2 \times 10^{-2}} = 2000 \mathrm{~V/m}$

Question35

Two protons are kept at a separation of $10 \mathrm{~nm}$. Let F_n and F_e be the nuclear force and the electrostatic force between them

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Options:

A. $F_e = F_n$

B. $F_e \gg F_n$

C. $F_e \ll F_n$

D. F_e and F_n differ only slightly

Answer: B

Solution:

Distance between two protons in nucleus

$d = 10 \mathrm{~nm} = 10^{-8} \mathrm{~m}$

Protons are separated by a much greater distance from 0.7 fermi, hence electrostatic force between two protons is much greater than nuclear force between them.

Question36

A certain charge $2Q$ is divided at first into two parts q_1 and q_2. Later the charges are placed at a certain distance. If the force of interaction between two chagrges is maximum then $\frac{Q}{q_1}$ is

KCET 2019

Options:

A. 4

B. 2

C. 1

D. 0.5

Answer: C

Solution:

Given, $q_1 + q_2 = 2Q$ .... (i)

Force of interaction between two charges derived from a single charge is maximum when both have same charge, i.e. $q_1 = q_2 = \frac{2Q}{2} = Q$

$\therefore \quad \frac{Q}{q_1} = \frac{Q}{Q} = 1$

Question37

A particle of mass m and charge q is placed at rest in uniform electric field E and then released. The kinetic energy attained by the particle after moving a distance y is

KCET 2019

Options:

A. qEy^2

B. qE^2y

C. qEy

D. q^2Ey

Answer: C

Solution:

When a charge particle of mass m and charge q is released in the uniform electric field, then it is accelerated in the direction of electric field,

$\therefore$ Acceleration of the charge particle, $a = \frac{F}{m}, a = \frac{qE}{m}$

$[\because F = qE]$

$\therefore$ Final velocity of electron at a distance y is given by

$$v^2 = u^2 + 2ay = 0 + 2 \cdot \frac{qE}{m} \cdot y$$
$$v^2 = \frac{2qEy}{m}$$

$\therefore$ Kinetic energy KE $= \frac{1}{2}mv^2 = \frac{1}{2}m \cdot \frac{2qEy}{m} = Eqy$

Question38

An electric dipole is kept in non-uniform electric field. It generally experiences

KCET 2019

Options:

A. a force and torque

B. a force but not a torque

C. a torque but not a force

D. neither a force nor a torque

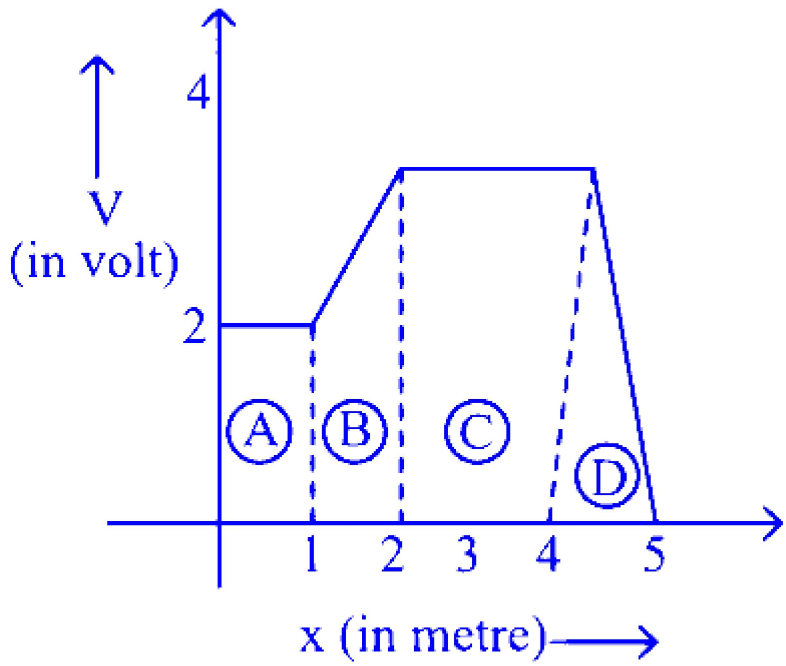
Answer: A

Solution:

When an electric dipole is placed in a non-uniform electric field, it experiences both a resultant force and a torque. However, in a uniform electric field, the dipole only experiences torque.

Question39

The figure gives the electric potential V as a function of distance through four regions on x-axis. Which of the following is true for the magnitude of the electric field E in these regions?



KCET 2019

Options:

A. $E_A > E_B > E_C > E_D$

B. $E_A = E_C$ and $E_B < E_D$

C. $E_B = E_D$ and $E_A < E_C$

D. $E_A < E_B < E_C < E_D$

Answer: B

Solution:

The slope of given graph represent electric field.

i.e. $E = -\frac{\Delta V}{\Delta x}$ .... (i)

From figure, $E_A = E_C = 0$

Slope of graph B is positive and slope of graph D is negative therefore from Eq(i), Electric field associated with graph D is more than graph B.

$\therefore \quad E_B < E_D$

Question40

A system of two charges separated by a certain distance apart stores electrical potential energy. If the distance between them is increased, the potential energy of the system

KCET 2019

Options:

A. increases in any case

B. decreases in any case

C. may increase or decrease

D. remains the same

Answer: C

Solution:

PE of a system of two charges, $U = \frac{kq_1q_2}{r}$

U-depends on nature of charges.

(i) For like charges, U Positive

$\therefore$ As r increased, U decreases

i.e when like charges are taken away, PE of system decreases.

(ii) For unlike charges, U negative

$\therefore$ as r increased, U increased

(negative U decreases $\Rightarrow$ U increases)

When unlike charges taken away,

PE of system increases.

So, PE may increase or decrease depending on nature of charges.

Question41

The magnitude of point charge due to which the electric field 30 cm away has the magnitude $2\mathrm{NC}^{-1}$ will be

KCET 2018

Options:

A. $2 \times 10^{-11}\mathrm{C}$

B. $3 \times 10^{-11}\mathrm{C}$

C. $5 \times 10^{-11}\mathrm{C}$

D. $9 \times 10^{-11}\mathrm{C}$

Answer: A

Solution:

To find the magnitude of the point charge, we use the formula for the electric field due to a point charge:

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

where

E is the electric field,

k is Coulomb's constant, approximately $9 \times 10^9\,\mathrm{N\,m^2/C^2}$,

q is the charge, and

r is the distance from the charge.

Given:

$E = 2\,\mathrm{N/C}$,

$r = 30\,\mathrm{cm} = 0.30\,\mathrm{m}$.

We solve for q by rearranging the formula:

$q = \frac{Er^2}{k}$

Steps:

Calculate r^2:

$r^2 = (0.30\,\text{m})^2 = 0.09\,\text{m}^2.$

Substitute the values into the equation:

$q = \frac{(2\,\text{N/C})(0.09\,\text{m}^2)}{9\times10^9\,\text{N m}^2/\text{C}^2}.$

Multiply the numerator:

$2 \times 0.09 = 0.18\,\text{N m}^2/\text{C}.$

Divide to find q:

$q = \frac{0.18}{9\times10^9}\,\text{C} = 0.02 \times 10^{-9}\,\text{C} = 2 \times 10^{-11}\,\text{C}.$

Thus, the magnitude of the point charge is:

Option A: $2 \times 10^{-11}\,\text{C}.$

Question42

A mass of 1 kg carrying a charge of 2 C is accelerated through a potential of 1 V . The velocity acquired by it is

KCET 2018

Options:

A. $\sqrt{2}\ \text{ms}^{-1}$

B. $2\ \text{ms}^{-1}$

C. $\frac{1}{\sqrt{2}}\ \text{ms}^{-1}$

D. $\frac{1}{2}\ \text{ms}^{-1}$

Answer: B

Solution:

Let's analyze the problem step by step:

When a charge is accelerated through a potential difference, it gains kinetic energy equal to the work done by the electric field. This work is given by:

$W = qV$

Here,

$q = 2\,\text{C}$

$V = 1\,\text{V}$

So,

$W = 2 \times 1 = 2\,\text{J}$

This work done is converted into kinetic energy of the mass. The kinetic energy (KE) of an object of mass m moving with velocity v is given by:

$\text{KE} = \frac{1}{2}mv^2$

Given that the kinetic energy is 2 J and the mass $m = 1\,\text{kg}$, we have:

$\frac{1}{2}(1)v^2 = 2$

Solve for v:

Multiply both sides by 2:

$v^2 = 4$

Take the square root of both sides:

$v = \sqrt{4} = 2\,\text{ms}^{-1}$

Thus, the velocity acquired by the mass is $2\,\text{ms}^{-1}$.

Reviewing the options, Option B is the correct answer.

Question43

The force of repulsion between two identical positive charges when kept with a separation r in air is F. Half the gap between the two charges is filled by a dielectric slab of dielectric constant $= 4$. Then, the new force of repulsion between those two charges becomes

KCET 2018

Options:

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

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

C. $\frac{F}{4}$

D. $\frac{4F}{9}$

Answer: C

Solution:

The force of repulsion between two identical positive charges separated by a distance r in air is denoted as F. Initially, the force is calculated using Coulomb's law:

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

When half of the gap between the charges is filled with a dielectric slab having a dielectric constant, $K = 4$, the new force of repulsion is:

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

Thus, the new force of repulsion between the charges becomes $\frac{F}{4}$.

Question44

The work done to move a charge on an equipotential surface is

KCET 2018

Options:

A. infinity

B. less than 1

C. greater than 1

D. zero

Answer: D

Solution:

The work done to move a charge on an equipotential surface is zero. Here's why:

On an equipotential surface, the electric potential V is the same at every point.

The work done W in moving a charge q between two points is given by:

$$W = q\Delta V$$

where ΔV is the potential difference between the final and initial points.

Since $\Delta V = 0$ on an equipotential surface, it follows that:

$W = q \times 0 = 0$

Thus, the correct answer is Option D: zero.

Question45

Two point charges $A = +3\text{nC}$ and $B = +1\text{nC}$ are placed 5 cm apart in air. The work done to move charge B towards A by 1 cm is

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Options:

A. 2.0×10^{-7} J

B. 2.7×10^{-7} J

C. 12.1×10^{-7} J

D. 1.35×10^{-7} J

Answer: D

Solution:

Given the problem:

Charge $A = +3\,\text{nC} = 3 \times 10^{-9}\,\text{C}$

Charge $B = +1\,\text{nC} = 1 \times 10^{-9}\,\text{C}$

Distance between the two charges:

Initial distance, $r_1 = 5\,\text{cm} = 0.05\,\text{m} = 5 \times 10^{-2}\,\text{m}$

After moving charge B towards A by 1 cm, the new distance is $r_2 = 4\,\text{cm} = 0.04\,\text{m} = 4 \times 10^{-2}\,\text{m}$

The formula for the work done (W) in moving a charge in an electric field is:

$W = U_B - U_A = \frac{kq_1q_2}{r_2} - \frac{kq_1q_2}{r_1}$

Substituting the values:

$$
\begin{aligned}
W &= kq_1q_2\left[\frac{1}{r_2}-\frac{1}{r_1}\right] \\
&= 9\times10^9\times3\times10^{-9}\times1\times10^{-9}\left[\frac{1}{4\times10^{-2}}-\frac{1}{5\times10^{-2}}\right] \\
&= 9\times10^9\times3\times10^{-9}\times1\times10^{-9}\left[\frac{5-4}{4\times5\times10^{-2}}\right] \\
&= 27\times10^{-9}\times\frac{1}{20\times10^{-2}} \\
&= \frac{27}{20}\times10^{-7} \\
&= 1.35\times10^{-7}\,\mathrm{J}
\end{aligned}
$$

Thus, the work done to move charge B towards A by 1 cm is 1.35×10^{-7} J.

Question46

4×10^{10} electrons are removed from a neutral metal sphere of diameter 20 cm placed in air. The magnitude of the electric field (in NC^{-1}) at a distance of 20 cm from its centre is

KCET 2017

Options:

A. 640

B. 5760

C. Zero

D. 1440

Answer: D

Solution:

Given the following parameters:

Number of electrons removed (n)**:** 4×10^{10}

**Diameter of the sphere (D) : ∗ ∗ \(20 cm

**Radius of the sphere (r) : ∗ ∗ \($\frac{20}{2}=10\,\mathrm{cm}=0.1\,\mathrm{m}$

We need to calculate the magnitude of the electric field at a distance of 20 cm from the center of the sphere.

The formula for the electric field outside the sphere is:

$E = \frac{q}{4\pi\varepsilon_0 r^2} = \frac{ne}{4\pi\varepsilon_0 r^2}$

Where:

$e = 1.6 \times 10^{-19}\,\mathrm{C}$ (charge of an electron)

$\varepsilon_0 = 8.854 \times 10^{-12}\,\mathrm{C}^2/\mathrm{N} \cdot \mathrm{m}^2$ (permittivity of free space)

Since $r = 20\,\mathrm{cm} = 0.2\,\mathrm{m}$, substituting the values:

$E = \frac{4\times10^{10}\times1.6\times10^{-19}\times9\times10^{9}}{(0.2)^2}$

Breaking down the calculation:

$E = \frac{4\times1.6\times9\times10^{4}}{0.04} = \frac{4\times1.6\times9\times10^{4}}{20\times20\times10^{-4}}$

Simplifying further:

$E = 1.6 \times 9 \times 10^2 = 1.44 \times 10^2$

Thus, the magnitude of the electric field at a distance of $20\,\mathrm{cm}$ from the center is:

$E = 1440\,\mathrm{NC}^{-1}$

Question47

Two spheres of electric charges +2 nC and -8 nC are placed at a distance d apart. If they are allowed to touch each other, what is the new distance between them to get a repulsive force of same magnitude as before?

KCET 2017

Options:

A. d

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

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

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

Answer: C

Solution:

In the initial scenario, two spheres have electric charges $q_1 = +2\,\text{nC} = 2 \times 10^{-9}\,\text{C}$ and $q_2 = -8\,\text{nC} = -8 \times 10^{-9}\,\text{C}$. The force between them is given by:

$F = \frac{k \cdot q_1 \cdot q_2}{d^2}$

Substituting the values:

$F = \frac{k \cdot (2 \times 10^{-9}) \cdot (-8 \times 10^{-9})}{d^2} = \frac{k \cdot (-16 \times 10^{-18})}{d^2}$

This is our equation (i).

After the spheres are allowed to touch each other, the total charge becomes:

$2\,\text{nC} - 8\,\text{nC} = -6\,\text{nC}$

Thus, each sphere carries a charge of:

$\frac{-6\,\text{nC}}{2} = -3\,\text{nC} = -3 \times 10^{-9}\,\text{C}$

The new force F_1 after separation is:

$F_1 = \frac{k \cdot (3 \times 10^{-9}) \cdot (3 \times 10^{-9})}{d'^2} = \frac{k \cdot (9 \times 10^{-18})}{d'^2}$

This is equation (ii).

To maintain the same magnitude of force as before:

$\frac{k \cdot (16 \times 10^{-18})}{d^2} = \frac{k \cdot (9 \times 10^{-18})}{d'^2}$

Solving for the new distance d':

$\frac{d^2}{d'^2} = \frac{16 \times 10^{-18}}{9 \times 10^{-18}} = \frac{16}{9}$

Taking the square root:

$\frac{d}{d'} = \sqrt{\frac{16}{9}} = \frac{4}{3}$

Therefore:

$d = \frac{4}{3} d'$

Solving for d':

$d' = \frac{3}{4} d$

So, the new distance between the spheres to achieve the same magnitude of repulsive force is $\frac{3}{4} d$.

Question48

Three point charges of $+2q$, $+2q$ and $-4q$ are placed at the corners A, B and C of an equilateral triangle ABC of side x. The magnitude

of the electric dipole moment of this system is

KCET 2017

Options:

A. $2qx$

B. $3\sqrt{2}qx$

C. $3qx$

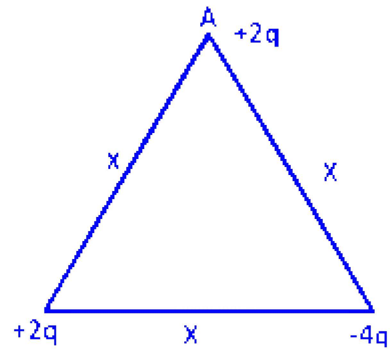
D. $2\sqrt{3}qx$

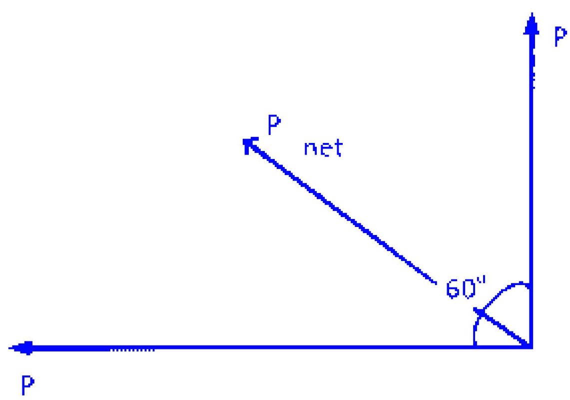
Answer: D

Solution:

According to question,

The magnitude of electric dipole moment





$$P_{\text{net}} = \sqrt{p^2 + p^2 + 2pp\cos 60^\circ}$$
$$= \sqrt{2p^2 + 2p^2 \times \frac{1}{2}}$$
$$= \sqrt{3} \cdot p$$

We know that, $p = 2q \cdot x$ $[\because p = q \cdot l]$

$$= \sqrt{3} \cdot 2qx = 2\sqrt{3}qx$$
