Electrostatics JEE Main PYQ - 3

Total Time: 1 Hour : 15 Minute **Total Marks:** 120

Instructions

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1. Test will auto submit when the Time is up.
2. The Test comprises of multiple choice questions (MCQ) with one or more correct answers.
3. The clock in the top right corner will display the remaining time available for you to complete the examination.

Navigating & Answering a Question

1. The answer will be saved automatically upon clicking on an option amongst the given choices of answer.
2. To deselect your chosen answer, click on the clear response button.
3. The marking scheme will be displayed for each question on the top right corner of the test window.

Electrostatics

1. **A dipole with two electric charges of $2\,\mu C$ magnitude each, with separation distance $0.5\,\mu m$, is placed between the plates of a capacitor such that its axis is parallel to an electric field established between the plates when a potential difference of $5\,V$ is applied. Separation between the plates is $0.5\,mm$. If the dipole is rotated by 30° from the axis, it tends to realign in the direction due to a torque. The value of torque is :** **(+4, -1)**

a. $5 \times 10^{-9}\,Nm$

b. $5 \times 10^{-3}\,Nm$

c. $2.5 \times 10^{-12}\,Nm$

d. $2.5 \times 10^{-9}\,Nm$

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2. **Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).** **(+4, -1)**
Assertion (A): The outer body of an aircraft is made of metal which protects persons sitting inside from lightning strikes.
Reason (R): The electric field inside the cavity enclosed by a conductor is zero. In the light of the above statements, choose the most appropriate answer from the options given below:

a. Both (A) and (R) are correct and (R) is the correct explanation of (A)

b. (A) is correct but (R) is not correct

c. Both (A) and (R) are correct but (R) is not the correct explanation of (A)

d. (A) is not correct but (R) is correct

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3. Using a battery, a 100 pF capacitor is charged to 60 V and then the battery is removed. After that, a second uncharged capacitor is connected to the first capacitor in parallel. If the final voltage across the second capacitor is 20 V, its capacitance is : (in pF) **(+4, -1)**

a. 600

b. 200

c. 400

d. 100

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4. The electrostatic potential on the surface of uniformly charged spherical shell of radius R = 10 cm is 120 V. The potential at the centre of shell, at a distance r = 5 cm from centre, and at a distance r = 15 cm from the centre of the shell respectively, are: (+4, -1)

a. 120V, 120V, 80V

b. 40V, 40V, 80V

c. 0V, 0V, 80V

d. 0V, 120V, 40V

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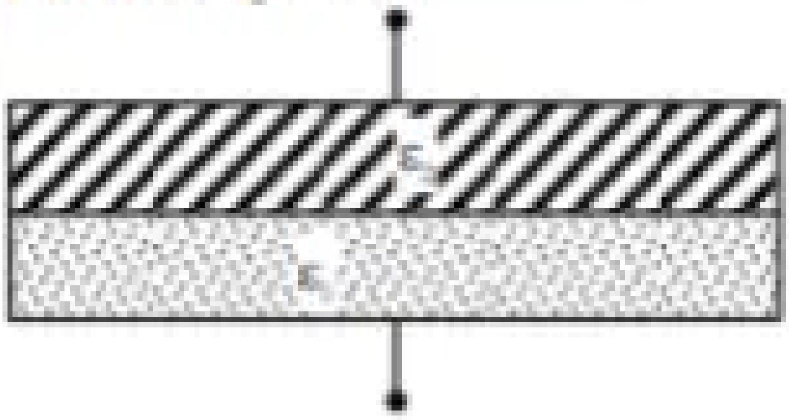
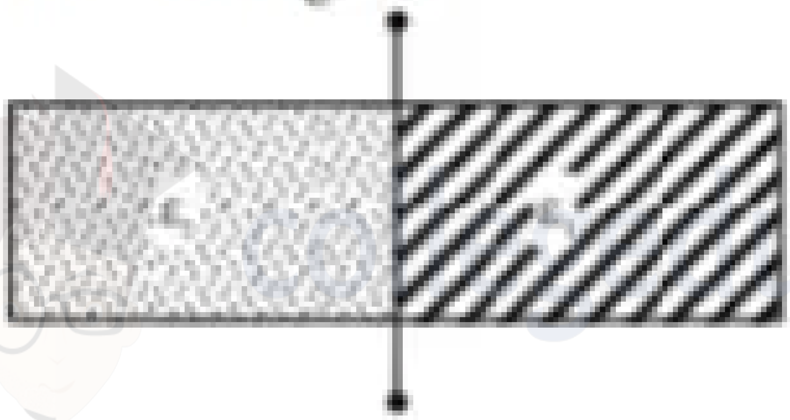
5. A parallel plate capacitor is filled equally (half) with two dielectrics of dielectric constant ϵ_1 and ϵ_2, as shown in figures. The distance between the plates is d and area of each plate is A. If capacitance in first configuration and second configuration are C_1 and C_2 respectively, then $\frac{C_1}{C_2}$ is: (+4, -1)

First Configuration



Second Configuration



a. $\frac{\epsilon_1\epsilon_2}{(\epsilon_1+\epsilon_2)^2}$

b. $\frac{4\epsilon_1\epsilon_2}{(\epsilon_1+\epsilon_2)^2}$

c. $\frac{\epsilon_1\epsilon_2}{\epsilon_1+\epsilon_2}$

d. $\frac{\epsilon_0(\epsilon_1+\epsilon_2)}{2}$

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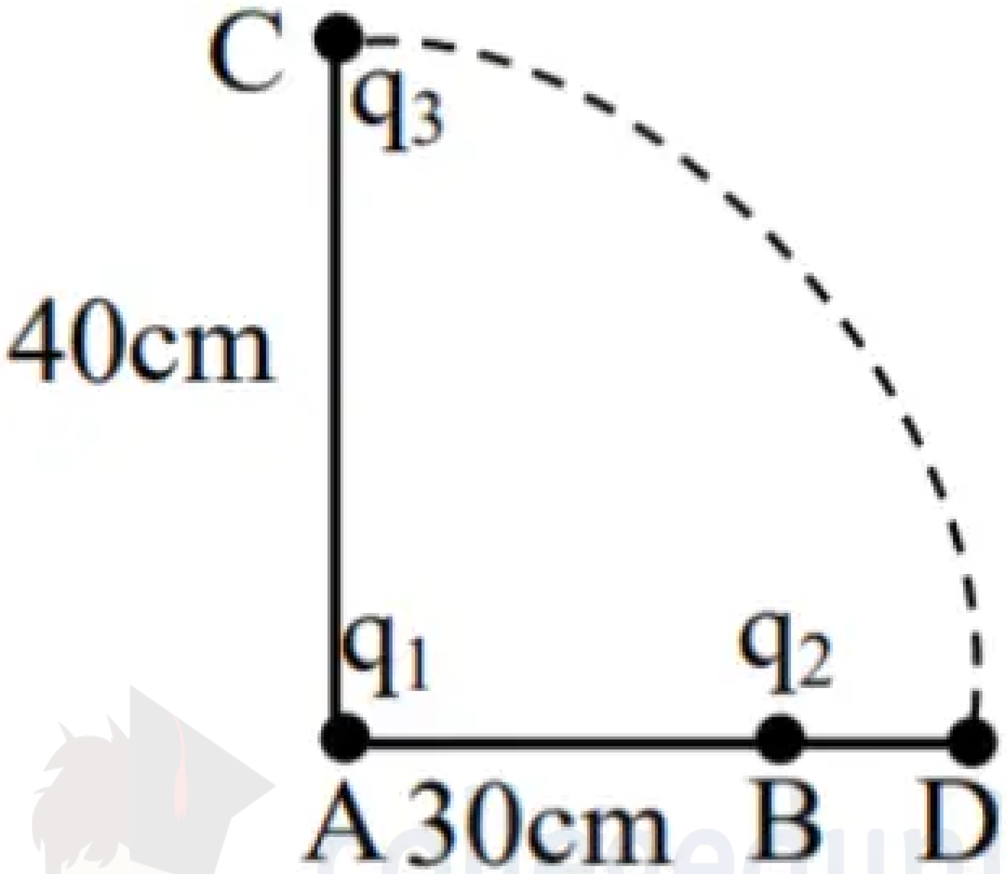
6. Two charges q_1 and q_2 are separated by a distance of 30 cm. A third charge q_3 initially at C as shown in the figure, is moved along the circular path of radius 40 cm from C to D. If the difference in potential energy due to the movement of q_3 from C to D is given by $\frac{q_3 K}{4\pi\epsilon_0}$, the value of K is: (+4, -1)



a. $8q_2$

b. $6q_2$

c. $8q_1$

d. $6q_1$

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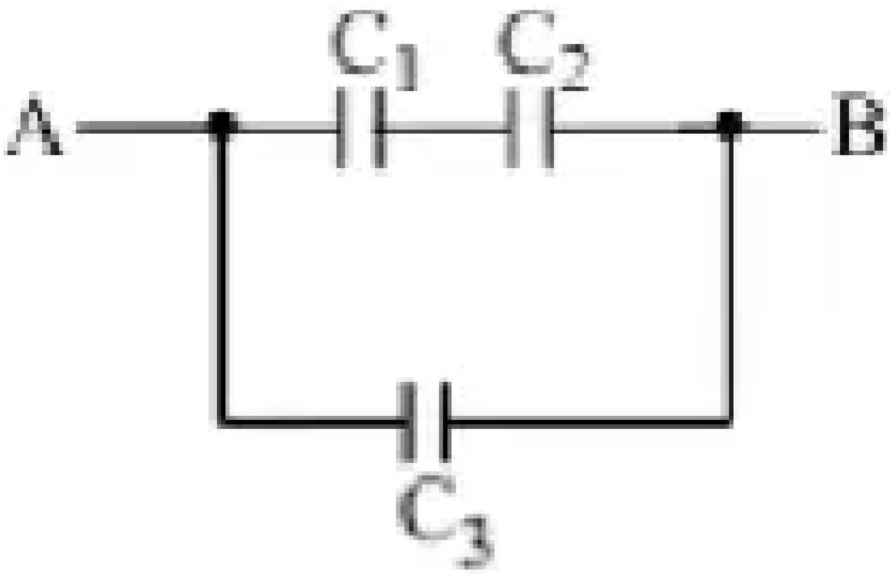
7. Three parallel plate capacitors C_1, C_2, and C_3 each of capacitance 5 μF are connected as shown in the figure. The effective capacitance between points A and B, when the space between the parallel plates of C_1 capacitor is filled with a dielectric medium having dielectric constant of 4, is: (+4, -1)

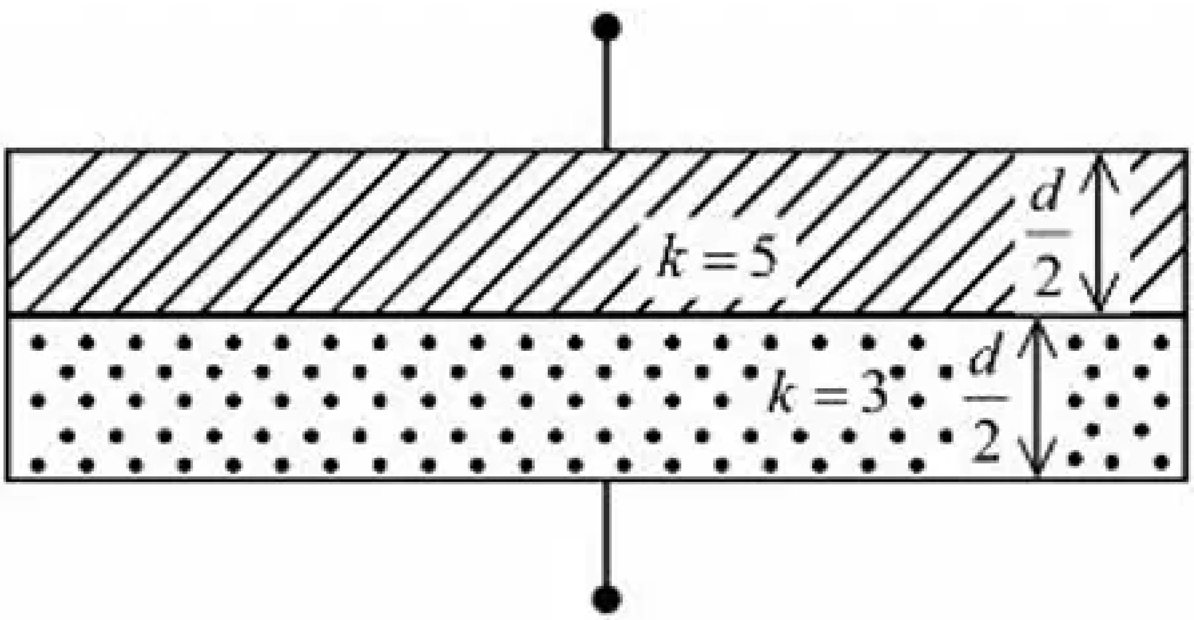


a. 22.5 μF

b. 7.5 μF

c. 9 μF

d. 30 μF

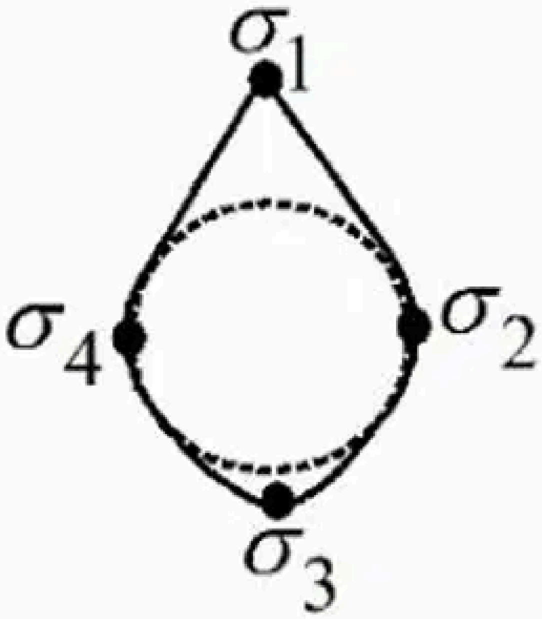


8.

Space between the plates of a parallel plate capacitor of plate area 4 cm^2 and separation of $d = 1.77\,\text{mm}$, is filled with uniform dielectric materials with dielectric constants (3 and 5) as shown in figure. Another capacitor of capacitance 7.5 pF is connected in parallel with it. The effective capacitance of this combination is ____ pF. (+4, -1)

9. An electron is released from rest near an infinite non-conducting sheet of uniform charge density '−σ'. The rate of change of de-Broglie wavelength associated with the electron varies inversely as n^{th} power of time. The numerical value of n is ______. (+4, -1)

10. Electric charge is transferred to an irregular metallic disk as shown in the figure. If σ_1, σ_2, σ_3, and σ_4 are charge densities at given points, then choose the correct answer from the options given below: (+4, -1)



A. $\sigma_1 > \sigma_3$; $\sigma_2 = \sigma_4$

B. $\sigma_1 > \sigma_2$; $\sigma_3 > \sigma_4$

C. $\sigma_1 > \sigma_3 > \sigma_2 = \sigma_4$

D. $\sigma_1 < \sigma_3 < \sigma_2 = \sigma_4$

E. $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4$

a. D and E Only

b. A and C Only

c. A, B, and C Only

d. B and C Only

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11. **Two metal spheres of radius R and $3R$ have same surface charge density σ. If they are brought in contact and then separated, the surface charge density on smaller and bigger sphere becomes σ_1 and σ_2, respectively. The ratio $\frac{\sigma_1}{\sigma_2}$ is:** **(+4, -1)**

a. 9

b. $\frac{1}{3}$

c. $\frac{1}{9}$

d. 3

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12. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R **(+4, -1)**

Assertion A: Work done in moving a test charge between two points inside a uniformly charged spherical shell is zero, no matter which path is chosen.

Reason R: Electrostatic potential inside a uniformly charged spherical shell is constant and is same as that on the surface of the shell.

In the light of the above statements, choose the correct answer from the options given below

a. A is false but R is true

b. Both A and R are true and R is the correct explanation of A

c. Both A and R are true but R is NOT the correct explanation of A

d. A is true but R is false

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13. Assertion (A): Work done to move a charge between two points is zero inside a uniformly charged shell. **(+4, -1)**

Reason (R): Potential inside a uniformly charged shell is constant and equal to the potential at its surface.

a. Both (A) \& (R) are correct, and Reason is the correct explanation of (A).

b. Both (A) \& (R) are correct but R is not correct explanation of A.

c. A is correct and R is incorrect

d. A is correct and R is correct

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14. There are two charged spheres of radius R and $3R$. When the spheres are made to touch each other and then separate, the surface charge density becomes σ_1 and σ_2 respectively. Find the ratio $\frac{\sigma_1}{\sigma_2}$. (+4, -1)

a. 5

b. 5

c. 3

d. 9

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15. Given $\lambda = \frac{2nc}{m}$ (linear charge density) for a wire which is passing through the body diagonal of a closed cube of side length $\sqrt{3}$ cm. Find the flux through the cube. (+4, -1)

a. 1.44π

b. 0.72π

c. 2.16π

d. 6.84π

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16. There are two charged spheres of radius R and $3R$. When the spheres are made to touch each other and then separate, the surface charge density becomes r_1 and r_2 respectively. Find $\frac{r_1}{r_2}$. (+4, -1)

a. $\frac{1}{9}$

b. $\frac{1}{3}$

c. 3

d. 9

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17. The electrostatic potential on the surface of a uniformly charged spherical shell of radius $R = 10\,\mathrm{cm}$ is 120 V. The potential at the centre of the shell, at a (+4, -1)

distance 5 cm from the centre, and at a distance 15 cm from the centre of the shell are:

a. $40\,V, 40\,V, 80\,V$

b. $120\,V, 120\,V, 80\,V$

c. $0\,V, 120\,V, 40\,V$

d. $0\,V, 0\,V, 80\,V$

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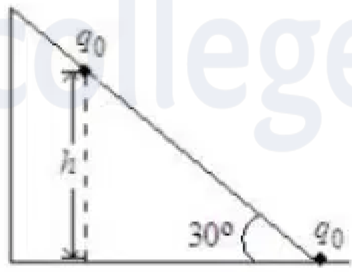
18. As shown in the figure, a configuration of two equal point charges (q_0 = + 2 μC) is placed on an inclined plane. Mass of each point charge is 20g. Assume that there is no friction between charge and plane. For the system of two point charges to be in equilibrium (at rest) the height $h = x \times 10^{-3}\,\mathrm{m}$. The value of x is _____ (+4, -1)



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19. A parallel plate capacitor of capacitance 2 F is charged to a potential V. The energy stored in the capacitor is E. The capacitor is now connected to another uncharged identical capacitor in parallel combination. The energy stored in the combination is E_5. The ratio E_5/E_1 is: (+4, -1)

a. 2 : 3

b. 1 : 2

c. 1 : 4

d. 2 : 1

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20. Two identical heater filaments are connected first in parallel and then in series. At the same applied voltage, the ratio of heat produced in same time for parallel to series will be: (+4, -1)

a. 1 : 2

b. 4 : 1

c. 1 : 4

d. 2 : 1

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21. A point charge causes an electric flux of $-2 \times 10^4\,\mathrm{Nm^2C^{-1}}$ to pass through a spherical Gaussian surface of 8.0 cm radius, centered on the charge. The value of the point charge is: (+4, -1)

a. $17.7 \times 10^{-7}\,\mathrm{C}$

b. $15.7 \times 10^{-7}\,\mathrm{C}$

c. $17.7 \times 10^{-6}\,\mathrm{C}$

d. $15.7 \times 10^{-6}\,\mathrm{C}$

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22. An electric dipole is placed at a distance of 2 cm from an infinite plane sheet having positive charge density σ. Choose the correct option from the following. (+4, -1)

a. Torque on dipole is zero and net force is directed away from the sheet.

b. Torque on dipole is zero and net force acts towards the sheet.

c. Potential energy of dipole is minimum and torque is zero.

d. Potential energy and torque both are maximum.

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23. Match List - I with List - II: (+4, -1)

List - I:

(A) Electric field inside (distance $r > 0$ from center) of a uniformly charged spherical shell with surface charge density σ, and radius R.
(B) Electric field at distance $r > 0$ from a uniformly charged infinite plane sheet with surface charge density σ.
(C) Electric field outside (distance $r > 0$ from center) of a uniformly charged spherical shell with surface charge density σ, and radius R.
(D) Electric field between two oppositely charged infinite plane parallel sheets with uniform surface charge density σ.

List - II:

(I) $\frac{\sigma}{\epsilon_0}$
(II) $\frac{\sigma}{2\epsilon_0}$
(III) 0
(IV) $\frac{\sigma}{\epsilon_0 r^2}$ Choose the correct answer from the options given below:

a. (A)-(III),(B)-(II),(C)-(IV),(D)-(I)

b. (A)-(IV),(B)-(I),(C)-(III),(D)-(II)

c. (A)-(IV),(B)-(II),(C)-(III),(D)-(I)

d. (A)-(I),(B)-(II),(C)-(IV),(D)-(III)

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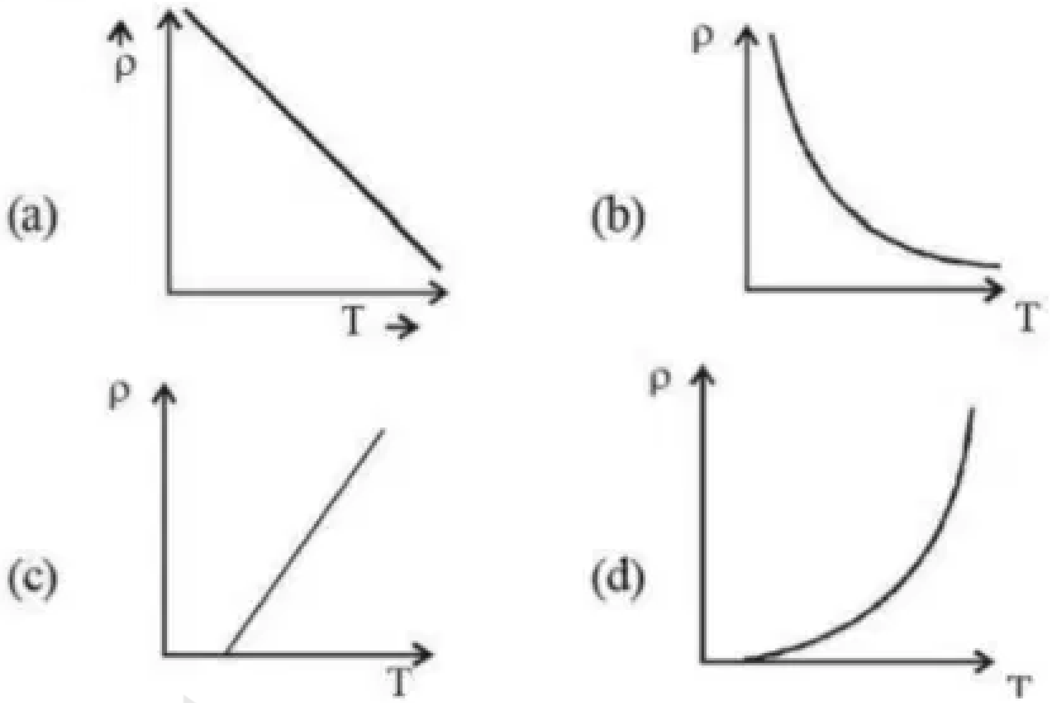
24. The resistivity (ρ) of a semiconductor varies with temperature. Which of the following curves represents the correct behavior? **(+4, -1)**



a. Curve (a)

b. Curve (b)

c. Curve (c)

d. Curve (d)

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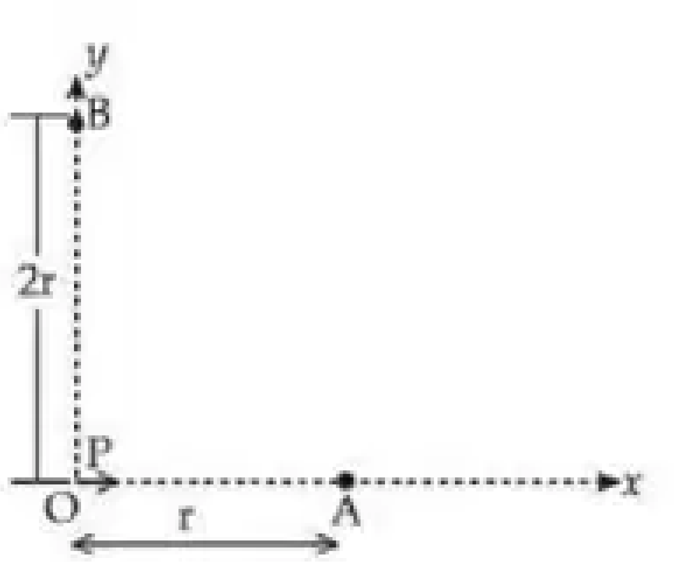
25. For a short dipole placed at origin O, the dipole moment P is along the x-axis, as shown in the figure. If the electric potential and electric field at A are V_0 and E_0 respectively, then the correct combination of the electric potential and electric field, respectively, at point B on the y-axis is given by: (+4, -1)



a. $\frac{V_0}{4}, \frac{E_0}{4}$

b. $0, \frac{E_0}{16}$

c. $\frac{V_0}{2}, \frac{E_0}{16}$

d. $\frac{E_0}{8}$

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26. Suppose a uniformly charged wall provides a uniform electric field of $2 \times 10^4\,\mathrm{N/C}$ normally. A charged particle of mass $2\,\mathrm{g}$ is suspended through a silk thread of length 20 cm and remains stayed at a distance of 10 cm from the wall. Then the charge on the particle will be **(+4, -1)**

$$\frac{1}{\sqrt{x}}\,\mu\mathrm{C},\ \text{where}\ x = \_.$$

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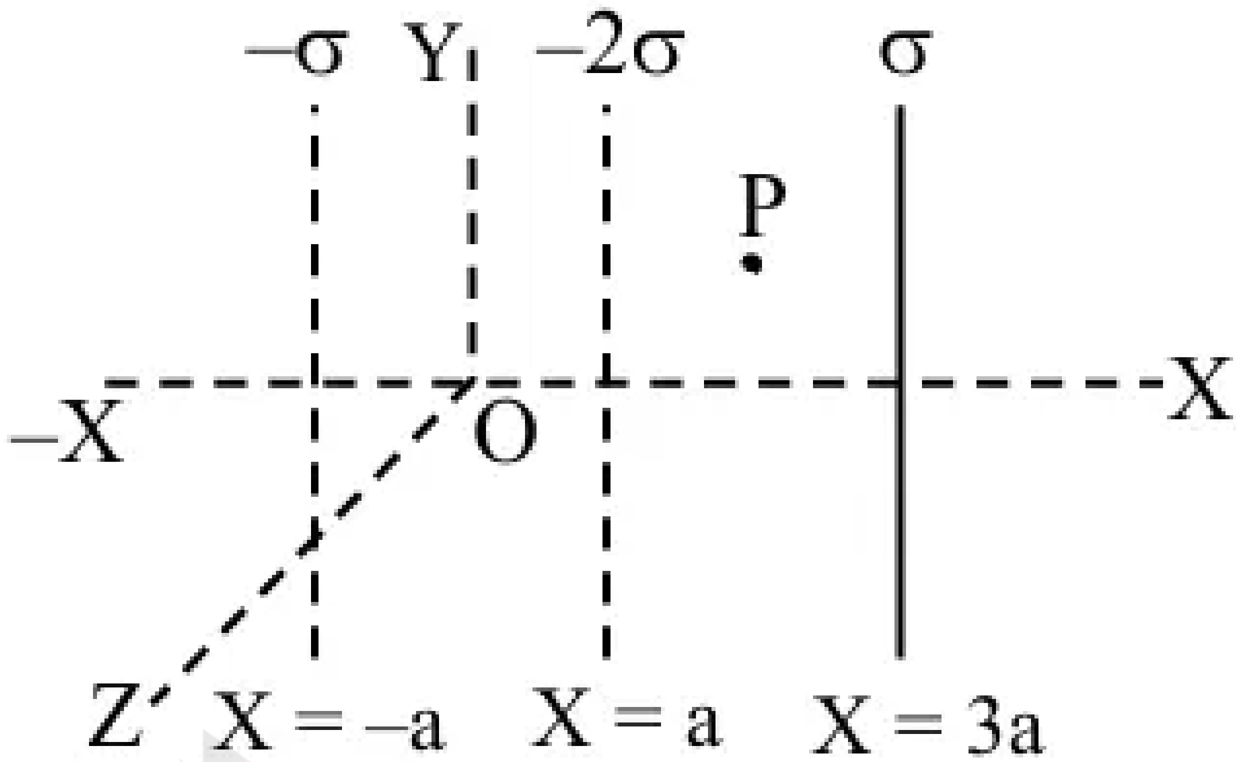
27. Three infinitely long charged thin sheets are placed as shown in the figure. The magnitude of the electric field at the point P is $\frac{x\sigma}{\epsilon_0}$. The value of x is _________. **(+4, -1)**

(All quantities are measured in SI units).



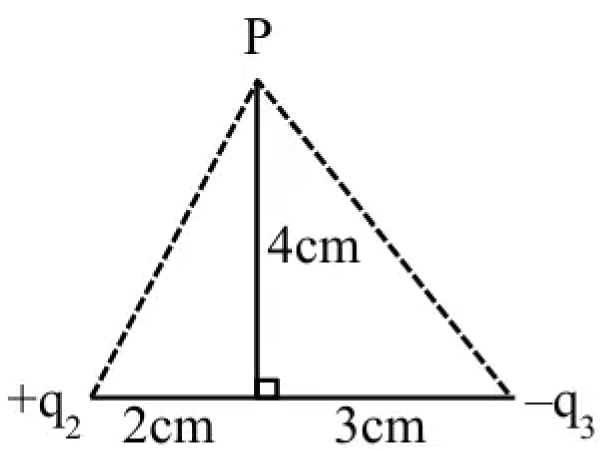
28. If the net electric field at point P along Y-axis is zero, then the ratio of **(+4, -1)**

$$\left|\frac{q_2}{q_3}\right|$$

is

$$\frac{8}{5\sqrt{x}},$$

where $x = \ldots\ldots\ldots\ldots\ldots$



29. The electric field at point p due to an electric dipole is E. The electric field at point R on equitorial line will be $\frac{E}{x}$. The value of x : **(+4, -1)**

30. The vehicles carrying inflammable fluids usually have metallic chains touching the ground : **(+4, -1)**

a. To conduct excess charge due to air friction to ground and prevent sparking.

b. To alert other vehicles.

c. To protect tyres from catching dirt from ground.

d. It is a custom.

Answers

1. **Answer: a**

Explanation:

To find the torque experienced by the electric dipole when it is rotated by 30°, we first need to understand the relationship between torque (τ), electric field (E), dipole moment (p), and the angle (θ) between the dipole and the electric field.

The torque (τ) experienced by a dipole of moment $\mathbf{p}$ in a uniform electric field $\mathbf{E}$ is given by the equation:

$\tau = pE \sin\theta$

Here, the dipole moment p is the product of the charge (q) and the separation distance (d):

$p = q \times d$

Given:

- Charge, $q = 2\,\mu C = 2 \times 10^{-6}\,C$
- Separation distance, $d = 0.5\,\mu m = 0.5 \times 10^{-6}\,m$
- Voltage, $V = 5\,V$
- Separation between capacitor plates, $s = 0.5\,mm = 0.5 \times 10^{-3}\,m$
- Angle, $\theta = 30^\circ$

First, calculate the electric field (E) using the voltage and separation:

$E = \frac{V}{s} = \frac{5}{0.5\times10^{-3}} = 10,000\,V/m$

Next, calculate the dipole moment:

$p = q \times d = (2 \times 10^{-6}) \times (0.5 \times 10^{-6}) = 1 \times 10^{-12}\,Cm$

Now, calculate the torque:

$\tau = pE \sin\theta = (1 \times 10^{-12}) \times (10,000) \times \sin 30^\circ$

Since $\sin 30^\circ = 0.5$:

$$\tau = (1 \times 10^{-12}\, Cm) \times (10,000\, V/m) \times 0.5 = 5 \times 10^{-9}\, Nm$$

Therefore, the torque is $5 \times 10^{-9}\, Nm$, which matches the correct answer option.

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2. **Answer: a**

Explanation:

The question presents an assertion and a reason concerning the safety features of an aircraft in the context of lightning strikes. Let's analyze both statements:

- **Assertion (A):** The outer body of an aircraft is made of metal which protects persons sitting inside from lightning strikes.
- **Reason (R):** The electric field inside the cavity enclosed by a conductor is zero.

Now, let's evaluate the statements:

Explanation:

1. The **Assertion (A)** states that the metal body of an aircraft offers protection against lightning by shielding the passengers inside. This is correct because lightning, which is a form of electrical discharge, will travel along the surface of a conductor—here, the metal fuselage—without penetrating inside. This phenomenon is explained by the Faraday Cage effect.
2. The **Reason (R)**

Thus, both statements are correct and the reason provided in (R) is indeed the correct explanation for (A). The outer metal body protects the passengers from lightning by utilizing the property that the electric field inside the conductor (the aircraft body) is zero, thanks to charge redistribution on the conductor's surface.

Conclusion:

The correct answer is: Both (A) and (R) are correct and (R) is the correct explanation of (A).

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3. **Answer: b**

Explanation:

Let the capacitance of the first capacitor be $C_1 = 100\,\text{pF}$ and its initial voltage be $V_i = 60\,\text{V}$.
The initial charge on the first capacitor is $Q_i = C_1 V_i = (100\,\text{pF})(60\,\text{V}) = 6000\,\text{pC}$.
A second uncharged capacitor with capacitance C_2 is connected in parallel to the first capacitor. When capacitors are connected in parallel, the voltage across them becomes equal.
The final voltage across the second capacitor is given as $V_f = 20\,\text{V}$.
Since they are in parallel, the final voltage across the first capacitor is also $V_f = 20\,\text{V}$.
The total charge in the system is conserved. The initial charge was only on the first capacitor, $Q_i = 6000\,\text{pC}$.
After connecting the second capacitor, this charge is distributed between the two capacitors.
The final charge on the first capacitor is $Q_{f1} = C_1 V_f = (100\,\text{pF})(20\,\text{V}) = 2000\,\text{pC}$.
The final charge on the second capacitor is $Q_{f2} = C_2 V_f = C_2(20\,\text{V})$.
By conservation of charge:

$$Q_i = Q_{f1} + Q_{f2}$$

$$6000\,\text{pC} = 2000\,\text{pC} + C_2(20\,\text{V})$$

$$4000\,\text{pC} = C_2(20\,\text{V})$$

$$C_2 = \frac{4000\,\text{pC}}{20\,\text{V}} = 200\,\text{pF}$$

The capacitance of the second capacitor is 200 pF. Alternatively, using the formula for the final voltage when a charged capacitor C_1 with initial voltage V_i is connected in parallel to an uncharged capacitor C_2:

$$V_f = \frac{C_1 V_i}{C_1 + C_2}$$

Given $V_f = 20\,\text{V}$, $C_1 = 100\,\text{pF}$, and $V_i = 60\,\text{V}$:

$$20 = \frac{(100)(60)}{100 + C_2}$$

$$20(100 + C_2) = 6000$$

$$2000 + 20C_2 = 6000$$

$$20C_2 = 4000$$

$$C_2 = \frac{4000}{20} = 200\,\mathrm{pF}$$

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4. **Answer: a**

Explanation:

In this problem, we need to find the electrostatic potential at the center, at a distance of 5 cm from the center, and at a distance of 15 cm from the center of a uniformly charged spherical shell with a given radius $R = 10\,\mathrm{cm}$. The surface potential is 120 V.

The concepts involved in this problem include:

1. The electrostatic potential V at any point inside a uniformly charged spherical shell is constant and equal to the potential on the surface of the shell. This is a result of the shell theorem.
2. Outside the shell, the potential V at a distance r from the center is given by the formula:

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

where k is Coulomb's constant and Q is the total charge on the shell.

Now, let's calculate the potential at each region mentioned:

1. **At the center of the shell:**
   - According to the properties of a spherical shell, the potential at any point inside is the same as on the surface. Therefore, the potential at the center is 120 V.
2. **At a distance $r = 5\,\mathrm{cm}$ from the center:**
   - This point is inside the spherical shell (since $5\,\mathrm{cm} < 10\,\mathrm{cm}$). Hence, the potential remains the same as on the surface. Thus, the potential is 120 V.
3. **At a distance $r = 15\,\mathrm{cm}$ from the center:**
   - This point is outside the spherical shell (since $15\,\mathrm{cm} > 10\,\mathrm{cm}$). We use the formula for the potential outside the shell:

$V = \frac{kQ}{15\,\mathrm{cm}}$

where $V = 120\,\mathrm{V}$ at $r = 10\,\mathrm{cm}$. Therefore, the potential at 15 cm is less than the surface potential and is calculated by:

$V_{15\text{ cm}} = \left(\frac{R}{15\text{ cm}}\right) \times 120 = \left(\frac{10}{15}\right) \times 120 = 80\text{ V}$

Thus, the potentials are:

- At the center: 120 V
- At $r = 5\,\text{cm}$: 120 V
- At $r = 15\,\text{cm}$: 80 V

The correct option is *120V, 120V, 80V.*

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5. **Answer: b**

Explanation:

Let $C_0 = \frac{\epsilon_0 A}{d}$

First Configuration: Area of plate is A.

Then $C = \frac{\epsilon_2 \epsilon_0 A}{d/2} = \frac{2\epsilon_2 \epsilon_0 A}{d} = 2\epsilon_2 C_0$ $C' = \frac{\epsilon_1 \epsilon_0 A}{d/2} = \frac{2\epsilon_1 \epsilon_0 A}{d} = 2\epsilon_1 C_0$ C and C' are in series.

$C_1 = \frac{CC'}{C+C'} = \frac{4\epsilon_1 \epsilon_2 C_0^2}{2C_0(\epsilon_2+\epsilon_1)}$

$C_1 = \frac{2\epsilon_2 \epsilon_1 C_0}{(\epsilon_2+\epsilon_1)}$

Second Configuration:

Here $C = \frac{\epsilon_1 \epsilon_0 A}{2d} = \frac{\epsilon_1 C_0}{2}$

$C' = \frac{\epsilon_2 C_0}{2}$ C and C' are in parallel.

$C_2 = C' + C = (\epsilon_1 + \epsilon_2)\frac{C_0}{2}$

Thus $\frac{C_1}{C_2} = \frac{2\epsilon_1 \epsilon_2 C_0}{(\epsilon_2+\epsilon_1)} \times \frac{2}{(\epsilon_1+\epsilon_2)C_0}$ $\frac{C_1}{C_2} = \frac{4\epsilon_1 \epsilon_2}{(\epsilon_2+\epsilon_1)^2}$

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6. **Answer: a**

Explanation:

We are given that: The charge q_1 and q_2 are separated by 30 cm. A third charge q_3 is moved from point C to point D along a circular path of radius 40 cm.

The change in potential energy is given by $\frac{q_3 K}{4\pi\epsilon_0}$.
The potential energy of a system of charges is given by:

$$U = \frac{q_1 q_2}{4\pi\epsilon_0 r}$$

Where r is the distance between the charges. In this case, the distance changes as q_3 moves from C to D.
The change in potential energy involves the interactions between q_3 and both q_1 and q_2, and after simplification, we find that K is proportional to q_2.
Final Answer (1) $8q_2$

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7. Answer: c

Explanation:

The given problem involves calculating the effective capacitance between points A and B in a circuit of capacitors. We have three capacitors, C_1, C_2, and C_3, each with a capacitance of 5 μF. The capacitor C_1 has a dielectric medium with a dielectric constant of 4.

Step-by-step Solution:

1. The dielectric affects C_1, increasing its capacitance by the factor of the dielectric constant:

$$C_1' = \kappa \cdot C_1 = 4 \cdot 5\,\mu\text{F} = 20\,\mu\text{F}$$

1. Now, we have C_1' with 20 μF, C_2 with 5 μF, and C_3 with 5 μF.
2. C_1' and C_2 are in series, so their equivalent capacitance C_{12} is calculated as follows:

$$\frac{1}{C_{12}} = \frac{1}{C_1'} + \frac{1}{C_2} = \frac{1}{20} + \frac{1}{5} = \frac{1}{20} + \frac{4}{20} = \frac{5}{20}$$

1.

$$C_{12} = \frac{20}{5} = 4\,\mu\text{F}$$

1. C_{12} is in parallel with C_3, so the total capacitance C_{total} is:

$$C_{\text{total}} = C_{12} + C_3 = 4\,\mu\text{F} + 5\,\mu\text{F} = 9\,\mu\text{F}$$

Conclusion:

The effective capacitance between points A and B is 9 μF. The correct answer is **9 μF**.

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8. Answer: 15 - 15

Explanation:

The problem involves calculating the effective capacitance of a parallel plate capacitor arrangement with two dielectric materials and another capacitor connected in parallel.

First, the capacitance of the given capacitor with dielectric materials can be calculated. This capacitor is split into two capacitors in series due to the different dielectric constants.

Using the capacitance formula for a parallel plate capacitor: $C = \frac{k\varepsilon_0 A}{d}$, where k is the dielectric constant, ε_0 is the permittivity of free space $(8.85 \times 10^{-12}\,\text{F/m})$, A is the area, and d is the separation.

Calculate the capacitance for each layer:

1. Top layer $(k_1 = 5)$: $C_1 = \frac{k_1\varepsilon_0 A}{d/2} = \frac{5\times 8.85\times 10^{-12}\times 4\times 10^{-4}}{0.885\times 10^{-3}}$
2. Bottom layer $(k_2 = 3)$: $C_2 = \frac{k_2\varepsilon_0 A}{d/2} = \frac{3\times 8.85\times 10^{-12}\times 4\times 10^{-4}}{0.885\times 10^{-3}}$

Calculate C_1 and C_2:

- $C_1 = 2 \times 10^{-12}\,\text{F}$
- $C_2 = 1.2 \times 10^{-12}\,\text{F}$

The series combination C_s is given by:

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} \implies C_s = \frac{C_1 \times C_2}{C_1 + C_2} = \frac{(2\times 10^{-12})\times(1.2\times 10^{-12})}{2\times 10^{-12} + 1.2\times 10^{-12}} = 0.75 \times 10^{-12}\,\text{F}$$

Convert to picofarads: $C_s = 7.5\,\text{pF}$.

Another 7.5 pF capacitor is connected in parallel, so the effective capacitance C_{eff} is:

$$C_{\text{eff}} = C_s + 7.5 = 7.5 + 7.5 = 15\,\text{pF}.$$

The computed capacitance falls within the given range of [15,15] pF.

Therefore, the effective capacitance is **15 pF**.

---

9. **Answer: 2 - 2**

Explanation:

Let the momentum of the electron at any time t be p, and its de-Broglie wavelength is λ.

Then, the momentum is given by:

$$p = \frac{h}{\lambda}$$

The rate of change of momentum is:

$$\frac{dp}{dt} = -\frac{h}{\lambda^2}\frac{d\lambda}{dt}$$

Now, using $ma = F$ (where m is the mass of the electron), we have:

$$ma = -\frac{h}{\lambda}\frac{d\lambda}{dt}$$

Where the negative sign represents a decrease in λ with time.

From the above equation:

$$ma = -\frac{h}{\left(\frac{h}{p}\right)^2}\frac{d\lambda}{dt}$$

Simplifying further:

$$a = -\frac{p^2}{mh}\frac{d\lambda}{dt}$$

$$a = -\frac{mv^2}{h}\frac{d\lambda}{dt}$$

From this, we can find:

$$\frac{d\lambda}{dt} = -\frac{ah}{mv^2} \quad \cdots (1)$$

Here, $a = \frac{qE}{m} = \frac{e}{m}\frac{\sigma}{2\epsilon_0}$

Also, $v = u + at$, and since $u = 0$, we have:

$v = at$

Substituting the values of a and v in equation (1):

$\frac{d\lambda}{dt} = -\frac{2h\epsilon_0}{\sigma e t^2}$

Thus, we get:

$\frac{d\lambda}{dt} \propto \frac{1}{t^2}$

Therefore, $n = 2$

---

10. Answer: c

Explanation:

To solve this problem, we need to use the concept of surface charge density on a conductor. The key principle here is that charge tends to accumulate on parts of a conductive surface that are more curved, i.e., where the radius of curvature is smaller. This means sharper points on a conductor will have higher charge density.

Consider the points on the irregular metallic disk:

- σ_1 is at a sharp corner, which generally has a higher curvature.
- σ_2 and σ_4 are at relatively flatter regions.
- σ_3 is also at a sharper point, similar to σ_1.

Based on these observations:

1. The charge density, σ_1, is likely greater than both σ_2 and σ_4 because σ_1 is at a more curved (sharper) point.
2. The charge density, σ_3, might also be high because it shares high curvature (acuity) with σ_1.
3. The charge densities at σ_2 and σ_4 are likely lower since the surface is flatter, meaning these points have a larger radius of curvature.

Therefore, comparing the options:

- **Option A**: $\sigma_1 > \sigma_3; \sigma_2 = \sigma_4$ - Possible as σ_1 is in a more sharply curved area.
- **Option B**: $\sigma_1 > \sigma_2; \sigma_3 > \sigma_4$ - Possible as it maintains the relative positions based on curvature.

- **Option C:** $\sigma_1 > \sigma_3 > \sigma_2 = \sigma_4$ - This aligns well with our understanding, as sharper points have higher density than flatter ones.
- **Option D** and **Option E** are incorrect based on the principles of charge accumulation.

The correct answer is: **A, B, and C Only**.

---

11. Answer: d

Explanation:

To solve this problem, we need to understand how charge distribution occurs when two conducting spheres are brought into contact and then separated.

1. Given two metal spheres with radii R and $3R$ and the same initial surface charge density σ, the charges Q_1 and Q_2 on these spheres can be calculated as:
   - The surface area of the smaller sphere = $4\pi R^2$
   - The surface area of the larger sphere = $4\pi(3R)^2 = 36\pi R^2$
   - Initial charge on smaller sphere $Q_1 = \sigma \times 4\pi R^2$
   - Initial charge on larger sphere $Q_2 = \sigma \times 36\pi R^2$
2. Total initial charge before contact:
   - $Q_{\text{total}} = Q_1 + Q_2 = \sigma \times 4\pi R^2 + \sigma \times 36\pi R^2 = 40\pi R^2\sigma$
3. When both spheres are brought into contact, charge will redistribute based on the spheres' capacitances (which are proportional to their radii). The smaller sphere has radius R and the larger sphere has radius $3R$.
4. Total capacitance is $C_{\text{total}} = R + 3R = 4R$. Charge is distributed in direct proportion to capacitance:
   - Charge on smaller sphere after separation $Q_1' = \frac{R}{4R} \times 40\pi R^2\sigma = 10\pi R^2\sigma$
   - Charge on larger sphere after separation $Q_2' = \frac{3R}{4R} \times 40\pi R^2\sigma = 30\pi R^2\sigma$
5. Surface charge density after separation:
   - $\sigma_1 = \frac{Q_1'}{4\pi R^2} = \frac{10\pi R^2\sigma}{4\pi R^2} = 2.5\sigma$
   - $\sigma_2 = \frac{Q_2'}{36\pi R^2} = \frac{30\pi R^2\sigma}{36\pi R^2} = \frac{5\sigma}{6}$
6. Hence, the ratio $\frac{\sigma_1}{\sigma_2}$ is calculated as:
   - $\frac{\sigma_1}{\sigma_2} = \frac{2.5\sigma}{\frac{5\sigma}{6}} = \frac{2.5\times6}{5} = 3$

The correct answer is therefore the ratio $\frac{\sigma_1}{\sigma_2} = 3$.

---

12. **Answer: b**

Explanation:

To determine the correct answer, let's analyze the assertion and the reason given:

1. **Assertion (A):** Work done in moving a test charge between two points inside a uniformly charged spherical shell is zero, no matter which path is chosen.
2. **Reason (R):** Electrostatic potential inside a uniformly charged spherical shell is constant and is the same as that on the surface of the shell.

Now, let's examine each statement:

1. The assertion states that the work done inside a uniformly charged spherical shell is zero when moving a test charge between two points. This statement is true because, according to Gauss's Law, the electric field inside a uniformly charged spherical shell is zero. Therefore, no work is done (work = force × distance) as there is no electric force acting on the test charge inside the shell.
2. The reason states that the electrostatic potential inside the shell is constant and is the same as on the surface. This is also true. The potential inside a uniformly charged spherical shell is constant because the electric field inside the shell is zero, leading to no change in potential with movement. Additionally, this potential value is equal to the potential on the surface of the shell.

Both statements are true. Furthermore, the constancy of the potential (Reason) is the explanation for why no work is done (Assertion). In electrostatics, when the potential is constant, the work done in moving a charge is zero. Hence, Reason (R) correctly explains Assertion (A).

Therefore, the correct answer is:

Both A and R are true and R is the correct explanation of A

---

13. **Answer: a**

Explanation:

We are given two statements:
Assertion (A): Work done to move a charge between two points is zero inside a uniformly charged shell.
Reason (R): Potential inside a uniformly charged shell is constant and equal to the potential at its surface.

Step 1: Verifying Assertion (A)
The work done to move a charge between two points is zero when the points lie within a region of constant potential.
According to Gauss's Law, the electric field inside a uniformly charged spherical shell is zero, meaning there is no force acting on the charge inside the shell.
Since there is no force, no work is done in moving the charge inside the shell.
Therefore, assertion (A) is correct.
Step 2: Verifying Reason (R)
The potential inside a uniformly charged spherical shell is constant and equal to the potential at its surface.
This is a consequence of the fact that the electric field inside a spherical shell is zero, and therefore, the potential inside must be uniform.
The potential inside the shell is the same as the potential on the surface of the shell.
Therefore, reason (R) is also correct.
Step 3: Relation between Assertion and Reason
Since both assertion (A) and reason (R) are correct and the reason explains the assertion, the correct option is (1).

---

14. Answer: c

Explanation:

Step 1: Charge Redistribution When two conducting spheres are in contact, charge will redistribute between them until the electric potential on both spheres is the same. Let the initial charges on the spheres be Q_1 and Q_2 for the spheres of radii R and $3R$ respectively. ###
Step 1: Charge Redistribution When the spheres touch, the potential on both spheres becomes equal.
The potential on a sphere is given by:

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

where k is Coulomb's constant, Q is the charge, and R is the radius of the sphere. Since the potentials are equal after they touch, we have:

$$\frac{kQ_1}{R} = \frac{kQ_2}{3R}$$

Simplifying this equation:

$$Q_1 = \frac{Q_2}{3}$$

###
Step 2: Total Charge Conservation Let the total charge be Q_{total}.
Since charge is conserved:

$$Q_1 + Q_2 = Q_{\text{total}}$$

Substituting $Q_1 = \frac{Q_2}{3}$ into this:

$$\frac{Q_2}{3} + Q_2 = Q_{\text{total}}$$

$$\frac{4Q_2}{3} = Q_{\text{total}} \quad \Rightarrow \quad Q_2 = \frac{3Q_{\text{total}}}{4}$$

Thus, $Q_1 = \frac{Q_{\text{total}}}{4}$. ###
Step 3: Surface Charge Densities The surface charge density σ on a sphere is given by:

$$\sigma = \frac{Q}{A} = \frac{Q}{4\pi r^2}$$

For the sphere with radius R, the surface charge density σ_1 is:

$$\sigma_1 = \frac{Q_1}{4\pi R^2} = \frac{\frac{Q_{\text{total}}}{4}}{4\pi R^2} = \frac{Q_{\text{total}}}{16\pi R^2}$$

For the sphere with radius $3R$, the surface charge density σ_2 is:

$$\sigma_2 = \frac{Q_2}{4\pi(3R)^2} = \frac{\frac{3Q_{\text{total}}}{4}}{4\pi(9R^2)} = \frac{3Q_{\text{total}}}{36\pi R^2} = \frac{Q_{\text{total}}}{12\pi R^2}$$

###
Step 4: Ratio of Surface Charge Densities Now, the ratio of the surface charge densities is:

$$\frac{\sigma_1}{\sigma_2} = \frac{\frac{Q_{\text{total}}}{16\pi R^2}}{\frac{Q_{\text{total}}}{12\pi R^2}} = \frac{12}{16} = \frac{3}{4}$$

Thus, the ratio of $\frac{\sigma_1}{\sigma_2}$ is 3, so the correct answer is (3).

---

15. Answer: a

Explanation:

We are given the linear charge density λ, which is the charge per unit length, and the wire passes through the body diagonal of a cube with a side length $\sqrt{3}\,\text{cm}$.
1. **Flux Calculation:** The total flux Φ through a closed surface due to a linear charge distribution is given by Gauss's law:

$$\Phi = \frac{q_{\text{enclosed}}}{\epsilon_0}.$$

Since the wire is passing through the body diagonal of the cube, it divides the cube into two parts. The flux through the cube depends on how much of the wire is inside the cube.
The total charge enclosed by the cube is the charge on the length of the wire that passes through the body diagonal. The length of the body diagonal of the cube is:

$$L = \sqrt{3} \times \text{side length of the cube} = \sqrt{3} \times \sqrt{3}\,\text{cm} = 3\,\text{cm}.$$

2. **Charge on the wire:** The total charge q_{enclosed} on the wire is given by:

$$q_{\text{enclosed}} = \lambda \times L = \frac{2nc}{m} \times 3.$$

3. **Using Gauss's Law:** We apply Gauss's law for the flux through the cube, noting that the flux is proportional to the charge enclosed. The flux will be:

$$\Phi = \frac{q_{\text{enclosed}}}{\epsilon_0} = 1.44\pi.$$

Thus, the correct answer is 1.44π.

---

16. Answer: a

Explanation:

When two charged spheres touch each other, charge redistributes between them. The surface charge density σ is given by:

$$\sigma = \frac{Q}{A},$$

where Q is the charge on the sphere and A is the surface area of the sphere.
- The charge on a sphere is proportional to its radius, i.e., $Q \propto R^2$, where R is the radius of the sphere.
- When the spheres are in contact, they share charge. The total charge on the system is conserved, but the redistribution of charge depends on the radii of the spheres.
Let the charges on the spheres be Q_1 and Q_2, corresponding to radii R and $3R$, respectively. Since charge is proportional to the surface area, we can express the charge densities after they touch as:

$$r_1 = \frac{Q_1}{4\pi R^2}, \quad r_2 = \frac{Q_2}{4\pi (3R)^2}.$$

The total charge is conserved, and since the radii of the spheres are different, the surface charge density will be inversely proportional to the square of the radius. Using this relationship:

$$\frac{r_1}{r_2} = \frac{Q_1/(4\pi R^2)}{Q_2/(4\pi (3R)^2)} = \frac{Q_1/R^2}{Q_2/9R^2} = \frac{Q_1}{Q_2} \times 9.$$

Since the total charge is conserved, the ratio $\frac{Q_1}{Q_2} = \frac{1}{9}$, giving:

$$\frac{r_1}{r_2} = \frac{1}{9}.$$

Thus, the correct answer is (1) $\frac{1}{9}$.

---

17. **Answer: b**

Explanation:

The potential due to a spherical shell is constant at all points outside the shell, and it is also constant at any point on the shell. The potential inside the shell is the same as at the surface. Therefore: - At the center of the shell, the potential is equal to the surface potential, which is 120 V. - At a distance 5 cm from the center, inside the shell, the potential is also 120 V, as the potential inside a spherical shell is constant. - At a distance 15 cm from the center, outside the shell, the potential is 80 V (due to the decrease in potential with distance from the shell). Thus, the correct answer is $120\,\text{V}, 120\,\text{V}, 80\,\text{V}$.

---

18. **Answer: 300 - 300**

Explanation:

The point charge is in equilibrium at rest. Hence, the forces on the point charge must balance out. The force due to the gravitational pull is counteracted by the electrostatic force.
The forces acting on the point charge are:
- The electrostatic force, F_e, due to the other charge.
- The gravitational force, mg, acting downward.

Since the system is in equilibrium, the electrostatic force is balanced by the component of gravitational force along the plane:

$$F_e = mg\sin\theta$$

Now, we know the formula for the electrostatic force between two point charges:

$$F_e = \frac{kq_0^2}{r^2}$$

Where:
- $k = 9 \times 10^9\,\text{N} \cdot \text{m}^2 \cdot \text{C}^{-2}$,
- $q_0 = 2 \times 10^{-6}\,\text{C}$ (the charge),
- r is the distance between the charges, which is related to h by the geometry of the inclined plane, where $r = \frac{h}{\sin\theta}$.
Substituting the values into the equation:

$$\frac{kq_0^2}{r^2} = mg\sin 30^\circ$$

Substituting the known values:

$$\frac{9 \times 10^9 \times (2 \times 10^{-6})^2}{\left(\frac{h}{\sin 30^\circ}\right)^2} = 20 \times 10^{-3} \times 10 \times \sin 30^\circ$$

Solving this equation:

$$h^2 = 9 \times 10^{10} \Rightarrow h = 300 \times 10^{-3}\,\text{m}$$

Thus, the value of x is 300.

---

19. Answer: d

Explanation:

The energy stored in a capacitor is given by the formula:

$$E = \frac{1}{2} C V^2$$

For a single capacitor with capacitance $C = 2\,\text{F}$, the energy is:

$$E_1 = \frac{1}{2} \times 2 \times V^2 = V^2$$

Now, the two capacitors are connected in parallel, and the total capacitance becomes:

$$C_{\text{total}} = C + C = 2C = 4\,\text{F}$$

The energy in the parallel combination is:

$$E_5 = \frac{1}{2} \times 4 \times V^2 = 2V^2$$

Now, the ratio of the energies is:

$$\frac{E_5}{E_1} = \frac{2V^2}{V^2} = 2$$

Thus, the ratio of the energies is $2 : 1$.

---

20. Answer: b

Explanation:

The power dissipated in a resistor is given by the formula:

$$P = \frac{V^2}{R}$$

For two identical resistors, the heat produced in parallel and series configurations is as follows:
For parallel connection, the effective resistance is $R_{\text{eff}} = \frac{R}{2}$, and the power is:

$$P_{\text{parallel}} = \frac{V^2}{R/2} = 2\frac{V^2}{R}$$

For series connection, the effective resistance is $R_{\text{eff}} = 2R$, and the power is:

$$P_{\text{series}} = \frac{V^2}{2R}$$

Now, the ratio of heat produced in parallel to series is:

$$\frac{P_{\text{parallel}}}{P_{\text{series}}} = \frac{2\frac{V^2}{R}}{\frac{V^2}{2R}} = 4$$

Thus, the ratio of heat produced is $4:1$.

---

21. Answer: a

Explanation:

According to Gauss's law, the electric flux through a closed surface is related to the charge enclosed by the surface:

$$\Phi_E = \frac{q}{\epsilon_0}$$

where Φ_E is the electric flux, q is the charge, and ϵ_0 is the permittivity of free space. Given that $\Phi_E = -2 \times 10^4 \,\text{Nm}^2\text{C}^{-1}$ and the radius of the Gaussian surface is $r = 8.0\,\text{cm}$, we can solve for the charge q as:

$$q = \Phi_E \times \epsilon_0 = (-2 \times 10^4) \times (8.85 \times 10^{-12}) = 17.7 \times 10^{-7}\,\text{C}$$

---

22. **Answer: c**

Explanation:

The electric field due to an infinite plane sheet of charge is given by:

$$E = \frac{\sigma}{2\epsilon_0}$$

The electric field is uniform, and there is no variation in the field across the dipole, meaning the torque on the dipole is zero.
Also, the dipole is in the minimum potential energy configuration when aligned with the electric field, and the net force on the dipole due to the uniform electric field is zero.
Therefore, the potential energy of the dipole is minimum, and the torque is zero.

---

23. **Answer: a**

Explanation:

To solve the given problem, we need to match the scenarios described in List I with their corresponding electric field expressions from List II. Let's analyze each scenario:

List I:

1. **(A) Electric field inside a uniformly charged spherical shell:** For a uniformly charged spherical shell, the electric field inside (distance $r > 0$ from the center) is zero, due to the symmetry of the shell. This matches with **List II: (III)**.
2. **(B) Electric field at distance $r > 0$ from a uniformly charged infinite plane sheet:** The electric field due to an infinite plane sheet with surface charge density σ is given by $\frac{\sigma}{2\epsilon_0}$, regardless of the distance from the sheet. This matches with **List II: (II)**.
3. **(C) Electric field outside a uniformly charged spherical shell:** At a point outside a uniformly charged spherical shell, the electric field is the same as if all the charge were concentrated at the center, given by $\frac{\sigma}{\epsilon_0 r^2}$.
4. **(D) Electric field between two oppositely charged infinite plane parallel sheets:** The electric field between two oppositely charged infinite planes each with surface charge density σ results in a field $\frac{\sigma}{\epsilon_0}$. This matches with **List II: (I)**.

Matching results:

Thus, the matches are:

- (A) - (III)
- (B) - (II)
- (C) - (IV)
- (D) - (I)

The correct answer from the options is:

(A)-(III),(B)-(II),(C)-(IV),(D)-(I)

---

24. Answer: b

Explanation:

Step 1: Understanding Resistivity in Semiconductors
The resistivity ρ of a semiconductor is given by:

$$\rho = \frac{m}{ne^2\tau}$$

where: - m is the electron mass, - n is the number density of charge carriers, - e is the charge of an electron, - τ is the relaxation time.
Step 2: Effect of Temperature on Resistivity
In semiconductors, as temperature increases: The number density n of charge carriers increases significantly due to thermal excitation. The relaxation time τ decreases due to increased scattering.
However, the increase in n dominates over the decrease in τ, leading to a net decrease in resistivity.
Step 3: Choosing the Correct Curve
Since resistivity decreases exponentially with increasing temperature in a semiconductor, the correct curve must show a steep downward trend. The given image confirms that Curve (b) represents this behavior. **Final Answer:** The correct behavior of resistivity with temperature in a semiconductor is represented by Curve (b).

---

25. Answer: b

Explanation:

Step 1: Compute the electric potential at point B. The electric potential due to a dipole at any point is given by:

$$V = \frac{1}{4\pi\epsilon_0}\frac{\mathbf{p}\cdot\hat{r}}{r^2}.$$

Since point B is on the perpendicular bisector of the dipole, $\mathbf{p}\cdot\hat{r} = 0$, implying:

$$V_B = 0.$$

Step 2: Compute the electric field at point B. The magnitude of the electric field along the perpendicular bisector of a dipole is:

$$E = \frac{1}{4\pi\epsilon_0}\frac{p}{(r^2+d^2)^{3/2}}.$$

For small dipole approximation $d \ll r$, we use:

$$E_B = \frac{E_0}{16}.$$

Thus, the answer is $\boxed{0, \frac{E_0}{16}}$.

---

26. Answer: 3 - 3

Explanation:

Problem Setup:

We have a charged object placed in a uniform electric field $\vec{E}$, where the field makes an angle θ with the horizontal. The object is subjected to the force due to the electric field, and gravity. The setup is shown in the diagram, where the object is in equilibrium, and we are to find the value of the charge q on the object.

Step 1: Relation between the forces

From the diagram, we know the force due to the electric field is $\vec{F}_E = q\vec{E}$ and the gravitational force is mg. In equilibrium, the forces balance out, and we can use trigonometry to relate the angle θ and the forces.

The equation for the forces in equilibrium can be written as:

$$\tan\theta = \frac{F_E}{mg} = \frac{qE}{mg}$$

Step 2: Given values

From the problem statement, the angle $\theta = 30^\circ$, the distance $d = 10\,\text{cm} = 0.1\,\text{m}$, and the electric field $E = 2 \times 10^4\,\text{N/C}$. The equation for tangent becomes:

$$\tan 30^\circ = \frac{q \times 2 \times 10^4}{1 \times 10^{-3} \times 10}$$

Step 3: Solving for q

Using $\tan 30^\circ = \frac{1}{\sqrt{3}}$, we can solve for the charge q:

$$\frac{1}{\sqrt{3}} = \frac{q \times 2 \times 10^4}{1 \times 10^{-3} \times 10}$$

Simplifying this expression gives:

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

Conclusion:

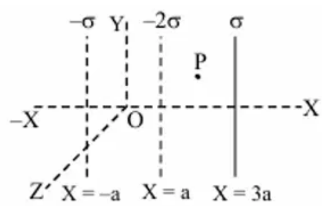
The charge on the object is $q = 10^{-6}\,\text{C}$, which matches the expected result of $\boxed{3} \times 10^{-6}\,\text{C}$

---

27. Answer: 2 - 2

Explanation:

The electric field at P is the vector sum of the fields due to the three charged sheets.



Using Gauss's Law:

$$\vec{E} = \frac{\sigma}{2\epsilon_0}$$

For the point P:

$$\vec{E}_P = \left(\frac{\sigma}{2\epsilon_0} + \frac{2\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0}\right)(-\hat{i})$$

Simplify:

$$\vec{E}_P = \frac{4\sigma}{2\epsilon_0}(-\hat{i}) = \frac{2\sigma}{\epsilon_0}(-\hat{i})$$

Thus, $x = 2$.

---

28. Answer: 5 - 5

Explanation:

To find the ratio $\left|\frac{q_2}{q_3}\right|$, where the net electric field at point P along the Y-axis is zero, we analyze the system of charges. Given:
1. $+q_2$ is located 2 cm from the point P.
2. $-q_3$ is located 3 cm from the point P.
Point P is vertically 4 cm above the line connecting q_2 and q_3.

Step-by-step Solution:
The net electric field E at point P due to charges q_2 and q_3 must be zero.

$$E_2 \cdot \sin\theta_2 + E_3 \cdot \sin\theta_3 = 0$$

Where E_2 and E_3 are the magnitudes of the electric fields due to q_2 and q_3, respectively. Using the Pythagorean theorem, the distances from the charges to P are:
$r_2 = \sqrt{2^2 + 4^2} = \sqrt{20}$ cm
$r_3 = \sqrt{3^2 + 4^2} = \sqrt{25}$ cm = 5 cm

The electric field magnitudes are given by:

$$E_2 = \frac{k|q_2|}{r_2^2} \quad \text{and} \quad E_3 = \frac{k|q_3|}{r_3^2}$$

The sine components are derived from the respective angles:

$$\sin\theta_2 = \frac{4}{\sqrt{20}} = \frac{2}{\sqrt{5}} \quad \text{and} \quad \sin\theta_3 = \frac{4}{5}$$

For the fields to cancel each other:

$$\frac{k|q_2|}{20} \cdot \frac{2}{\sqrt{5}} = \frac{k|q_3|}{25} \cdot \frac{4}{5}$$

$$\frac{2|q_2|}{20\sqrt{5}} = \frac{4|q_3|}{125}$$

Solving for $\left|\frac{q_2}{q_3}\right|$:

$$\frac{|q_2|}{|q_3|} = \frac{4 \cdot 20\sqrt{5}}{2 \cdot 125} = \frac{80\sqrt{5}}{250} = \frac{8}{5\sqrt{5}}$$

Finding x:
The problem gives $\frac{8}{5\sqrt{x}}$. Comparing with $\frac{8}{5\sqrt{5}}$:
Hence, $x = 5$.

Verification Against Range:
The computed value $x = 5$ fits the given range (5,5) perfectly.

---

29. **Answer: 16 - 16**

Explanation:

Given:
- Electric field at point P on the axial line: $E_P = E = \frac{2Kp}{r^3}$

- Electric field at point R on the equatorial line: $E_R = \frac{Kp}{(2r)^3}$, where:
- K is the Coulomb constant,
- p is the dipole moment,
- r is the distance from the dipole center to the point of observation.

Step 1: Calculate the Electric Field at R
The electric field at point R on the equatorial line is given by:

$$E_R = \frac{Kp}{(2r)^3}.$$

Simplify $(2r)^3$:

$$E_R = \frac{Kp}{8r^3}.$$

Step 2: Compare the Electric Fields
The electric field at P on the axial line is:

$$E_P = \frac{2Kp}{r^3}.$$

The electric field at R is related to E_P as:

$$E_R = \frac{E_P}{x}.$$

Substitute $E_P = \frac{2Kp}{r^3}$ and $E_R = \frac{Kp}{8r^3}$:

$$\frac{Kp}{8r^3} = \frac{2Kp}{xr^3}.$$

Step 3: Solve for x
Simplify the equation:

$$\frac{Kp}{8r^3} = \frac{2Kp}{xr^3}.$$

Cancel Kp and r^3 (as they are non-zero):

$$\frac{1}{8} = \frac{2}{x}.$$

Rearrange to solve for x:

$$x = 2 \times 8 = 16.$$

Thus, the value of x is 16.

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30. Answer: a

Explanation:

When vehicles move, particularly at high speeds, friction between the vehicle body and the air can cause the accumulation of static electric charge on the surface of the vehicle. For vehicles carrying inflammable fluids, the presence of static electricity poses a significant risk as it can lead to sparking, which may cause combustion or an explosion if the fluid is highly flammable.
To mitigate this risk, metallic chains are often attached to such vehicles, ensuring that they touch the ground. The metallic chains provide a conductive path for the excess static charge to flow safely to the ground, thereby preventing the buildup of static electricity and reducing the risk of sparking.