Electrostatics JEE Main PYQ - 3

Total Time: 25 Minute **Total Marks:** 40

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 uniformly charged solid sphere of radius R has potential V_0 9 measured with respect to ∞) on its surface. For this sphere the equipotential surfaces with potentials $\frac{3V_0}{2}$, $\frac{5V_0}{4}$, $\frac{3V_0}{4}$ and $\frac{V_0}{4}$ have radius R_1, R_2, R_3 and R_4 respectively. Then **(+4, -1)**

[2015]

a. $R_1 \neq 0$ and $(R_2 - R_1) > (R_4 - R_3)$

b. $R_1 = 0$ and $R_2 > (R_4 - R_3)$

c. $2R < R_4$

d. $R_1 = 0$ and $R_2 < (R_4 - R_3)$

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2. Assume that an electric field $\vec{E} = 30x^2\hat{i}$ exists in space. Then the potential difference $V_A - V_{O'}$ where V_O is the potential at the origin and V_A the potential at $x = 2\,m$ is **(+4, -1)**

[2014]

a. 120 J

b. -120 J

c. -80 J

d. 80 J

---

3. In the following figure is shown a system of four capacitors connected across a $10\,V$ battery. Charge that will flow from switch S when it is closed is **(+4, -1)**

[Online April 11, 2015]

a. 5 μC from b to a

b. 20 μC from a to b

c. 5 μC from a to b

d. $zero$

---

4. In the circuit shown, find C if the effective capacitance of the whole circuit is to be $0.5\mu F$. All values in the circuit are in μF. **(+4, -1)**

[12 Jan. 2019 II]

a. $\frac{7}{10}\mu F$

b. $\frac{7}{11}\mu F$

c. $\frac{6}{5}\mu F$

d. $4\mu F$

---

5. In the figure shown, after the switch $'S'$ is turned from position $'A'$ to position $'B'$, the energy dissipated in the circuit in terms of capacitance $'C'$ and total charge $'Q'$ is: **(+4, -1)**

[12 Jan. 2019 I]

a. $\frac{3}{8}\frac{Q^2}{C}$

b. $\frac{4}{3}\frac{Q^2}{C}$

c. $\frac{1}{8}\frac{Q^2}{C}$

d. $\frac{5}{8}\frac{Q^2}{C}$

---

6. In the figure shown below, the charge on the left plate of the $10\ \mu F$ capacitor is $-30\ \mu C$. The charge on the right plate of the $6\ \mu F$ capacitor is : **(+4, -1)**

[11 Jan. 2019 I]

a. $-18\ \mu C$

b. $-12\ \mu C$

c. $+12\ \mu C$

d. $+18\ \mu C$

---

7. Voltage rating of a parallel plate capacitor is $500\,V$. Its dielectric can withstand a maximum electric field of 10^6 V/m. The plate area is $10^{-4}\ m^2$. What is the dielectric constant is the capacitance is $15\,pF$? (given $\in_0 = 8.86 \times 10^{-12} C^2/Nm^2$) **(+4, -1)**

[8 April 2019 I]

a. 3.8

b. 4.5

c. 6.2

d. 8.5

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8. The surface charge density of a thin charged disc of radius R is σ. The value of the electric field at the centre of the disc is $\frac{\sigma}{2\epsilon_0}$. With respect to the field at the centre, the electric field along the axis at a distance R from the centre of the disc : **(+4, -1)**

a. reduces by 70.7%

b. reduces by 29.3%

c. reduces by 9.7%

d. reduces by 14.6%

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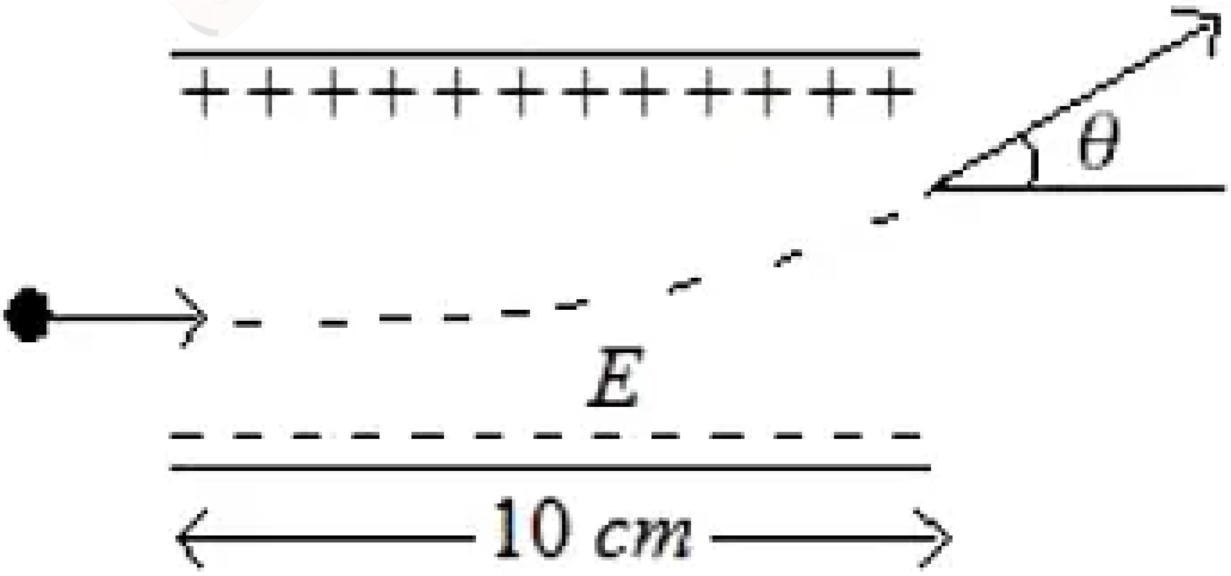
9. A uniform electric field of $10 N/C$ is created between two parallel charged plates (as shown in figure) An electron enters the field symmetrically between the plates with a kinetic energy $05 eV$ The length of each plate is $10 cm$ The angle (θ) of deviation of the path of electron as it comes out of the field is ___ (in degree) **(+4, -1)**



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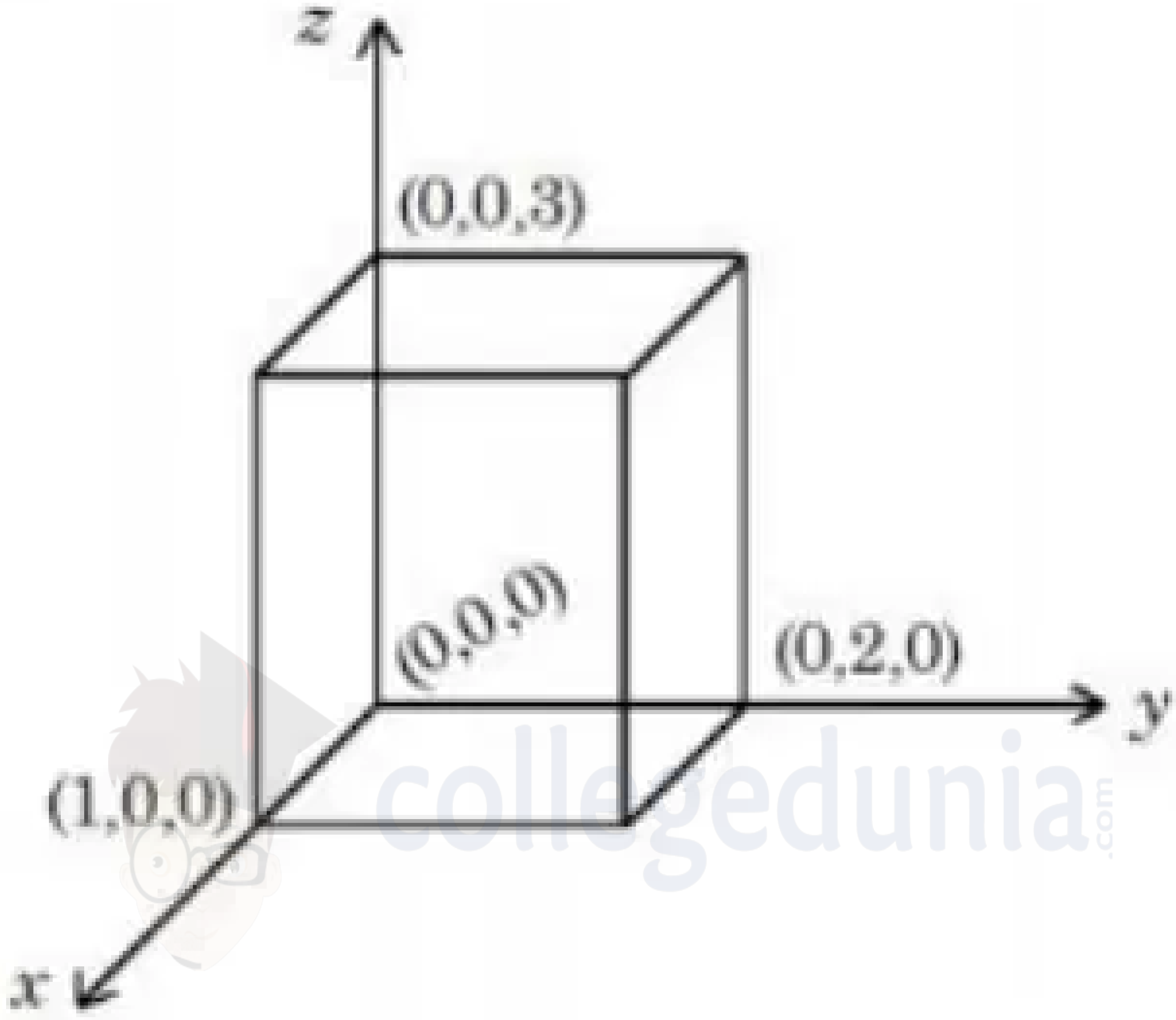
10. As shown in figure, a cuboid lies in a region with electric field $E = 2x^2\hat{i} - 4y\hat{j} + 6\hat{k} N/C$. The magnitude of charge within the cuboid is $n\epsilon_0 C$. The value of n is _____. (if dimension of cuboid is $1 \times 2 \times 3 m^3$) **(+4, -1)**

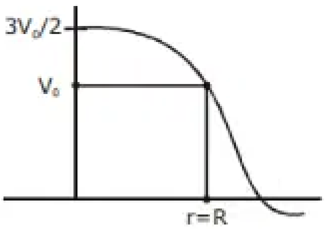
[25-Jan-2023 Shift1]


z
(0,0,3)
(0,0,0)
(0,2,0)
y
(1,0,0)
x

Answers

1. **Answer: c**

Explanation:



$R_1 = \frac{3V_0}{2}; R_2 = \frac{5V_0}{4}; R_3 \frac{3V_0}{4}; R_4 = \frac{V_0}{4}$

$\therefore r < R \quad V = \frac{KQ}{2R^3}\left(3R^2 - r^2\right)$

$v = \frac{3V_0}{2}, \ R_1 = 0$

$\frac{5V_0}{4} = \frac{KQ}{2R^3}\left(3R^2 - R_2^2\right)$

$\therefore R_2 = \frac{R}{\sqrt{2}}$

$r > R$

$\frac{3V_0}{4} = \frac{KQ}{R_3}$

$R_3 = \frac{4KQ}{3V_0} = \frac{KQ \times R}{3 \times KQ} = \frac{R}{3}$

$\frac{V_0}{4} = \frac{KQ}{R_4}$

$\therefore R_4 = \frac{4KQ}{V_0} = \frac{4KQ}{KQ} \times R = 4R$

On comparing we get

$(1)\&(2)$

Concepts:

1. **Electrostatic Potential and Capacitance:**

Electrostatic Potential

The potential of a point is defined as the work done per unit charge that results in bringing a charge from infinity to a certain point.

Some major things that we should know about electric potential:

- They are denoted by V and are a scalar quantity.

- It is measured in volts.

Capacitance

The ability of a capacitor of holding the energy in form of an electric charge is defined as capacitance. Similarly, we can also say that capacitance is the storing ability of capacitors, and the unit in which they are measured is “farads”.

Read More: Electrostatic Potential and Capacitance

The capacitor is in Series and in Parallel as defined below;

In Series

Both the Capacitors C_1 and C_2 can easily get connected in series. When the capacitor s are connected in series then the total capacitance that is C_{total} is less than any one of the capacitor’s capacitance.

In Parallel

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2. **Answer: c**

Explanation:

$$dV = -\vec{E} \cdot \overline{dx}$$
$$\int_{V_0}^{V_A} dV = -\int_0^2 30x^2 dx$$
$$V_A - V_O = -\left[10x^3\right]_0^2 = -80\,J$$

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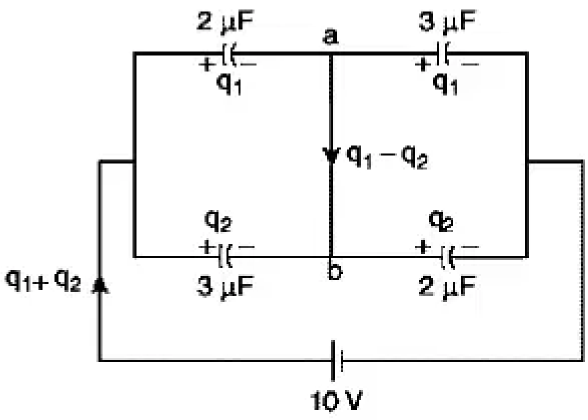
3. Answer: a

Explanation:



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4. **Answer: b**

Explanation:

From equs.

$$\frac{\frac{7C}{3}}{\frac{7}{3}+C} = \frac{1}{2}$$

$$\Rightarrow 14C = 7 + 3C$$

$$\Rightarrow C = \frac{7}{11}$$

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5. **Answer: a**

Explanation:

$$V_i = \frac{1}{2}CE^2$$
$$V_f = \frac{(CE)^2}{2\times 4c} = \frac{1}{2}\frac{CE^2}{4}$$
$$\Delta E = \frac{1}{2}CE^2 \times \frac{3}{4} = \frac{3}{8}CE^2$$

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6. Answer: d

Explanation:

$6\mu F$ & $4\mu F$ are in parallel & total charge on this combination is $30\ \mu C$
$\therefore$ Charge on $6\mu F$ capacitor $= \frac{6}{6+4} \times 30$
$= 18\ \mu C$
Since charge is asked on right plate therefore is $+18\mu C$

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7. **Answer: d**

Explanation:

$A = 10^{-4}m^2$
$E_{max} = 10^6 V/m$
$C = 15\mu F$
$C = \frac{k\varepsilon_0 A}{d}$
$\frac{Cd}{\varepsilon_0 A} = k$
$k = \frac{15\times10^{-12}\times500\times10^{-6}}{8.86\times10^{-12}\times10^4}$

$= \frac{15 \times 5}{8.86} = 8.465$
$k \approx 8.5$

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8. **Answer: a**

Explanation:

Electric field intensity at the centre of the disc. $E = \frac{\sigma}{2\in_0}$ (given)

Electric field along the axis at any distance x from the centre of the disc $E' = \frac{\sigma}{2\in_0}\left(1 - \frac{x}{\sqrt{x^2+R^2}}\right)$

From question, x=R (radius of disc)
$\therefore E' = \frac{\sigma}{2\in_0}\left(1 - \frac{R}{\sqrt{R^2+R^2}}\right) = \frac{\sigma}{2\in_0}\left(\frac{\sqrt{2}R-R}{\sqrt{2}R}\right) = \frac{4}{14}E$

$\therefore$ % reduction in the value of electric field $= \frac{\left(E-\frac{4}{14}E\right)\times 100}{E} = \frac{1000}{14}\% \approx 70.7\%$

Hence, The correct answer is option (A): reduces by 70.7%

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9. **Answer: 45 - 45**

Explanation:

The correct answer is 45
0.5e $= \frac{1}{2} mv_x^2 \Rightarrow v_x = \sqrt{\frac{e}{m}}$
Along x L = $v_x t = \sqrt{\frac{e}{m}} t$
Along y $v_y = \frac{eE}{m} t$
dividing $\frac{v_y}{L} = E\sqrt{\frac{e}{m}} = Ev_x$
$\Rightarrow$ Tan $\theta = \frac{v_y}{v_x} = E \times L = 10 \times 0.1 = 1$
$\theta = 45^\circ$

Concepts:

1. **Electric charges and field:**

What is Electric Charge

It is the property of subatomic particles that experiences a force when put in an electric and magnetic field.

What is Electric Field

It is a property associated with each point in space when charge is present in any form. The magnitude and direction of the electric field are expressed by *E*, called electric field strength or electric field intensity.

Electric charges are of two types: Positive and Negative. It is commonly carried by charge carriers protons and electrons.

Properties of Electric Charge

Various properties of charge include the following :-

- Additivity of Electric Charge
- Conservation of Electric Charge
- Quantization of Electric Charge

Types of electric charge

Two kinds of electric charges are there :-

Negative Charge - When an object has a negative charge it means that it has more electrons than protons.

Positive Charge - When an object has a positive charge it means that it has more protons than electrons.

When there is an identical number of positive and negative charges, the negative and positive charges would cancel out each other and the object would become neutral.

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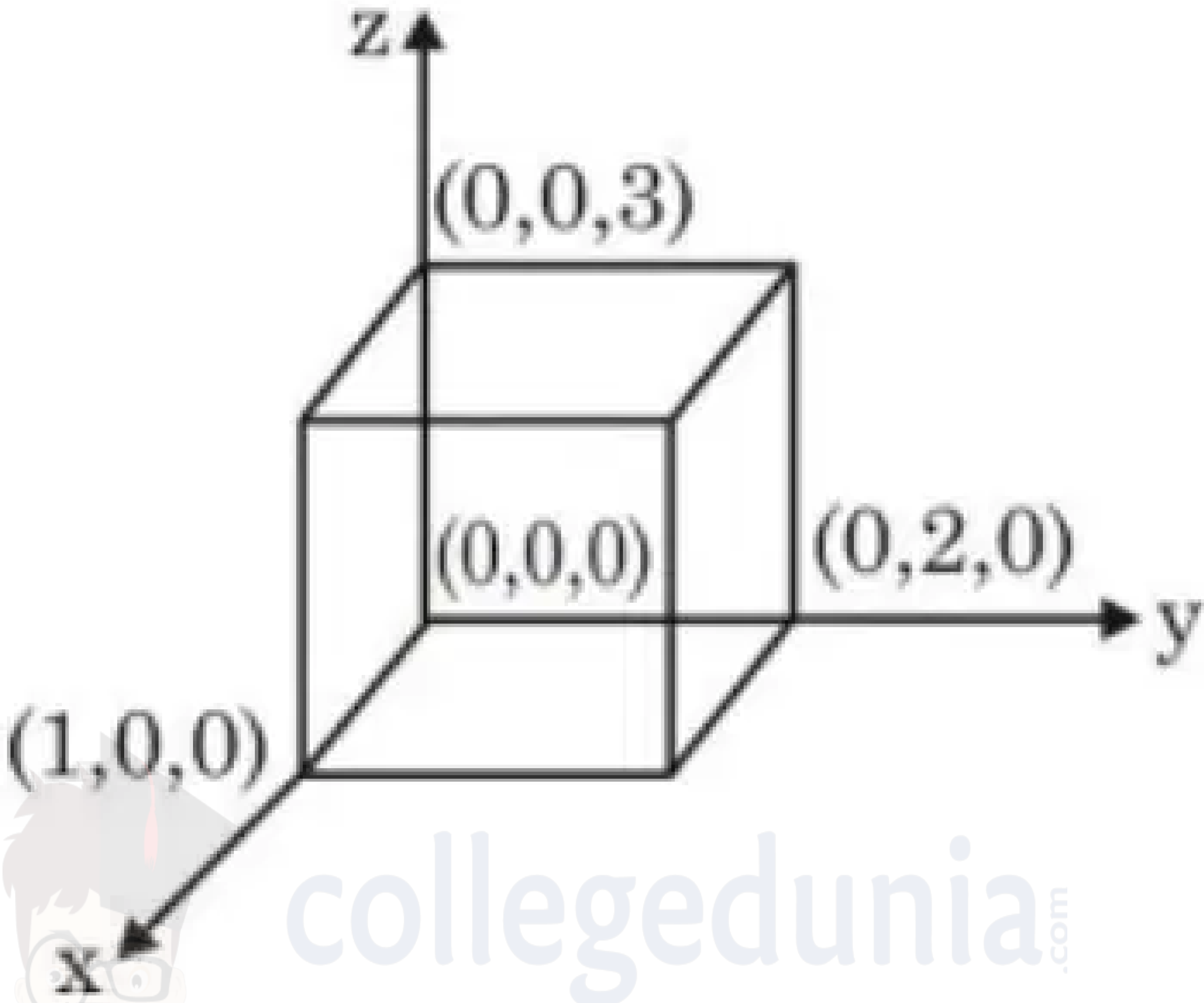
10. Answer: 12 - 12

Explanation:

The correct answer is 12.
$\overrightarrow{E} = 2x^2\hat{i} - 4y\hat{j} + 6\hat{k}$



$\phi_{net} = -8 \times 3 + 2 \times 6 = -12$

$-12 = \frac{q}{\epsilon_0}$

$|q| = 12\epsilon_0$

So, the answer is 12.

Concepts:

1. Electrostatic Potential:

The electrostatic potential is also known as the electric field potential, electric potential, or potential drop is defined as **"The amount of work that is done in order to move a unit charge from a reference point to a specific point inside the field without producing an acceleration."**

SI Unit of Electrostatic Potential:

SI unit of electrostatic potential - volt

Other units - statvolt

Symbol of electrostatic potential - V or φ

Dimensional formula - $ML^2T^3I^{-1}$

Electric Potential Formula:

The electric potential energy of the system is given by the following formula:

U = 1/(4πε°) × [q1q2/d]

Where q1 and q2 are the two charges that are separated by the distance d.

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