Electrostatics JEE Main PYQ - 2

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 capacitor C is fully charged with voltage V_0. After disconnecting the voltage source, it is connected in parallel with another uncharged capacitor of capacitance $\frac{C}{2}$. The energy loss in the process after the charge is distributed between the two capacitors is : **(+4, -1)**

[Sep. 04,2020 (II)]

a. $\frac{1}{6}CV_0^2$

b. $\frac{1}{2}CV_0^2$

c. $\frac{1}{3}CV_0^2$

d. $\frac{1}{4}CV_0^2$

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2. A capacitor is made of two square plates each of side $'a'$ making a very small angle a between them, as shown in figure. The capacitance will be close to : **(+4, -1)**

[8 Jan 2020 II]

a. $\frac{\epsilon_0 a^2}{d}\left(1-\frac{\alpha a}{4d}\right)$

b. $\frac{\epsilon_0 a^2}{d}\left(1+\frac{\alpha a}{d}\right)$

c. $\frac{\epsilon_0 a^2}{d}\left(1-\frac{\alpha a}{2d}\right)$

d. $\frac{\epsilon_0 a^2}{d}\left(1-\frac{3\alpha a}{2d}\right)$

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3. A charge Q is uniformly distributed over a long rod AB of length L as shown in the figure. The electric potential at the point O lying at distance L from the end A is **(+4, -1)**

[Sep. 02, 2020 (II)]

a. $\frac{Q}{8p\varepsilon_0 L}$

b. $\frac{3Q}{4p\varepsilon_0 L}$

c. $\frac{Q}{4p\varepsilon_0 L\, In\, 2}$

d. $\frac{Q\, In\, 2}{4p\varepsilon_0 L}$

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4. A parallel plate capacitor is made of two circular plates separated by a distance of 5 mm and with a dielectric of dielectric constant 2.2 between them. When the electric field in the dielectric is $3 \times 10^4\, V/m$, the charge density of the positive plate will be close to **(+4, -1)**

[2014]

a. $6 \times 10^{-7} C/m^2$

b. $3 \times 10^{-7} C/m^2$

c. $3 \times 10^4\, C/m^2$

d. $6 \times 10^4\, C/m^2$

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5. A parallel plate capacitor of capacitance $90\, pF$ is connected to a battery of emf $20\, V$. If a dielectric material of dielectric constant $K = \frac{5}{3}$ is inserted between the plates, the magnitude of the induced charge will be : **(+4, -1)**

[2018]

a. 1.2 n C

b. 0.3 n C

c. 2.4 n C

d. 0.9 n C

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6. A plane electromagnetic wave of frequency $50\, MHz$ travels in free space along the positive x-direction. At a particular point in space and time, $\vec{E} = 6.3\hat{j} V/m$. The corresponding magnetic field $\vec{B}$, at that point will be: **(+4, -1)**

[11-Apr-2023 shift 1]

a. $18.9 \times 10^{-8} \hat{k} T$

b. $6.3 \times 10^{-8} \hat{k} T$

c. $2.1 \times 10^{-8} \hat{k} T$

d. $18.9 \times 10^{8} \hat{k} T$

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7. A solid conducting sphere, having a charge Q, is surrounded by an uncharged conducting hollow spherical shell. Let the potential difference **(+4, -1)**

between the surface of the solid sphere and that of the outer surface o f the hollow shell be V. If the shell is now given a charge of $-4Q$, the new potential difference between the same two surfaces is :

[8 April 2019 I]

a. V

b. 2V

c. -2V

d. 4V

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8. A uniform electric field $\vec{E}$ exists between the plates of a charged condenser. A charged particle enters the space between the plates and perpendicular to $\vec{E}$. The path of the particle between the plates is a : **(+4, -1)**

[Online April 9, 2013]

a. straight line

b. hyperbola

c. parabola

d. circle

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9. A parallel plate capacitor with air between the plate has a capacitance of $15\,pF$ The separation between the plate becomes twice and the space between them is filled with a medium of dielectric constant 3.5. Then the capacitance becomes $\frac{x}{4}pF$ The value of x is _______ **(+4, -1)**

[31-Jan-2024 Shift 1]

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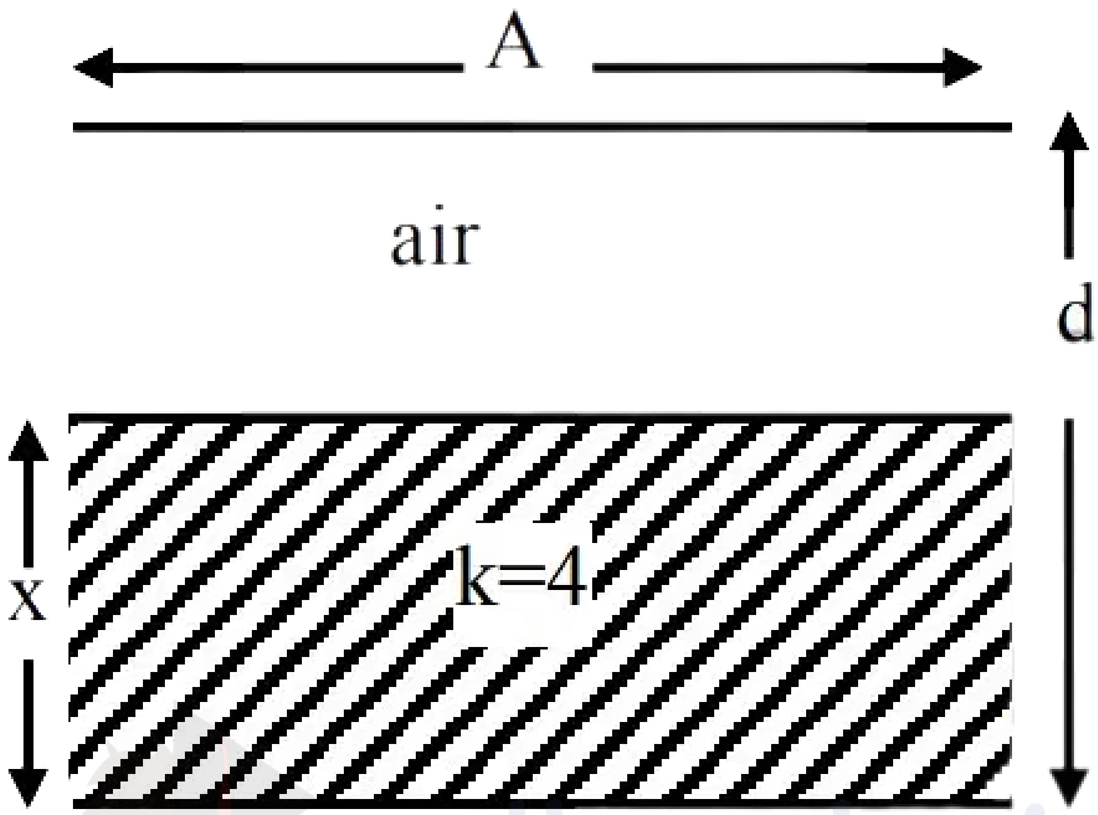
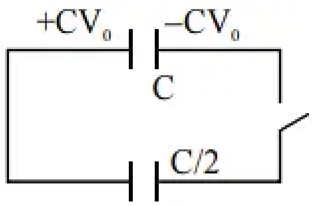
10. When x = $\frac{d}{3}$ then capacitance is C_1 = 2 μF then if x = $\frac{2d}{3}$ then capacitance C_2 will be (in μF). **(+4, -1)**

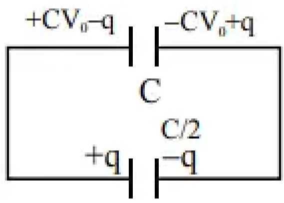

A
air
d
x
k=4

Answers

1. **Answer: a**

Explanation:





$$\frac{CV_0-q}{C}=\frac{q}{C/2}=\frac{2q}{C}$$
$$V_0=\frac{3q}{C}\quad\Rightarrow q=\frac{CV_0}{3}$$
$$U_i=\frac{1}{2}CV_0^2$$
$$U_f=\frac{\left(\frac{2CV_0}{3}\right)^2}{2C}+\frac{\left(\frac{CV_0}{3}\right)^2}{2\left(\frac{C}{2}\right)}$$
$$=\frac{1}{2}CV_0^2\left[\frac{4}{9}+\frac{2}{9}\right]=\frac{1}{2}CV_0^2\left(\frac{2}{3}\right)$$
$$\text{Heat loss}=\frac{1}{2}CV_0^2-\left(\frac{2}{3}\right)\left(\frac{1}{2}CV_0^2\right)$$
$$=\frac{1}{6}CV_0^2$$

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.

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2. **Answer: c**

Explanation:

Assume small element dx at a distance x from left end
Capacitance for small element dx is

$$dC = \frac{\varepsilon_0 a\, dx}{d + x\, \alpha}$$

$$C = \int_0^a \frac{\varepsilon_0 a\, dx}{d + x\, \alpha}$$

$$= \frac{\varepsilon_0\, a}{\alpha} In\left(\frac{1+\alpha a}{d}\right)\Big|_0^a \left(In\left(1+x\right) \approx x - \frac{x^2}{2}\right)$$

$$= \frac{\varepsilon_0 a^2}{d}\left(1 - \frac{\alpha a}{2d}\right)$$

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3. **Answer: d**

Explanation:

$$V = \int_L^{2L} \frac{kdQ}{x} = \int_L^{2L} \frac{k\left(\frac{Q}{L}\right)dx}{x} = \frac{Q}{4p\varepsilon_0 L} \int_L^{2L} \left(\frac{1}{x}\right)dx$$

$\hspace15mm =\frac{Q}{4 p\varepsilon_0 L} [\log_e\, x]^{2L}_L$
$\hspace15mm =\frac{Q}{4 p\varepsilon_0 L} [\log_e\, 2L- \log_e L]=\frac{Q}{4 p\varepsilon_0 L} In\, (2)$

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4. **Answer: a**

Explanation:

$$E = \frac{\sigma}{K\varepsilon_0}$$
$$\sigma = K\varepsilon_0 E$$
$$= 2.2 \times 8.85 \times 10^{-12} \times 3 \times 10^4 \approx 6 \times 10^{-7}\, C/m^2$$

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5. **Answer: a**

Explanation:

$$C' = KC_0$$
$$Q = KC_0V$$
$$Q_{\text{induced}} = Q\left(1 - \frac{1}{K}\right)$$
$$= \frac{5}{3} \times 90 \times 10^{-12} \times 20\left(1 - \frac{3}{5}\right)$$
$$= 1.2\,nC$$

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6. **Answer: c**

Explanation:

$|B| = \frac{|E|}{C} = \frac{6.3}{3\times10^8} = 2.1\times10^{-8}T$
and $\hat{E}\times\hat{B} = \hat{C}$
$\hat{j}\times\hat{B} = \hat{i}$
$\hat{B} = \hat{k}$
$\vec{B} = |B|\,\hat{B} = 2.1\times10^{8}\hat{k}T$

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7. Answer: a

Explanation:

As given in the first condition :
Both conducting spheres are shown.

$$V_{in} - V_{out} = \left(\frac{kQ}{r_1}\right) - \left(\frac{kQ}{r_2}\right)$$
$$= kQ\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = V$$
$$V_{in} - V_{out} = \left(\frac{kQ}{r_1} - \frac{4kQ}{r_2}\right) - \left(\frac{kQ}{r_2} - \frac{4kQ}{r_2}\right)$$
$$= \frac{kQ}{r_1} - \frac{kQ}{r_2}$$
$$= kQ\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = V$$

Hence, we also obtain that potential difference does not depend on charge of outer

sphere.
∴ P.d. remains same

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8. **Answer: c**

Explanation:

When charged particle enters perpendicularly in an electric field, it describes a parabolic path
$y = \frac{1}{2}\left(\frac{QE}{m}\right)\left(\frac{x}{4}\right)^2$
This is the equation of parabola.

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9. **Answer: 105 - 105**

Explanation:

The correct answer is 105.

$C_0 = \frac{\epsilon_0 A}{d} = 15pF$

$C = \frac{K\epsilon_0 A}{2d} = \frac{3.5}{2} \times 15pF = \frac{105}{4}pF$

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10. **Answer: 3 - 3**

Explanation:

$$\frac{1}{C_{eq}} = \frac{1}{C_{air}} + \frac{1}{C_{di}}$$
$$\frac{1}{C_{eq}} = \frac{2d}{3(\epsilon_0 A)} + \frac{d}{(3)4\epsilon_0 A} = \frac{3d}{4A\epsilon_0}$$
$$C_{eq} = \frac{4A\epsilon_0}{3d} = 2\mu F$$
$$\frac{A\epsilon_0}{d} = 1.5\mu F$$
$$\frac{1}{C'_{eq}} = \frac{d}{3(\epsilon_0 A)} + \frac{2d}{(3)4\epsilon_0 A} = \frac{(4+2)d}{12\epsilon_0 A} = \frac{6d}{12\epsilon_0 A} \Rightarrow C'_{eq} = 2[\frac{\epsilon_0 A}{d}] = 3\mu F$$

So, the correct answer is 3 μF

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