Electrostatics JEE Main PYQ - 1

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. Two equal capacitors are first connected in series and then in parallel. The ratio of the equivalent capacities in the two cases will be: **(+4, -1)**

[24 Feb 2021 shift1]

a. 4:01

b. 2:01

c. 1:04

d. 1:02

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2. A charge Q is distributed over two concentric conducting thin spherical shells radii r and R $(R > r)$. If the surface charge densities on the two shells are equal, the electric potential at the common centre is : **(+4, -1)**

[Sep. 02, 2020 (II)]

a. $\frac{1}{4\pi\varepsilon_0}\frac{(R+2r)Q}{2(R^2+r^2)}$

b. $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{2(R^2+r^2)}Q$

c. $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{(R^2+r^2)}Q$

d. $\frac{1}{4\pi\varepsilon_0}\frac{(2R+r)}{(R^2+r^2)}Q$

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3. A parallel plate capacitor is of area $6\ cm^2$ and a separation $3\,mm$. The gap is filled with three dielectric materials of equal thickness (see figure) with dielectric constants $K_1, = 10, K_2 = 12$ and $K_3 = 14$. The dielectric constant of a material which when fully inserted in above capacitor, gives same capacitance would be : **(+4, -1)**

[10 Jan. 2019 I]

a. 12

b. 4

c. 36

d. 14

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4. A parallel plate capacitor with square plates is filled with four dielectrics of dielectric constants K_1, K_2, K_3, K_4 arranged as shown in the figure. The effective dielectric constant K will be : **(+4, -1)**

[9 Jan 2019 II]

a. $K = \frac{(K_1+K_2)(K_3+K_4)}{2(K_1+K_2+K_3+K_4)}$

b. $K = \frac{(K_1+K_2)(K_3+K_4)}{(K_1+K_2+K_3+K_4)}$

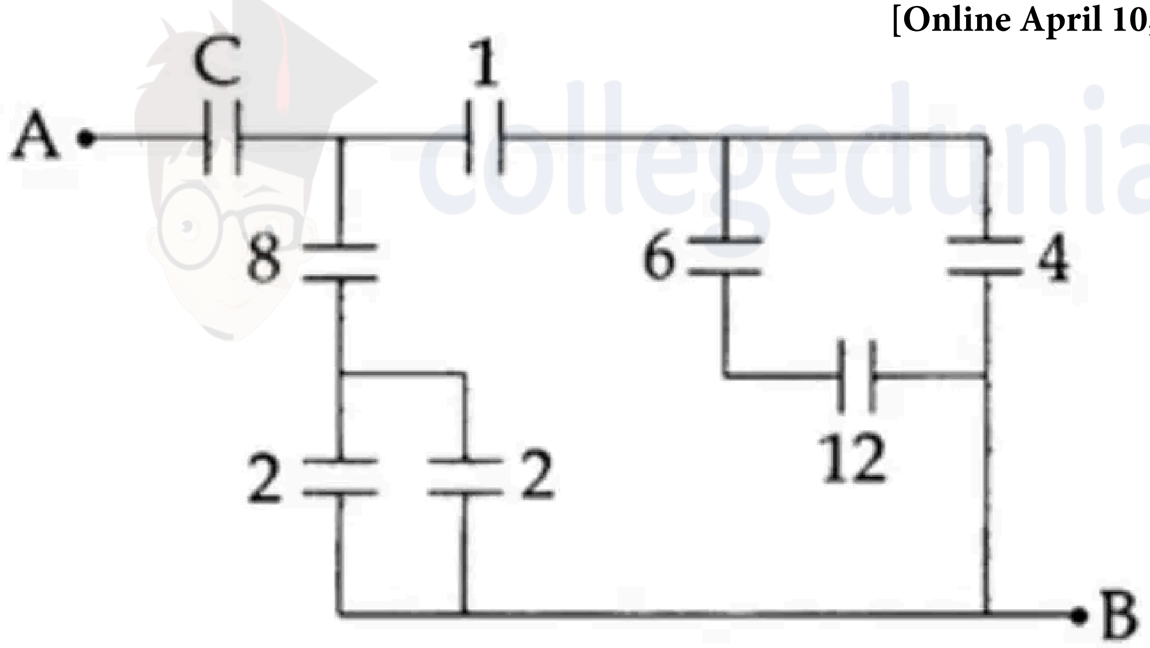
c. $K = \frac{(K_1+K_4)(K_2+K_3)}{2(K_1+K_2+K_3+K_4)}$

d. $K = \frac{(K_1+K_3)(K_2+K_4)}{K_1+K_2+K_3+K_4}$

---

5. Figure shows a network of capacitors where the numbers indicates capacitances in micro Farad. The value of capacitance C if the equivalent capacitance between point A and B is to be $1\,\mu F$ is : **(+4, -1)**

[Online April 10, 2016]



a. $\frac{31}{23}\mu F$

b. $\frac{32}{23}\mu F$

c. $\frac{33}{23}\mu F$

d. $\frac{34}{23}\mu F$

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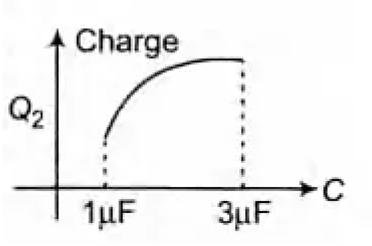
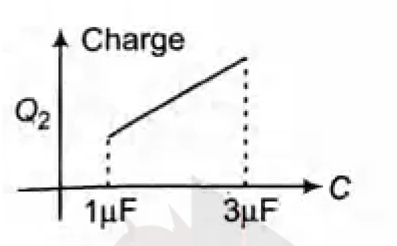
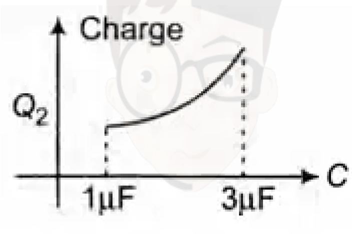
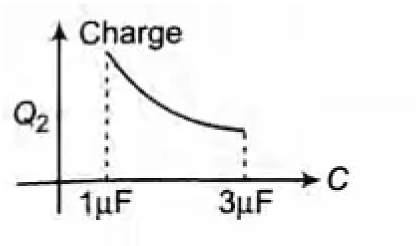
6. In the given circuit, charge Q_2 on the $2\mu F$ capacitor changes as C is varied from $1\mu F$ to $3\mu F$. Q_2 as a function of $'C'$ is given properly by (figures are drawn schematically and are not to scale) **(+4, -1)**

[2015]

a. 

b. 

c. 

d. 

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7. A combination of capacitors is set up as shown in the figure. The magnitude of the electric field, due to a point charge Q (having a charge equal to the sum of the charges on the $4\,\mu F$ and $9\,\mu F$ capacitors), at a point distant $30\,m$ from it, would equal : **(+4, -1)**

[2016]

a. 240 N/C

b. 360 N/C

c. 420 N/C

d. 480 N/C

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8. A capacitance of $2\,\mu F$ is required in an electrical circuit across a potential difference of $1.0\,kV$. A large number of $1\,\mu F$ capacitors are available which can withstand a potential difference of not more than $300\,V$. The minimum number of capacitors required to achieve this is : (+4, -1)

[2017]

a. 2

b. 16

c. 24

d. 32

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9. A capacitor of capacitance $900\,\mu F$ is charged by a $100\,V$ battery The capacitor is disconnected from the battery and connected to another uncharged identical capacitor such that one plate of uncharged capacitor connected to positive plate and another plate of uncharged capacitor connected to negative plate of the charged capacitor The loss of energy in this process is measured as $x \times 10^{-2} J$ The value of x is ______ (+4, -1)

[30-Jan-2023 Shift1]

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10. A capacitor has capacitance $5\mu F$ when it's parallel plates are separated by air medium of thickness d A slab of material of dielectric constant 15 having area equal to that of plates but thickness $\frac{d}{2}$ is inserted between the plates Capacitance of the capacitor in the presence of slab will be ___μF (+4, -1)

[25-Jan-2023 Shift2]

Answers

1. Answer: c

Explanation:

For series combination

$$\frac{1}{C_{eq_1}} = \frac{1}{C} + \frac{1}{C}$$
$$\Rightarrow C_{eq_1} = \frac{C}{2}$$

For parallel combination

$$C_{eq_2} = C + C$$
$$\Rightarrow C_{eq_2} = 2C$$
$$\Rightarrow \frac{C_{eq_1}}{eq_2} = \frac{C/2}{2C} = \frac{1}{4} = 1:4$$

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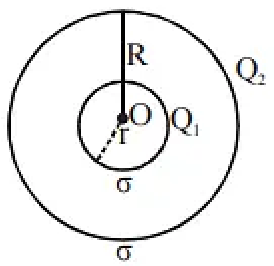
2. Answer: c

Explanation:

Let the charges on inner and outer spheres are Q_1 and Q_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 capacitors 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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3. Answer: a

Explanation:

Let dielectric constant of material used be K.

$$\therefore \frac{10\in_0 A/3}{d} + \frac{12\in_0 A/3}{d} + \frac{14\in_0 A/3}{d} = \frac{K\in_0 A}{d}$$

$$\Rightarrow K = 12$$

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4. **Answer: d**

Explanation:

$C_{12}=\frac{C_1C_2}{C_1+C_2}=\frac{\frac{k_1\in_0\frac{L}{2}\times L}{d/2}\cdot\frac{k_2\left[\in_0\frac{L}{2}\times L\right]}{d/2}}{(k_1+k_2)\left[\frac{\in_0\cdot\frac{L}{2}\times L}{d/2}\right]}$

$C_{12}=\frac{k_1k_2}{k_1+k_2}\frac{\in_0L^2}{d}$

in the same way we get, $C_{34}=\frac{k_3k_4}{k_3+k_4}\frac{\in_0L^2}{d}$

$\therefore C_{eq}=C_{12}+C_{34}=\left[\frac{k_1k_2}{k_1+k_2}+\frac{k_3k_4}{k_3+k_4}\right]\frac{\in_0L^2}{d}$

....(i)

Now if $k_{eq}=k, C_{eq}=\frac{k\in_0L^2}{d}$ .....(ii)

on comparing equation (i) to equation (ii), we get

$k_{eq}=\frac{k_1k_2(k_3+k_4)+k_3k_4(k_1+k_2)}{(k_1+k_2)(k_3+k_4)}$

This does not match with any of the options so probably they have assumed the wrong combination

$C_{13}=\frac{k_1\in_0L\frac{L}{2}}{d/2}+k_3\in_0\frac{L.\frac{L}{2}}{d/2}$

$=(k_1+k_3)\frac{\in_0L^2}{d}$

$C_{24}=(k_2+k_4)\frac{\in_0L^2}{d}$

$C_{eq}=\frac{C_{13}C_{24}}{C_{13}C_{24}}=\frac{(k_1+k_3)(k_2+k_4)}{(k_1+k_2+k_3+k_4)}\frac{\in_0L^2}{d}$

$=\frac{k\in_0L^2}{d}$

$k=\frac{(k_1+k_3)(k_2+k_4)}{(k_1+k_2+k_3+k_4)}$

However this is one of the four options. It must be a "Bonus" logically but of the given options probably they might go with (4)

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5. **Answer: b**

Explanation:

$\frac{8\times12}{18} = 4\,\mu F$

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6. **Answer: a**

Explanation:

$q = \left(\frac{3C}{C+3}\right) E$
$q = CV$
$q \propto C$
$q_2 = \left(\frac{3C}{C+3}\right) E \left(\frac{2}{3}\right)$
$q_2 = \left(\frac{2C}{C+3}\right) E$
$q_2 = \left(\frac{2c}{1+\frac{3}{C}}\right) E \quad q = CV$
$C \uparrow q_2 \uparrow$
If $C \rightarrow \infty, q =$ constant value.

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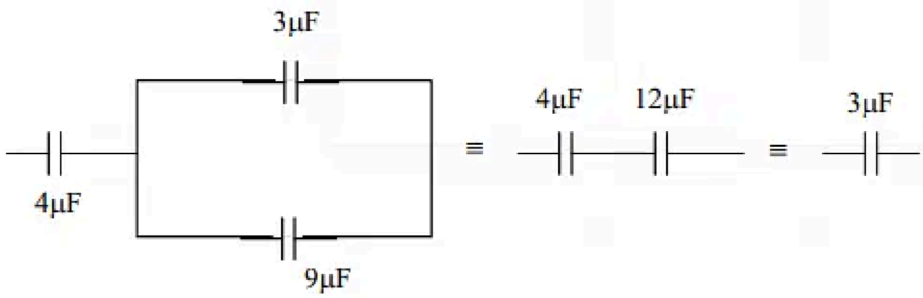
7. **Answer: c**

Explanation:



The equivalent capacitance of the above branch will be $\frac{4(9+3)}{4+9+3} = 3\mu F$
The total charge in the above branch will be Q=CV=24 μF
Now voltage across 12μF V= gives the combination of capacitors $\frac{Q}{C} = \frac{24}{12} = 2\,V$
This is the same as the voltage across 9μF capacitor.
Hence, the charge on 9 μF capacitor is =24+18=42μC
Now by Coulomb's law,
$E = \frac{kQ}{r^2}$
$E = \frac{9\times10^9\times42\times10^{-6}}{30^2}$=420 N/C

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8. **Answer: d**

Explanation:

Following arrangement will do the needful :
8 capacitors of $1\,\mu F$ in parallel with four such branches in series.

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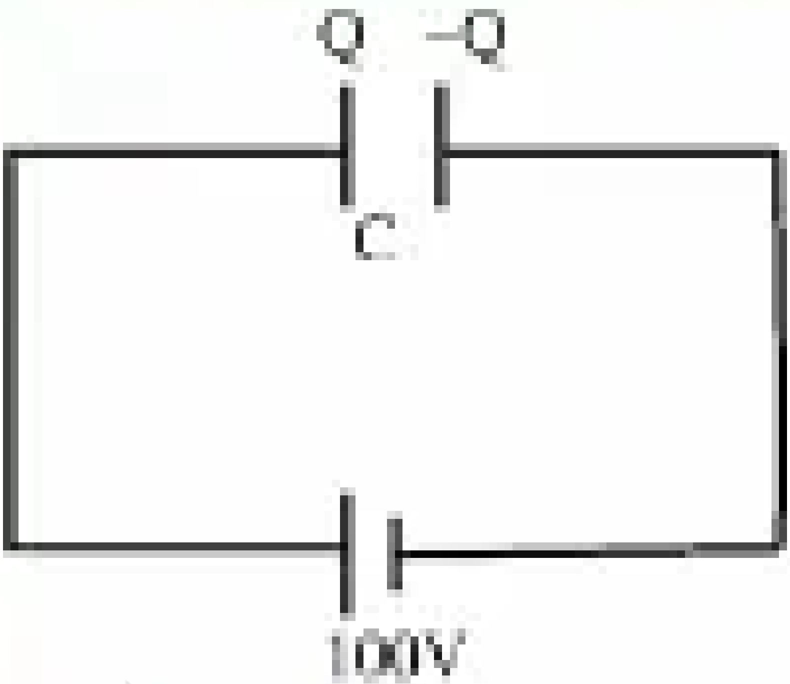
9. **Answer: 225 - 225**

Explanation:

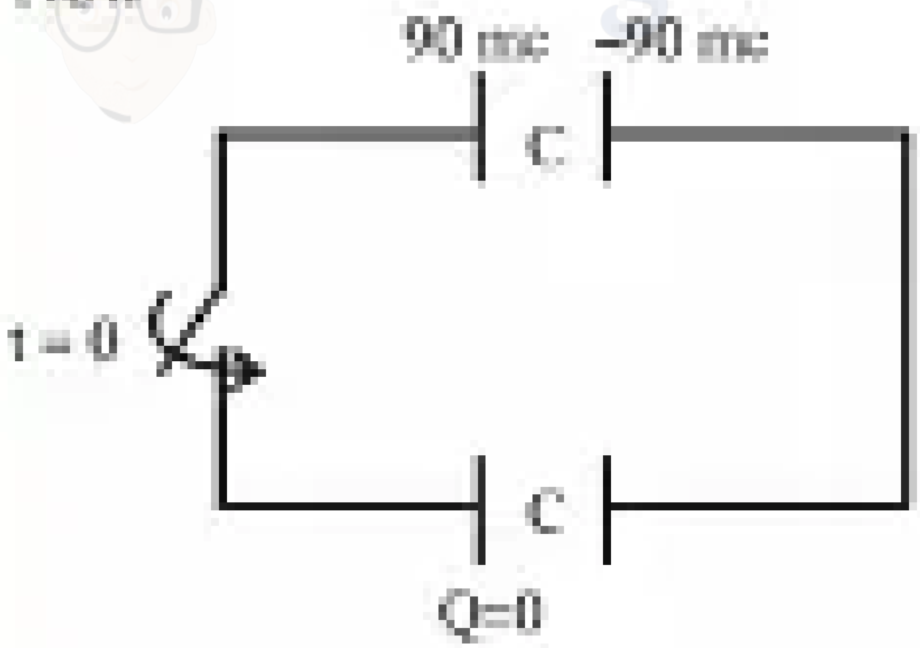
The correct answer is 225.

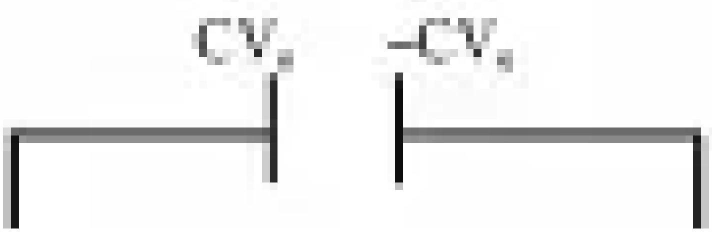


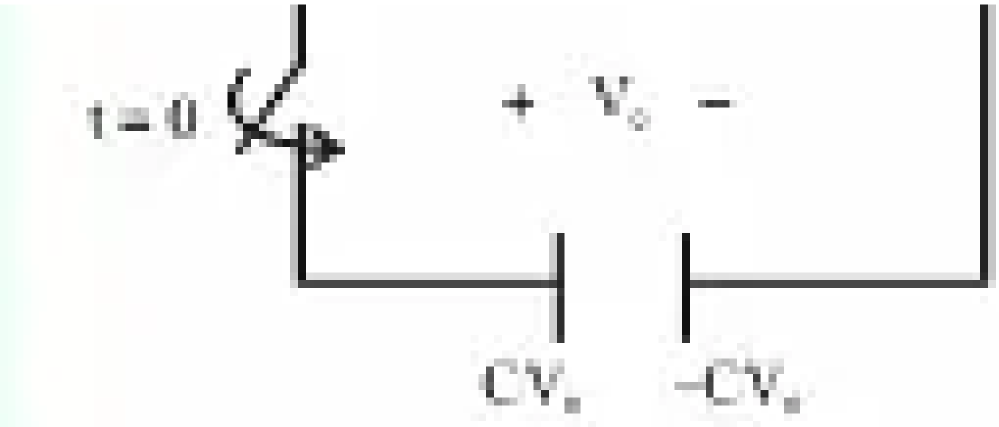
C = 900 μF

$Q = CV = 900 \times 10^{-6} \times 100 = 9 \times 10^{-2} = 90$ M

Now





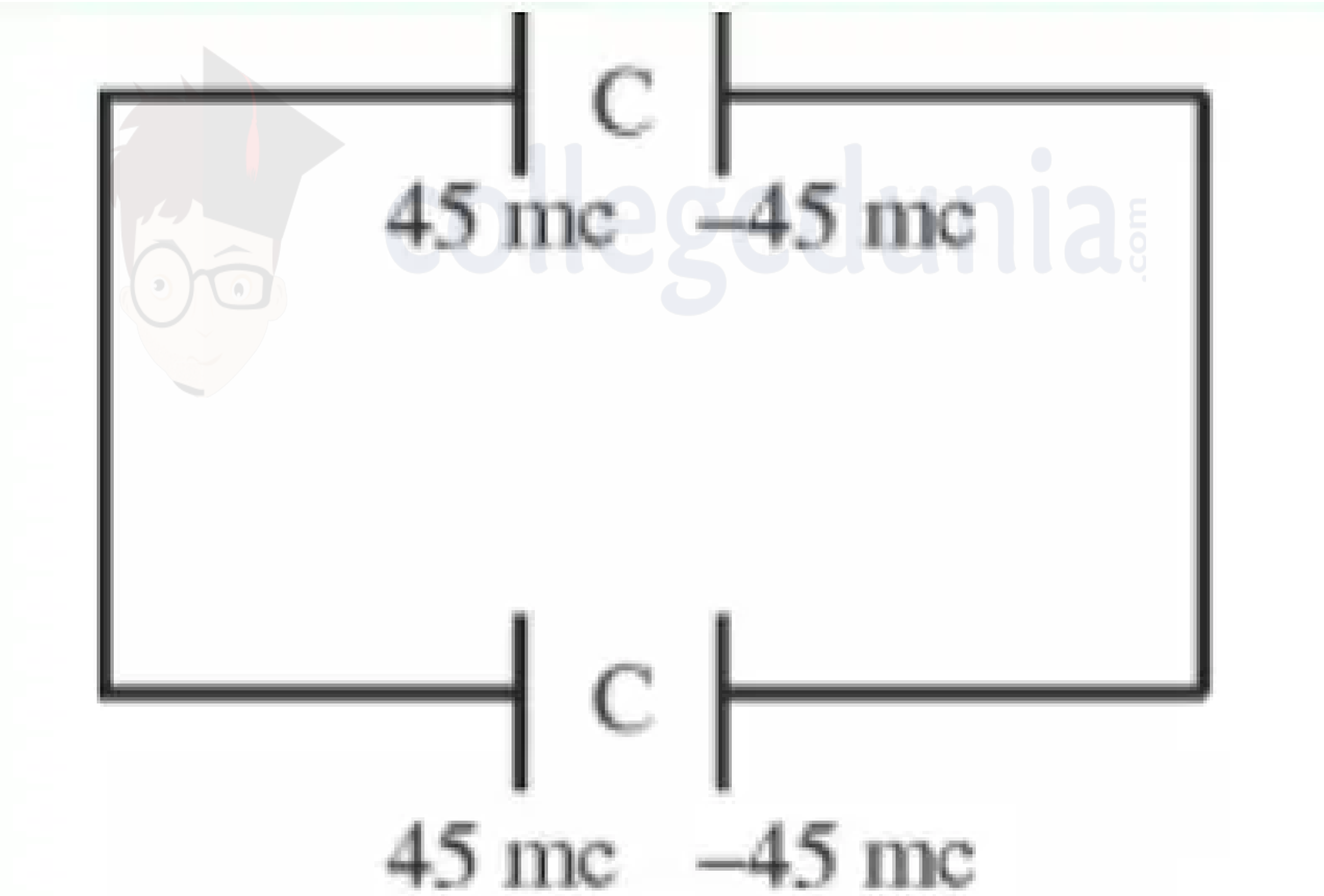


Common potential will be developed across both capacitors by kVL

Total charge on left plates of capacitors should be conserved.

$\therefore 90\,mc + 0 = 2cv_0$

$cv_0 = 45\,mc$



Heat dissipated $= U_i - U_f$ [Change in energy stored in the capacitors]

$= \frac{1}{2}\frac{(90mc)^2}{900\mu F} - 2 \times \frac{1}{2}\frac{(45mc)^2}{900\mu F}\left[U = \frac{Q^2}{2c}\right]$

$= \frac{1}{2\times900\times10^{-6}}(8100 - 4050) \times 10^{-6}$

$= 2.25$ Joule

OR

$$\text{Heat } = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}(V_1-V_2)^2$$
$$= \frac{1}{2}\frac{C^2}{2C}(100-0)^2$$
$$= \frac{1}{2}\frac{900\times10^{-6}}{2}\times10^4 = \frac{9}{4}\text{ Joule } = 2.25 \text{ Joule}$$

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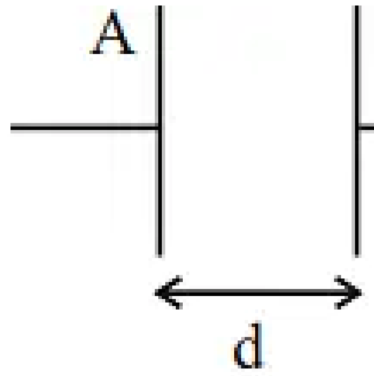
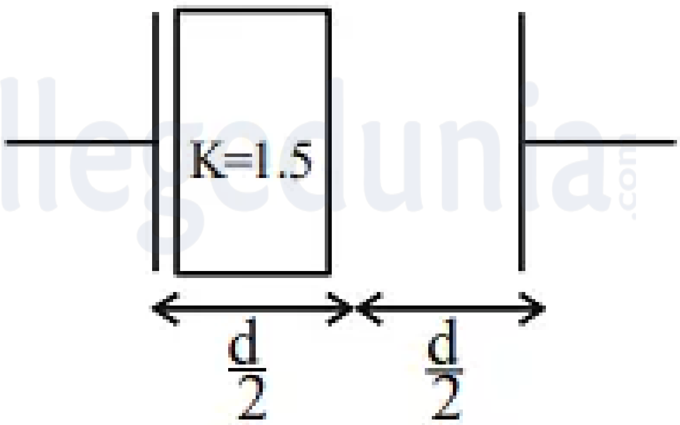
10. **Answer: 6 - 6**

Explanation:

The correct answer is 6.



$$\frac{\epsilon_0 A}{d} = 5\mu F$$



$$C_{new} = \frac{\epsilon_0 A}{\frac{\left(\frac{d}{2}\right)}{1.5} + \frac{\left(\frac{d}{2}\right)}{1}}$$

$= \frac{\epsilon_0 A}{\left(\frac{d}{3}+\frac{d}{2}\right)} = \frac{6\epsilon_0 A}{5d}$

$= \frac{6}{5} \times 5\mu F = 6\mu F$

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