

101

Closed book. No calculators are to be used for this quiz.

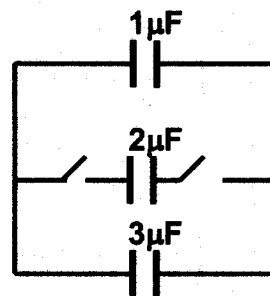
Quiz duration: 10 minutes

Name:

Student ID:

Signature:

The figure shows a capacitor network. Initially, the switches are off, the top and bottom capacitors are uncharged and the middle capacitor was charged to have an energy of 25 J. Then the switches are turned on. Calculate the final amount of energy stored in the middle capacitor.



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

$$25 = \frac{1}{2} \frac{Q^2}{2 \times 10^{-6}}$$

$$Q^2 = 10^{-4}$$

$$Q = 10^{-2} \text{ C}$$

After connection

$$\frac{Q_1}{C_1} = \frac{Q_2}{C_2} = \frac{Q_3}{C_3} = V$$

$$Q_1 + Q_2 + Q_3 = 10^{-2} \text{ C}$$

$$(C_1 + C_2 + C_3)V = 10^{-2}$$

$$V = \frac{10^{-2}}{6 \times 10^{-6}} = \frac{1}{6} \times 10^4$$

Energy on second capacitor will be

$$\begin{aligned} \frac{1}{2} C_2 V^2 &= \frac{1}{2} \times 2 \times 10^{-6} \times \left(\frac{1}{6}\right)^2 \times 10^8 \\ &= \frac{1}{36} \times 10^2 \text{ J} \end{aligned}$$

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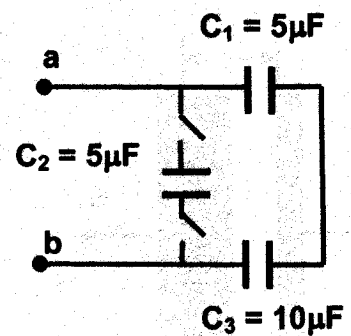
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For the capacitor network given in the figure, the switches are initially off and the voltage between the terminals a and b is measured to be $V_{ab} = 12V$. The capacitor C_2 is uncharged. Then the switches are turned on and C_2 is connected to the circuit. Calculate the final voltage V_{ab} and the charge of C_2 .



$Q_1 + C_3 V_3 = Q$, since they are in series we can write

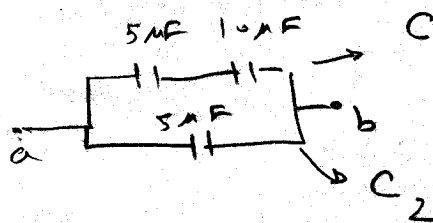
$$V = \frac{Q}{C}$$

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_3}} = \frac{1}{\frac{1}{5} + \frac{1}{10}} \times 10^{-6}$$

$$12 = \frac{Q}{\frac{1}{3} \times 10^{-5}} \Rightarrow Q = 4 \times 10^{-5} C$$

$$C = \frac{1}{3} \times 10^{-5}$$

After connection:



$$C = \frac{1}{3} \times 10^{-5}$$

$$C' = C + C_2 = 2 \times 10^{-6} + \frac{1}{3} \times 10^{-5} = 5 \times 10^{-6}$$

$$Q = C' V' = 5 \times 10^{-6} \times V = 4 \times 10^{-5} \Rightarrow V = \frac{4}{5} \times 10$$

$$4 \times 10^{-5} =$$

$$V = 8V$$

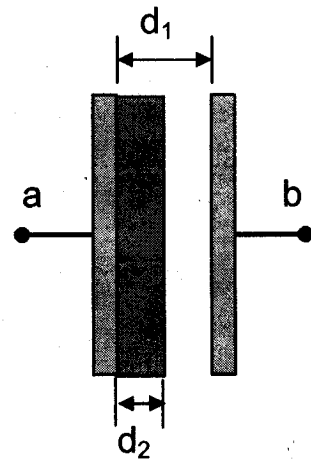
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A parallel plate capacitor consists of two flat metal plates each with area A separated by a distance d_1 . The initial potential difference between the plates is measured to be $V_{ab} = V$. Then, a dielectric slab having thickness d_2 , (where $d_2 < d_1$) and the dielectric constant K is inserted next to the left plate. The dielectric slab has the same shape and size as the plates. What is the value of V_{ab} in terms of V now?



$$C = \frac{Q}{V} = \epsilon \frac{A}{d}$$

$$C_1 = \epsilon_0 \frac{A}{d_1}$$

After inserting the dielectric media we can consider V two capacitor in series that.

$\epsilon = k \epsilon_0$
Permittivity of dielectric means

$$C' = \frac{1}{\frac{d_1 - d_2}{\epsilon_0 A} + \frac{d_2}{\epsilon A}} = \frac{A \epsilon \epsilon_0}{d_2(\epsilon_0 - \epsilon) + \epsilon_0 d_1}$$

$$Q_{\text{initial}} = C V, \quad Q_{\text{final}} = C' V' \Rightarrow \frac{V'}{V} = \frac{C}{C'}$$

$$\frac{V'}{V} = \frac{\epsilon_0 \frac{A}{d_1}}{\frac{A \epsilon \epsilon_0}{\epsilon_0 d_1 + (\epsilon_0 - \epsilon) d_2}} =$$

$$V' = \left(\frac{\epsilon_0 d_1 + (\epsilon_0 - \epsilon) d_2}{d_1 \epsilon} \right) V$$

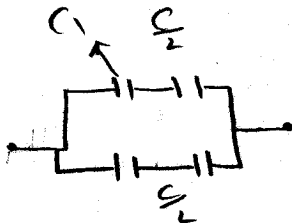
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Several identical capacitors of capacitance $0.25 \mu\text{F}$ are given. The maximum voltage across each capacitor is not to exceed 600 V . Using these capacitors, design an equivalent capacitor with capacitance $0.25 \mu\text{F}$ to be connected across a potential difference of 960 V . Show your design clearly and calculate the charge of one capacitor in your design.



$$C = \frac{C}{2} + \frac{C}{2}$$

$$Q = CV$$

$$Q = 0.25 \times 10^{-6} \times 960$$

$$Q = 24 \times 10^{-5} \text{ C}$$

Because of symmetry all the capacitor have the same charge

$$\Rightarrow Q_1 = \frac{24 \times 10^{-5}}{4} = 6 \times 10^{-5} \text{ C}$$

$$Q_1 = C_1 V_1 \Rightarrow 6 \times 10^{-5} = 0.25 \times 10^{-6} \times V_1 \Rightarrow V_1 = \frac{24 \times 10}{0.25} = 240 \text{ V}$$

Since they all have the same capacitance we have $\frac{C}{n}$ for n capacitor in series. So we must add n capacitor in parallel to have C as the final capacitance.

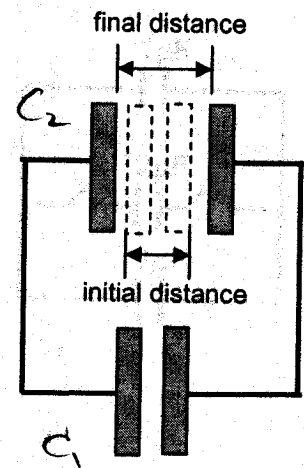
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Two identical capacitors of capacitance C are connected as shown in the figure. Then, the potential across the bottom capacitor is measured to be equal to V . Suppose that the distance between the plates of the top capacitor is doubled. What is the final voltage of the bottom capacitor in terms of V ?



The charge is conserved

$$Q_1 = C_1 V \quad , \quad C = \epsilon_0 \frac{A}{d}$$

$$Q_2 = C_2 V$$

$$C_1 = C_2 \quad \Rightarrow \quad Q_1 = Q_2 \quad \text{At the beginning} \quad \Rightarrow \quad Q = Q_1 + Q_2 = 2CV$$

$$Q = 2\epsilon_0 \frac{A}{d} V$$

final $C_2 = \epsilon_0 \frac{A}{2d} = \frac{C}{2} \Rightarrow Q$ doesn't change \Rightarrow

$$Q = \frac{C}{2} V' + C V' \Rightarrow \frac{C}{2} V' + C V' = 2CV$$

$$\frac{3}{2} V' = 2V$$

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