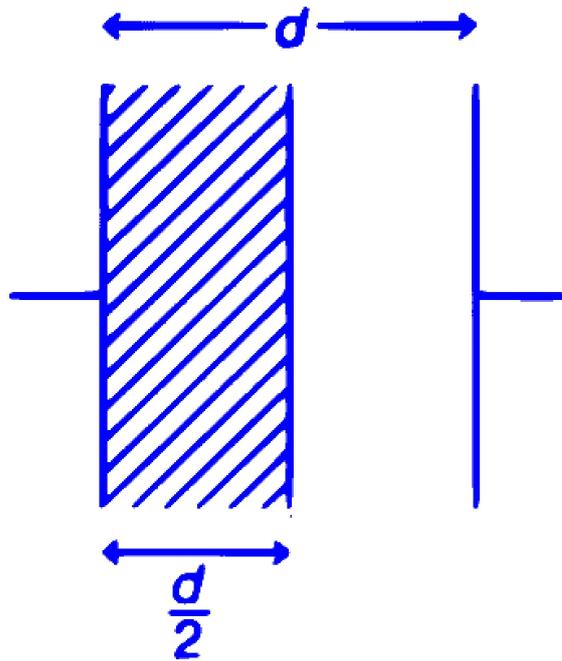# Capacitor

Question1

As shown in the figure, a dielectric of constant K is placed between the plates of a parallel plate capacitor and is charged to a potential V using a battery. If the dielectric is pulled out after disconnecting the battery from the capacitor, the final potential difference across the plates of the capacitor is

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Options:

A.

$\left(1 + \frac{1}{K}\right)2V$

B.

$2KV$

C.

$$\frac{2V}{\left(1+\frac{1}{K}\right)}$$

D.

$$\frac{V}{2}\left(1+\frac{1}{K}\right)$$

Answer: C

Solution:

When dielectric is filled, we model this as two capacitors in series.

For capacitor with dielectric,

$$C_1 = \frac{\varepsilon_0 A}{\frac{d}{2k}} = \frac{2KA\varepsilon_0}{d}$$

For capacitor without dielectric,

$$C_2 = \frac{\varepsilon_0 A}{\frac{d}{2}} = \frac{2\varepsilon_0 A}{d}$$

For series combination,

$$C = \frac{C_1 \times C_2}{C_1 + C_2}$$
$$C = \frac{\frac{2KA\varepsilon_0}{d} \times \frac{2\varepsilon_0 A}{d}}{\frac{2KA\varepsilon_0}{d} + \frac{2\varepsilon_0 A}{d}}$$
$$C = \frac{2\varepsilon_0 A}{d\left(1+\frac{1}{K}\right)}$$

Charge stored initially,

$$Q = CV = \frac{2\varepsilon_0 A}{d\left(1+\frac{1}{K}\right)} \cdot V$$

Now, the entire capacitor just vacuum,

$$C' = \frac{\varepsilon_0 A}{d}$$

So, final voltage, $V' = \frac{Q}{C'}$

$$= \frac{2\varepsilon_0 AV}{d\left(1+\frac{1}{K}\right)} \times \frac{d}{\varepsilon_0 A}$$
$$V' = \frac{2V}{\left(1+\frac{1}{K}\right)}$$

Question2

A capacitor of capacitance C is charged to a potential V and disconnected from the battery. Now, if the space between the plates is completely filled with a substance of dielectric constant K, the final charge and the final potential on the capacitor are respectively.

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Options:

A. KCV and $\frac{V}{K}$

B. CV and $\frac{V}{K}$

C. $\frac{CV}{K}$ and KV

D. $\frac{CV}{K}$ and $\frac{V}{K}$

Answer: B

Solution:

When a capacitor of capacitancec is charged to a' potential V, then initial charge on capacitor is,

$Q = CV$

When a dielectric material with dielectric constant K is inserted between the plates then new capacitance,

$C' = KC$

Charge on the capacitor remains the same because it is disconnected from the battery.

$Q' = Q = CV$

Final potential on the capacitor,

$V' = \frac{Q'}{C'} = \frac{CV}{KC}$

$V' = \frac{V}{K}$

Question3

For the displacement current through the plates of a parallel plate capacitor of capacitance 30μ F to be 150μ A, the potential difference

across the plates of the capacitor has to vary at the rate of

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Options:

A. $10\mathrm{Vs}^{-1}$

B. $5\mathrm{Vs}^{-1}$

C. $15\mathrm{Vs}^{-1}$

D. $20\mathrm{Vs}^{-1}$

Answer: B

Solution:

Given,

Current, $i_C = 150\mu$ A

Capacitance of capacitor, $C = 30\mu$ F

Rate of change of potential, $\frac{dV}{dt} = ?$

We know that,

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

$q = CV$

Differentiate the Eq. (i) w.r.t. to time t, we have

$\frac{dq}{dt} = C\frac{dV}{dt}$

As we know the rate to change of charge per unit of time is equal to the current, then

$i_C = C \cdot \frac{dV}{dt}$

Putting the value,

$150 \times 10^{-6} = 30 \times 10^{-6} \times \dfrac{dV}{dt}$

$\dfrac{dV}{dt} = \dfrac{150}{30}$

$\dfrac{dV}{dt} = 5\mathrm{Vs}^{-1}$

Question4

A capacitor of capacitance $(4.0 \pm 0.2)\mu\text{F}$ **is charged to a potential of** $(10.0 \pm 0\text{l})\text{V}$. **The charge on the capacitor is**

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Options:

A. $2.5\mu\text{C} \pm 3\%$

B. $2.5\mu\text{C} \pm 6\%$

C. $40\mu\text{C} \pm 6\%$

D. $2.5\mu\text{C} \pm 3\%$

Answer: C

Solution:

A capacitor has a capacitance of $(4.0 \pm 0.2)\,\mu\text{F}$ and is charged to a potential of $(10.0 \pm 0.1)\,\text{V}$.

Given:

Capacitance, $C = (4.0 \pm 0.2)\,\mu\text{F}$

Voltage, $V = (10.0 \pm 0.1)\,\text{V}$

The charge Q on the capacitor can be calculated using the formula:

$Q = C \times V$

So, the absolute charge value is:

$Q = 4.0\,\mu\text{F} \times 10.0\,\text{V} = 40\,\mu\text{C}$

To find the error in the charge, we use the formula for the combined relative error:

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

Substitute the given values:

$\frac{\Delta Q}{Q} = \left(\frac{0.2}{4.0}\right) + \left(\frac{0.1}{10.0}\right) = 0.05 + 0.01 = 0.06$

Therefore, the percentage error in the charge Q is:

$\frac{\Delta Q}{Q} \times 100 = 0.06 \times 100\% = 6\%$

The final charge on the capacitor, including the percentage error, is:

$Q = (40\,\mu\mathrm{C} \pm 6\%)$

Question5

Two capacitors of capacitances $1\mu\,\mathrm{F}$ and $2\mu\,\mathrm{F}$ can separately withstand potentials of 6 kV and 4 kV respectively. The total potential, they together can withstand when they are connected in series is
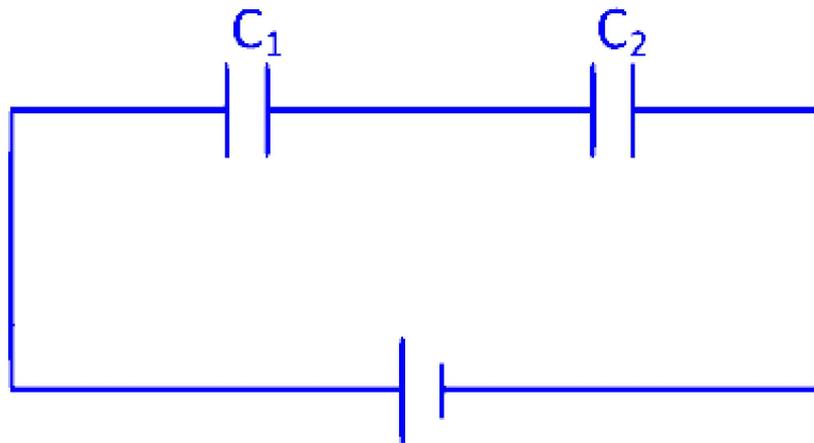
TG EAPCET 2024 (Online) 10th May Evening Shift

Options:

A. 9 kV

B. 4 kV

C. 6 kV

D. 2 kV

Answer: A

Solution:

Capacitor, $C_1 = 1\mu\,\mathrm{F}$

$C_2 = 2\mu\,\mathrm{F}$

According to question, maximum potential with stand by C_1 is 6 kV .

$\Rightarrow V_{1\,\mathrm{max}} = \dfrac{Q_{\mathrm{max}}}{C_1}$

$$Q_{\max} = C_1 V_{1\,\max}$$

$$\Rightarrow 1 \times 10^{-6} \times 6 \times 10^3$$

$$Q_{\max} = 6 \times 10^{-3}$$

On first capacitor

When C_1 and C_2 are connected in series, the charge on each capacitor is equal and is equal to the maximum charge the combination can withstand.

Since $C_1 V_{1\,\max} < C_2 V_{2\,\max}$

The resultant capacitance of combination is

$$C_R = \frac{C_2 C_1}{C_1 + C_2} = \frac{2 \times 1}{2 + 1}$$

$$C_R = \frac{2}{3} \times 10^{-6} \text{ F}$$

$$V_{\max} = \frac{Q_{\max}}{C_R} = \frac{6 \times 10^{-3}}{\frac{2}{3} \times 10^{-6}}$$

$$V_{\max} = 9 \times 10^3 \text{ V}$$

$$V_{\max} = 9\text{kV}$$

Question6

A 10μ F capacitor is charged by a 100 V battery. It is disconnected from the battery and is connected to another uncharged capacitor of capacitance 30μ F. During this process, the electrostatic energy lost by the first capacitor is

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Options:

A. 5×10^{-2} J

B. 125×10^{-2} J

C. 2.75×10^{-2} J

D. 375×10^{-2} J

Answer: D

Solution:

Capacitor $C_1 = 10\mu$ F

Charging voltage, $V = 100$ V

Initial stored energy of capacitor

$$U_{\text{initial}} = \frac{1}{2}C_1V^2$$

$$= \frac{1}{2} \times 10^{-6} \times 100 \times 100$$

$$= 0.5 \times 10^{-2} \text{ J}$$

Energy lost when connect to uncharged capacitor

$$\Delta U = \frac{1}{2}\frac{(C_1C_2)}{C_1+C_2}(V_1 - V_2)^2$$

$$V_2 = 0$$

$$\Delta U = \frac{1}{2} \times \frac{10 \times 30 \times 10^{-6}}{40} \times 100 \times 100$$

$$\Delta U = \frac{3}{80} \times 10^{-2} \times 100 = 0.0375$$

or $\Delta U = 3.75 \times 10^{-2}$ J

Question7

If half of the space between the plates of a parallel plate capacitor is filled with a medium of dielectric constant 4 , the capacitance is C_1. If one-third of the space between the plates of the capacitor is filled with the medium of dielectric constant 4 , the capacitance is C_2. If in both cases, the dielectric is placed parallel to the plated of the capacitor, then $C_1 : C_2 =$

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Options:

A. 2 : 3

B. 4 : 3

C. 6 : 5

D. 7 : 5

Answer: C

Solution:

Let us assume that the area of the plates is A and the separation between them is d

$\therefore \quad C = \frac{\varepsilon_0 A}{d}$

The capacitance with the dielectric of thickness, $t = \frac{d}{2}$,

$$C_1 = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}} = \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{2K}}$$

$$= \frac{2\varepsilon_0 A K}{d(K+1)} = \frac{2KC}{(K+1)}$$

$$= \frac{2 \times 4 \times C}{(5)} = \frac{8C}{5}$$

Again, when capacitor is filled upto $t = ?$

$$\therefore \quad C_2 = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}} = \frac{\varepsilon_0 A}{d - \frac{d}{3} + \frac{d}{3K}}$$

$$= \frac{\varepsilon_0 A}{\frac{2d}{3} + \frac{d}{3K}} = \frac{\varepsilon_0 A}{d\left(\frac{2K+1}{3K}\right)}$$

$$\Rightarrow \quad \frac{\varepsilon_0 A}{d} \frac{3K}{(2K+1)} = C \times \frac{3K}{(2K+1)}$$

$$C_2 = \frac{C \times 3 \times 4}{9} = \frac{4}{3}C$$

Now, $\frac{C_1}{C_2} = \frac{\frac{8}{5}C}{\frac{4}{3}C} \Rightarrow \frac{8}{5} \times \frac{3}{4} = \frac{6}{5}$

Question8

The natural frequency of an $L - C$ circuit is 120 kHz . When the capacitor in the circuit is totally filled dielectric material, the natural frequency of the circuit decreases by 20 kHz . Dielectric constant of

material is

Options:

A. 3.33

B. 1.44

C. 2.12

D. 1.91

Answer: B

Solution:

Natural frequency of $L - C$ circuit

$2\pi v = \frac{1}{\sqrt{LC}}$

When capacitor is filled with dielectric,

$C' = KC$

Thus $\omega_1 = \frac{1}{\sqrt{LC_1}}$ and $\omega_2 = \frac{1}{\sqrt{LC_2}}$

According to question, $2\pi \times 120 = \frac{1}{\sqrt{LC}}$

and $2\pi \times 100 = \frac{1}{\sqrt{LKC}}$

$\Rightarrow \frac{2\pi \times 120}{2\pi \times 100} = \frac{1}{\sqrt{LC}} \times \frac{\sqrt{LKC}}{1}$

$\frac{120}{100} = \sqrt{K}$

$1.2 = \sqrt{K}$

$\Rightarrow \quad K = (1.2)^2 = 1.44$

Question9

Three capacitors of capacitances 10μ F, 5μ F and 20μ F are connected in series with a 14 V DC supply. The charge on 5μ F

capacitor is

Options:
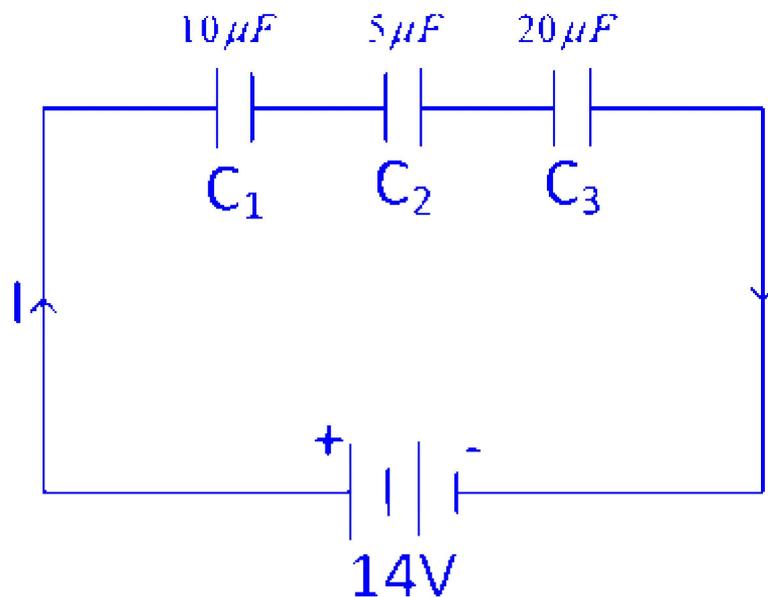
A. $20\mu C$

B. $40\mu C$

C. $70\mu C$

D. $2.8\mu C$

Answer: B

Solution:

When capacitor are connected in series, the total capacitance C_{Toal} ,

$$\frac{1}{C_{\text{Total}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Given,

$$C_1 = 10\mu \text{ F}, \quad C_2 = 5\mu \text{ F}, \quad C_3 = 20\mu \text{ F}$$

$$\frac{1}{C_{\text{Toul}}} = \frac{1}{10} + \frac{1}{5} + \frac{1}{20}$$

$$= \frac{2}{20} + \frac{4}{20} + \frac{1}{20} = \frac{7}{20}$$

For, $5\mu C$,

$$Q = C_{\text{Total}} \times V$$

$$= \frac{20}{7} \times 14 = \frac{280}{7} = 40\mu C$$

Question10

If a capacitor of capacitance 100μ F is charged at a steady rate of $100\mu\text{Cs}^{-1}$, then the time taken to produce a potential difference of 100 V between the capacitor plates is

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Options:

A. 50 s

B. 200 s

C. 150 s

D. 100 s

Answer: D

Solution:

Given:

Capacitance $C = 100\,\mu\text{F}$

Charging rate $q = 100\,\mu\text{C/s}$

Desired potential difference $V = 100\,\text{V}$

To find the time t required to achieve a potential difference of 100 V, use the relationship between charge, capacitance, and potential difference:

$$Q = C \cdot V$$

Since charge Q is also given by:

$$Q = q \cdot t$$

Equate the two expressions:

$$C \cdot V = q \cdot t$$

Rearrange to solve for time t:

$$t = \frac{C \cdot V}{q}$$

Insert the given values:

$$t = \frac{100 \times 10^{-6}\,\text{F} \times 100\,\text{V}}{100 \times 10^{-6}\,\text{C/s}}$$

$$t = 100\,\text{s}$$

Therefore, the time required to produce a potential difference of 100 V between the capacitor plates is 100 seconds.