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ENERGY STORED IN A CAPACITOR.

CLASS-XII

SUBJECT : PHYSICS
CHAPTER NUMBER: 02
CHAPTER NAME : ELECTROSTATIC POTENTIAL AND CAPACITANCE

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LEARNING OUTCOME

After this lesson, students will be able:

- To derive expressions for energy stored in a capacitor
- To identify series and parallel parts in the combination of connection of capacitors.
- To Calculate the effective capacitance in series and parallel given individual capacitances.
- To list three factors that determine the capacitance of a capacitor..

Slide 2

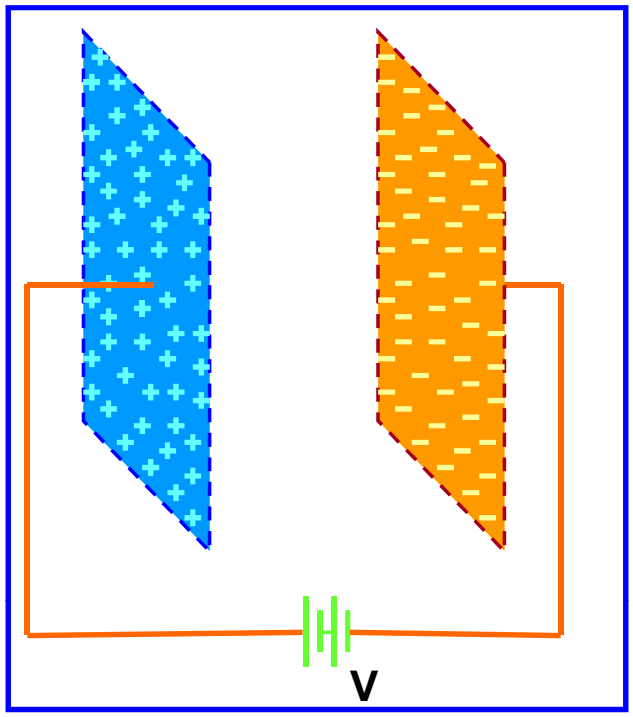
1	@Format for content and slide heading is missing? Just like you have mentioned in DOC., We need to specify, for each slide's heading and text content, what will be the font style +amanrouniyar@odmegroup.org _Assigned to you_ -Swoyan Satyendu , 6/17/2020

REVIEW

1. What are capacitors ?
2. What is the capacitance of an isolated capacitor?
3. What is the relation between dielectric constant and polarization vector?

ENERGY STORED IN A CAPACITOR:

The total work done (energy) to transfer charge q is



$$U = \int_0^q \frac{q}{C}\, dq \quad \text{or} \quad U = \frac{1}{2}\frac{q^2}{C} \quad \text{or} \quad U = \frac{1}{2} C V^2 \quad \text{or} \quad U = \frac{1}{2} q V$$

ENERGY DENSITY:

$$U = \frac{1}{2} C V^2 \qquad \text{But} \quad C = \frac{A \varepsilon_0}{d} \qquad \text{and} \quad V = E d$$

$$\therefore \; U = \frac{1}{2} \varepsilon_0 Ad E^2 \quad \text{or} \quad \frac{U}{Ad} = \frac{1}{2} \varepsilon_0 E^2 \quad \text{or} \quad \overline{U} = \frac{1}{2} \varepsilon_0 E^2$$

SI unit of energy density is J m^{-3}.

Energy density is generalised as energy per unit volume of the field.

ENERGY STORED IN A SERIES COMBINATION OF CAPACITORS:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots\ldots + \frac{1}{C_n}$$

$\therefore$ $$U = \frac{1}{2}\frac{q^2}{C}$$

$$U = \frac{1}{2} q^2 \left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots\ldots + \frac{1}{C_n} \right]$$

$$U = U_1 + U_2 + U_3 + \ldots\ldots\ldots + U_n$$

The total energy stored in the system is the sum of energy stored in the individual capacitors.

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ENERGY STORED IN A PARALLEL COMBINATION OF CAPACITORS:

$$C = C_1 + C_2 + C_3 + \ldots\ldots\ldots + C_n$$

$$U = \frac{1}{2} C V^2 \quad \therefore \quad U = \frac{1}{2} V^2 \left(C_1 + C_2 + C_3 + \ldots\ldots\ldots + C_n \right)$$

$$U = U_1 + U_2 + U_3 + \ldots\ldots\ldots + U_n$$

The total energy stored in the system is the sum of energy stored in the individual capacitors.

Note

The total energy stored in a series combination or parallel combination of capacitors is equal to the sum of the energies stored in the individual capacitors.

i.e. $U = U_1 + U_2 + U_3 + \ldots$

Loss of Energy on Sharing of Charges between the Capacitors in Parallel:

Consider two capacitors of capacitances C_1, C_2, charges q_1, q_2 and potentials V_1,V_2.

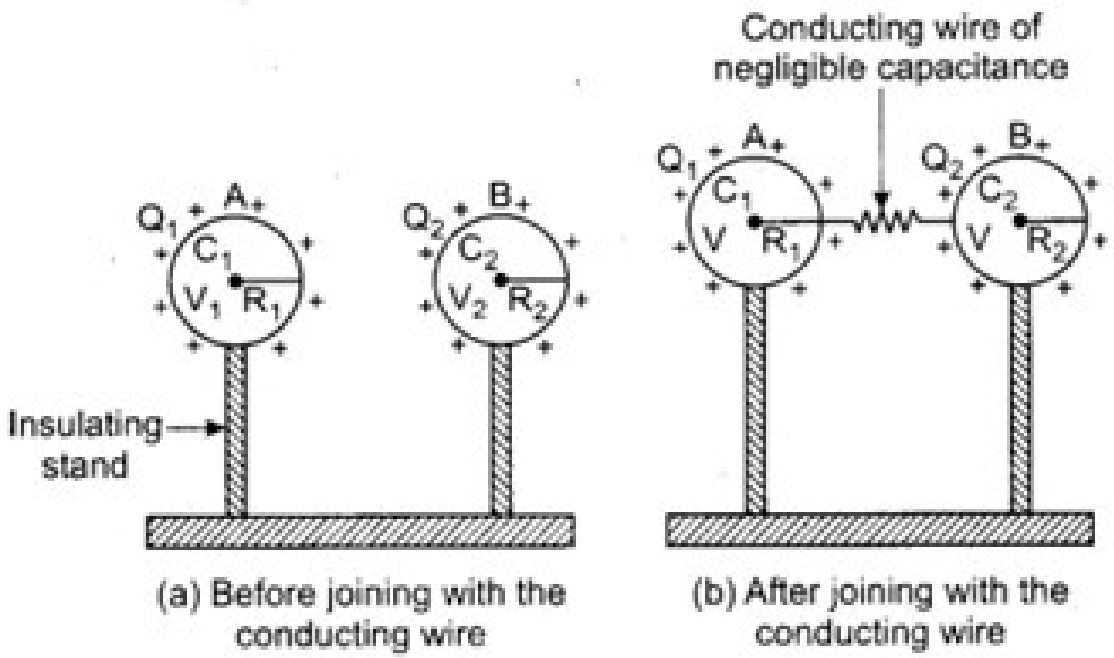
Total charge after sharing = Total charge before sharing

$$\therefore \quad (C_1 + C_2)\, V = C_1 V_1 + C_2 V_2$$

$$V = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$$

$$U_i - U_f = \frac{C_1 C_2 (V_1 - V_2)2}{2 (C_1 + C_2)}$$

$$U_i - U_f > 0 \quad \text{or} \quad U_i > U_f$$

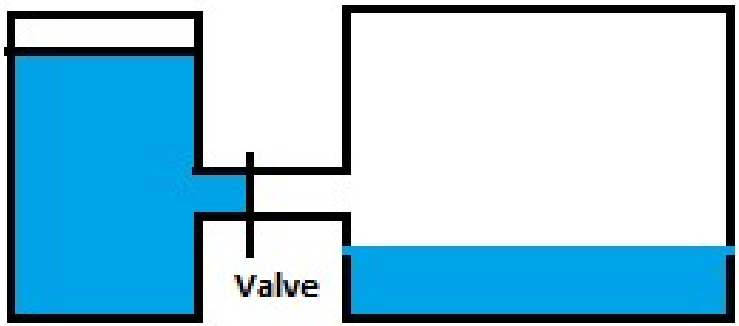


Therefore, there is some loss of energy when two charged capacitors are connected together.

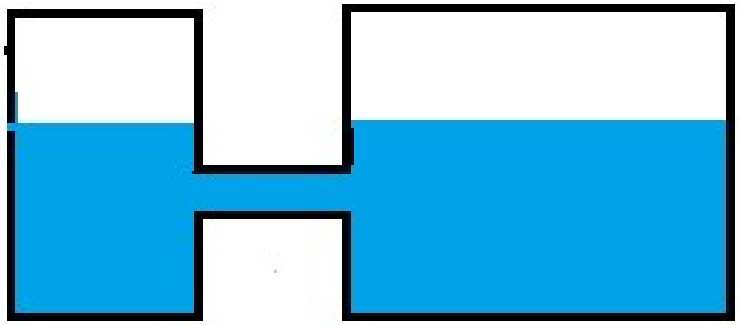
The loss of energy appears as heat and the wire connecting the two capacitors may become hot.

Note

The redistribution of charge is analogous to the following example



(Before opening the valve)



(After opening the valve)

When the valve is open, the level in both the vessels becomes equal but the volume of liquid in the right vessel is more than the left vessel.

Questions

Question: In which form energy is stored inside a capacitor?

Question: Where is the energy stored in a parallel plate capacitor?

Numerical

Question: An unknown capacitor is connected to the battery. Show that half of its energy supplied by the battery is lost as heat while charging the capacitor.

Numerical

Question: Show that the force on each plate of a parallel plate capacitor has a magnitude equal to $\frac{1}{2}QE$.where Q is the charge in the capacitor and $E$is the magnitude of the electric field between the plates.

Numerical

Question:

a) A 900pF capacitor is charged by a 100 V battery. How much electrostatic energy is stored by the capacitor?

b) The capacitor is disconnected from the battery and connected to another uncharged 900 pF capacitor. What is the electrostatic energy stored now?

c) Where has the remained energy gone?

HOME ASSIGNMENT

Question: When two charged conductors having different capacities and different potentials are joined together, show that there is always a loss of energy.

Question: A 600 pF capacitor is charged by a 200 V supply. It is then disconnected from the supplier and is connected to another 600 pF capacitor. How much electrostatic energy is lost in the process?

Question: Two parallel plate condensers A and B having capacitances of $1\mu F$ and $5\mu F$ are charged separately to the same potential of 100 V. Now the positive plate of A is connected to the negative plate of B. And the negative plate of A is connected to the positive plate of B. Find the final charge on each condenser and total loss of electric energy in the condenser?

THANKING YOU

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