MASTERJEE CLASSES

CAPACITOR AND CAPACITANCE

BRAIN MAP

CLASS XII

CAPACITOR

Capacitor is a passive electronic component that stores energy in the form of an electrostatic field. The ratio of charge and the potential it raised is called **capacitance**.

Dielectric and its Properties

$K = \dfrac{\varepsilon\ (\text{Permitivity of medium})}{\varepsilon_0(\text{Permitivity of free space})}$

Dielectric Constant

Types of Dielectric

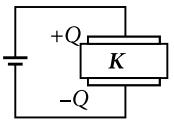
Polar dielectric
Permanent dipole moment exist in absence of electric field also.

Non-polar dielectric
Each molecule has zero dipole moment in its normal state.

Dielectric is an insulator which transmits electric effect without conducting. If field exceeds the dielectric strength, the dielectric begins to conduct.

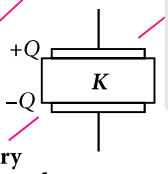
For linear isotropic dielectric
$\vec{P} = \chi_e \vec{E}$ (χ_e = electrical succeptibility)

- $C' = KC$
- $U = KU_0$
- $Q = KQ_0$
- $E = E_0$
- $V = V_0$



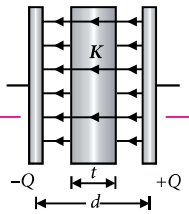
Capacitors with Dielectrics

Battery Connected



- $C' = KC$
- $Q = Q_0$
- $V = \dfrac{V_0}{K}$
- $U = \dfrac{U_0}{K}$
- $E = \dfrac{E_0}{K}$

Battery Disonnected



- **Partially filled dielectric**
  $C' = \dfrac{\varepsilon_0 A}{d - t + \dfrac{t}{K}}$

Energy Storage in a Capacitor

Parallel Plate Capacitor

Energy Stored
$U = \dfrac{1}{2}CV^2 = \dfrac{Q^2}{2C} = \dfrac{1}{2}QV$

Energy Density
$u = \dfrac{1}{2}\varepsilon_0 E^2$

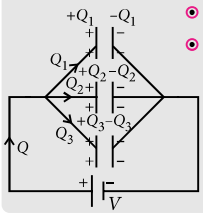
Spherical Conductor of Radius a

Energy Stored
$U = \dfrac{1}{2}QV = \dfrac{Q^2}{8\pi\varepsilon_0 a}$

Energy Density
$u = \dfrac{Q^2}{32\pi^2\varepsilon_0 r^4}$

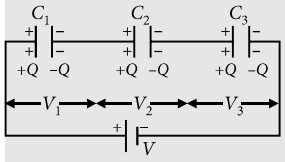
Combination of Capacitors

Parallel Combination



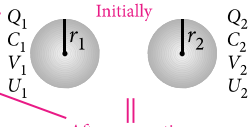
- $Q = Q_1 + Q_2 + Q_3$
- $C_{eq} = C_1 + C_2 + C_3$
- For n identical capacitor $C_{eq} = nC_1$ and $Q' = Q/n$
- Used when high capacity is required at low potential

Series Combination

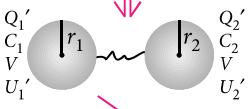


- $V = V_1 + V_2 + V_3$
- $\dfrac{1}{C_{eq}} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$
- For n identical capacitor $C_{eq} = C/n$ and $V' = V/n$

Charge Sharing Between Conductors



After connecting through conducting wire



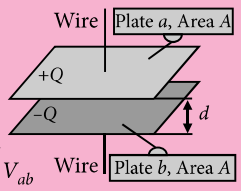
- **New charge**
  $Q_1' = Q\left[\dfrac{r_1}{r_1 + r_2}\right]$
  $Q_2' = Q\left[\dfrac{r_2}{r_1 + r_2}\right]$
- **Common potential**
  $V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$
- **Energy loss**
  $\Delta U = \dfrac{C_1C_2}{2(C_1 + C_2)}(V_1 - V_2)^2$

Types of Capacitors and their Capacitances

Parallel Plate Capacitor

It consists of two large plates placed parallel to each other with a separation d.

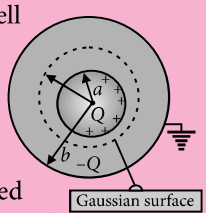
Capacitance:
$C = \dfrac{\varepsilon_0 A}{d}$



Spherical Capacitor

It consists of two concentric spherical conducting shells of radii a and b, say $b > a$. The outer shell is earthed.

Capacitance:
$C = \dfrac{4\pi\varepsilon_0 ab}{b - a}$



For a single isolated spherical conductor of radius R, $C = 4\pi\varepsilon_0 R$

Cylindrical Capacitor

It consists of two coaxial cylinders of radii a and b, say $b > a$ and length L. The outer one is earthed.

Capacitance:
$C = \dfrac{2\pi\varepsilon_0 L}{\ln\left(\dfrac{b}{a}\right)}$