# CAPACITOR

A conductor has a limited capacity to hold charge called capacitor some of suitable examples of capacitors are

(i) parallel plate capacitor (ii) spherical capacitor (iii) cylindrical capacitors

Capacitance of a capacitor is defined as the amount of charge required to raise the potential by unity. Experimentally, charge given to the conductor directly proportional to potential of the conductor.

i.e., $Q \ \alpha \ v \Rightarrow Q = cv$; c is proportionality constant called capacitance and it does depend upon the shape and size of the capacitor. is capacitence of conductor unit of capacitor is forced (coulomb volt$^{-1}$).

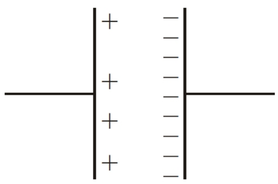
## FACTORS AFFECTING THE CAPACITENCE OF THE CAPACITOR :

1. The presence of another uncharged conductor near the charged one raises the capacitence of charged conductor.
2. Increase in surface area increase the capacitance.
3. Presence of dielectric increases the capacitance.

## PARALLEL PLATE CAPACITOR :

It consists two parallel metallic plates separated by a small distance having equal and opposite charges..

Electric field strength $\vec{E}$ is directed from positive plate to negative plate.



$$E = \frac{\sigma}{\varepsilon_o} = \frac{Q}{A\varepsilon_o}$$

$\sigma$ = surface charge density; Q = Charge appeared on each plate; A = Area of the plate

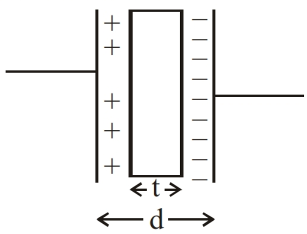
C = Capacitance of parallel plate capacitor

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

When dielectric of thickness t is inserted between parallel plate capacitor

$$V = \frac{Qd}{A\varepsilon_0}$$

$$C = \frac{A\varepsilon_o}{d - t + \frac{t}{k}}$$



As V = potential difference

$$= \frac{\sigma}{\varepsilon_o}(d - t) + \frac{\sigma}{\varepsilon_o K} \cdot t$$

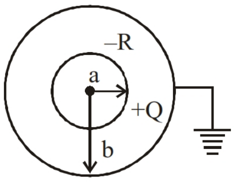
when length of dielectric state t = d (separation of two parallel plates)

Then $$C = \left(\frac{A\varepsilon_o}{d}\right)K.$$

Spherical Capacitor : It consists of two concentric conducting spheres of radii a and b (a < b). Inner sphere is given charge +Q. while outer sphere is carthed.

Potential Difference

$$V = Q\left(\frac{1}{4\pi\varepsilon_o} - \frac{1}{4\pi\varepsilon_o b}\right)$$

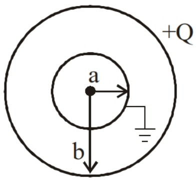



and capacitance $c = 4\pi\varepsilon_o \frac{ab}{b-a}$.

In presence of dielectric medium between spheres capacitence, $c = 4\pi\varepsilon_o K \frac{ab}{a-b}$

If outer sphre is given charge +Q while sphere is carthed inner then induced charge on inner sphere

$Q^1 = -\frac{a}{b}Q$ and capacitence is given an

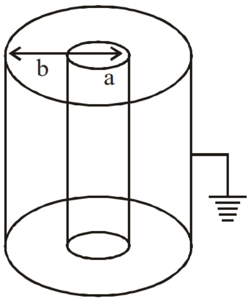



$$c = 4\pi\varepsilon_o \frac{b^2}{b-a} = 4\pi\varepsilon_o \frac{ab}{a-b} + 4\pi\varepsilon_o b$$

Cylindrical Capacitor :

It consists of two concentric cylinders of radii a and b (a < b), inner cylinder is given charge +Q while outer cylinder is earthed length of cylinders is l then

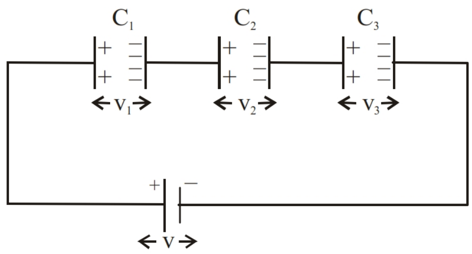
$$c = \frac{2\pi\varepsilon_o l}{\log_e(b/a)}$$




Grouping of Capacitor

1. Series grouping :

Two or more capacitors are said to be in series arrangement if there is same charge distributed on r each while sum of potential difference across and the capacitors is the potential difference across system of capacitors.




$v = v_1 + v_2 + v_3$ ...(i) and $c_1 v_1 = c_2 v_2 = c_3 v_3$ ...(ii)

$$\therefore \frac{1}{c_{eq}} = \frac{1}{c_1} + \frac{1}{c_2} + \frac{1}{c_3}$$

In series combination potential difference and energy distributes in the inverse ratio of capacitence i.e.

$$v = \alpha \frac{1}{c} \text{ and } U \alpha \frac{1}{c}.$$

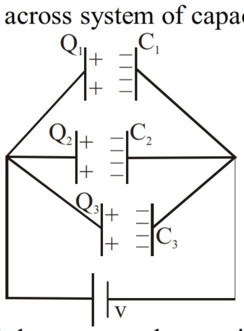
## 2. Parallel grouping :

Two are more capacitors are said to be in parallel arrangement if there is same potential difference across each and which is equal to applied potential difference across system of capacitors.

$$Q = Q_1 + Q_2 + Q_3$$

$$v_1 = \frac{Q_1}{C_1} = v_2 = \frac{Q_2}{C_2} = v_3 = \frac{Q_3}{C_3}$$

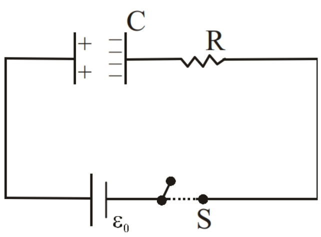
$$\Rightarrow C_{eq} = C_1 + C_2 + C_3$$




and charge drawn from source is equal to sum of charge on each capacitor. In parallel combination charge and energy distributes in ratio of capacitence i.e. $Q \; \alpha \; \ell$ and $U \; \alpha \; C$.

## RC-Circuit

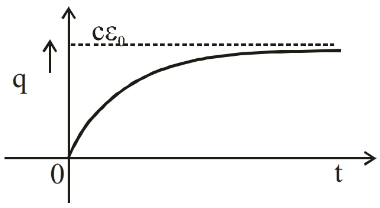
### 1. For charging




when S (switch) is closed capacitor starts charging, in the transient state of charging, potential difference appears across capacitor as well as resistor. When capacitor gets fully charged the entire potential difference appeared across the capacitor. The charge on capacitor at the t

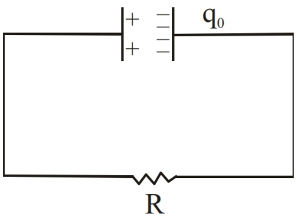
$$q(t) = c\varepsilon_0 \left(1 - e^{-\frac{t}{RC}}\right) \text{ and } i(t) = \frac{\varepsilon_0}{R} e^{t/Rc}$$

and $$v(t) = \varepsilon_o \left(1 - c^{-}t/Rc\right)$$




The quantity RC is called one time constant after one time constant the charge appears is 0.63 ( $c\varepsilon_0$ ) i.e. 63% of equilibrium charge

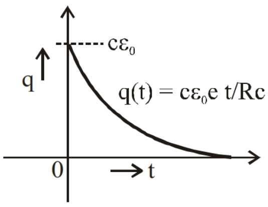
2. For discharging




After completion of charging, if battery is removed, capacitor starts discharging. In transient state charge on capacitor at any instant

$$q(t) = c\varepsilon_0 . e^{-t/Rc} = q_0 e^{-t/Rc}$$

and potential difference across capacitor $v(t) = \varepsilon_0 e^{-t/Rc}$




value of Rc is one time constant and during discharging it is time during which charge on a capacitor falls to 0.37 times of initial charge i.e., 37% of initial charge.

Energy stored in capacitor :

Capacitor is a device that stores electric energy

$U = \frac{1}{2}CV^2$; where C is the capacitance of capacitor and V be potential

$= \frac{1}{2}QV = \frac{Q^2}{2C}$; Q = charge appeared on the each plate of capacitor.

Dielectric :

Dielectrics are insulating (non-conducting) materials which transmits electric effect without conduction of charge. Dielectric are of two types :

1. Polar dielectrics :

A polar molecule has permanent electric dipole moment $(\vec{P})$ in absence of electric field to. But a polar dielectric has no-net dipolemoment in absence of electric field because polar molecules are randomly oriented. In the presence of electric field polar molecules tends to line up in direction of electric field, and the substance has finite dipole moment. e.g. water $CO_2$, HCl etc. are made of polar atoms/molecules.

## 2. Non polar dielectric :

In non-polar molecules, each molecule has zero dipole moment in its normal state. When electric field is applied, molecules become induced electric dipole e.g., $N_2$, $O_2$, benzene etc. are made of non-polar atoms/molecules.

In general, any non-conducting material can be called as a dielectric but broadly non-conducting material having non-polar molecules referred to on dielectric.

## Polarisation of dielectric Slab :

It is the process of inducing equal and opposite charges on the two faces of dielectric on the application of electric field.

$$\text{Dielectric const of dielectric medium (K).} = \frac{\text{Electric field between plates with air}}{\text{Electric field between plates with medium}}$$

If a very high electric field is created in a dielectric, then the dielectric behaves like a conductor. The phenomenon is dielectric break down.