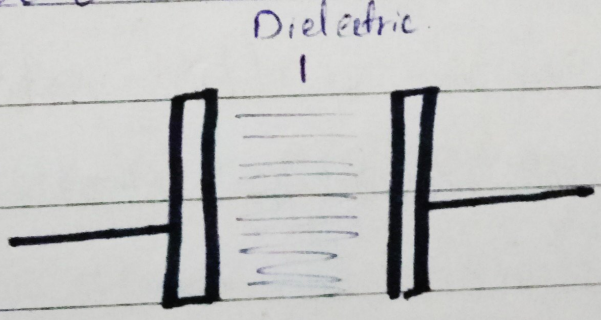
Capacitors

"Capacitor is a device used to store electrical charge and electrical energy."

→ It consist of two thin metal plates separated by a distance d

Dielectric

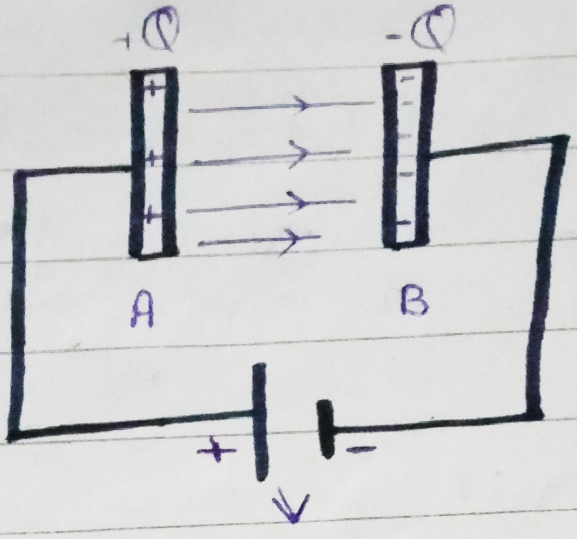
The medium between two plates is air or a sheet of some insulator. This medium is called dielectric.



∴ Parallel plate capacitor

→ If capacitor connected to battery of V volts Then a battery transfer a charge +Q

from plate B to plate A so that $-Q$ charge appears on plate B and $+Q$ charge appears on plate A.



- Due to this phenomenon charges are stored on plate and capacitor also stored electrical energy.
- The charges on each plate attract each other and thus remain bound within plate. In this way charge stored in a capacitor for a long time.
- It means the potential on capacitor plate is equal to battery potential

The charge Q stored on plates is directly proptional to the P.D V across the plates

$$Q \propto V$$

$$Q = CV$$

where C is constant of proportionality called capacitence of capacitor and defined as

"ability of capactior to charge"

Unit:-

SI unit of capacitence is farad (F)

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

The total charge stored in capacitor is zero $Q - Q = 0$

Factor effect:-

Capacitence is directly propotoned to area of cross section and inversly prepcational to distence between them

$$C \propto A$$

$$C \propto \frac{1}{d}$$

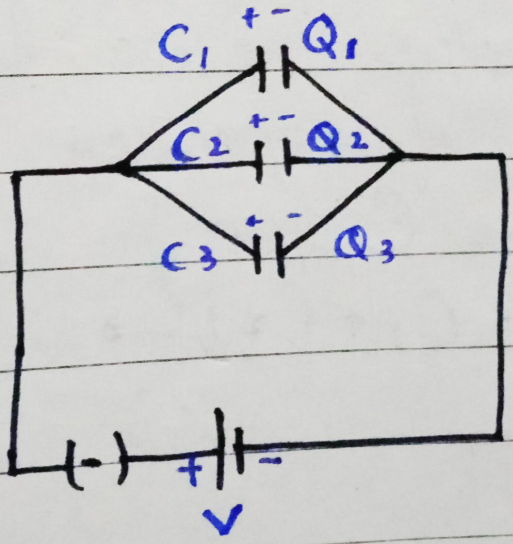
Application of Capacitors:

- Capacitors are used in ignition system of automobiles engines to eliminate sparking.
- Capacitor are used to reduce power fluctuations in power supplies and to increase the efficiency of power transmission.
- During cardiac arrest a device called heart defibrillator is used to give a sudden surge of large amount of electrical energy to patient chest.
- They are used in table fans, ceiling fans, exhaust fans, fan motor in air conditioner.
- They are used in resonant circuits that tunes radios to particular frequencies.

Combination of capacitors

(i) Capacitor in Parallel

In This combination, The plate of each capacitor is connected to positive terminal of a battery by conducting a wire and other connected to negative terminal of battery.



Each capacitor connected to a battery of voltage V has same potential clifference V

$$V_1 = V_2 = V_3 = V$$

- The charge developed across the plates of each capacitors will be different due to different value of capacitance
- The total charge Q supplied by the battery is divided among various capacitors

$$Q = Q_1 + Q_2 + Q_3$$

$$\because Q = CV$$

$$Q = C_1V + C_2V_2 + C_3V$$

$$\frac{Q}{V} = C_1 + C_2 + C_3$$

- We can replace the parallel combination of capacitors with an equivalent C_{eq}

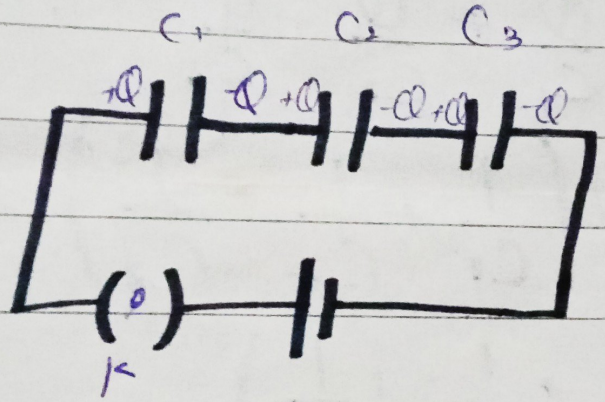
$$C_{eq} = C_1 + C_2 + C_3$$

$$\frac{Q}{V} = C_{eq}$$

- The equivalent capacitance of a parallel combination of capacitor is greater than any of individual capacitance

Capacitor in Series

In This combination The capacitors are connected side by side Rom right plate of one capacitor is connected to left plate of next capacitor.



Each capacitor has same charge across it. If battery supplies +Q charge to left plate of The capacitor C_1 and due to induction -Q charge is induced on its right plate and +Q charge on left plate of The capacitor C_2

$$Q_1 = Q_2 = Q_3 = Q$$

The potential difference across each capacitor is different due to different value of capacitance

The voltage of the battery has been divided among various capacitance

$$V = V_1 + V_2 + V_3$$

$$= \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$V = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\frac{V}{Q} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

Thus we can replace series combination of capacitor with an equivalent capacitor having capacitance

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

Energy stored in capacitor.

Capacitors not only stores the charge but also stores energy.

When a battery is connected to the capacitors electrons of total charge $-Q$ are transferred from one plate to other plate. To transfer the charge, work is done by battery.

This work done is stored as electrostatic potential energy in capacitor.

Work done is $W = F \cdot d$

$$dW = V dQ$$

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

Total work done to charge capacitance

$$W = \int V dQ$$

$$= \frac{Q}{C} \int dQ$$

$$W = \frac{Q^2}{2C}$$

The work done is stored a electrostatic potential energy U_E in the capacitors

$$Q = CV$$

$$W = \frac{1}{2} \frac{C^2 V^2}{C}$$

$$\boxed{W = \frac{1}{2} CV^2}$$

This stored energy is thus directly proportional to the capacitance of capacitor and the square of the voltage between the plate of capacitor.

$$C = \frac{\varepsilon A}{d} \quad \text{and} \quad V = Ed$$

$$W = \frac{1}{2} \left(\frac{\varepsilon_0 A}{d} \right) (Ed)^2$$

$$= \frac{1}{2} \varepsilon_0 (Ad) E^2$$

Date:

Acl = The volume of space