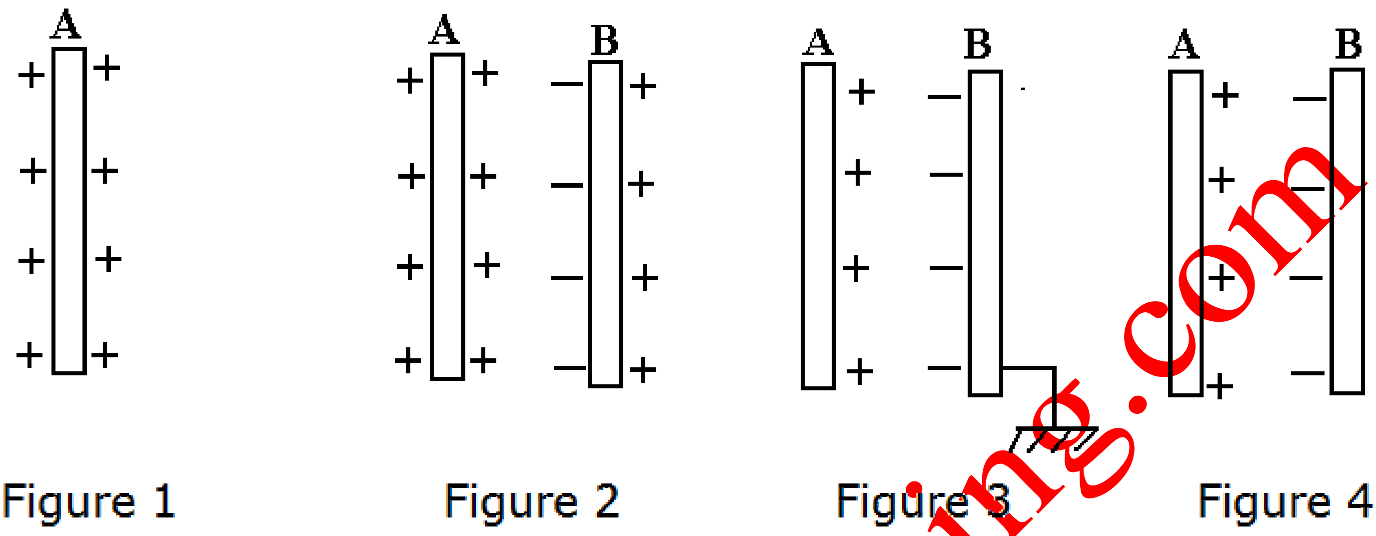
After this comes the concept of capacitor !

What is a capacitor; It is a device to store charge. Now why do we require to store ? Basically we want to use charge as and when required. So we devised a capacitor.

Let us understand the principle of capacitor :



In figure 1 there is a plane metallic sheet, and some charge is placed on it. Now if we see, for the first charge I don't have to do any work as there is no repulsive force, BUT for the second charge we will perform some work as we have some repulsive force, similarly as we increase the charge we have to do more and more work. Now work done per unit charge, is defined as potential.

In other words as the charge on conductor increases its potential increases.

Let us take 2 plates and charge them Refer to Figure 2 to Figure 4. When we give charge to plate A without giving any charge to plate B. now as B is conductor kept near a charged conductor it induces charge as shown in Figure 1. If now plate B is connected to ground all the charge +ve of plate B is goes to ground & only –ve charge stays on it as shown in Figure 2.

Now as the ground connection is removed the charges redistribute as shown in Figure 3. Now both +ve & –ve charges are attracting each other and thus are stored very closely in same conductor. As charge is introduced to conductor its potential increases we may say that Q is proportional to V voltage thus $Q \propto V$ or $Q = CV$

It can be stated that capacitance is ratio of potential to charge for a conductor. And its unit is Farad. So as discussed mathematically 1 Farad is said to be the capacity of capacitor or conductor if 1 Coulomb of charge raises the potential on conductor by 1 Volt.

To find the capacitance we do the same i.e. first charge the conductor & then study its potential in terms of charge, then we divide the two and get the capacitance.

Capacitors are classified as the shape of conductors forming it

(i) parallel plate capacitor.
(ii) spherical capacitor
(iii) cylindrical capacitor etc.
OR on the basis of material filled in between the plates i. e.
(i) Electrolytic
(ii) Ceramic
(iii) Paper
(iv) Mica

Most common capacitor is parallel plate capacitor.

Let us try to get the value of capacitance of parallel capacitor, if we take the capacitor with plate area 'A' and distance between the plates as 'd'. Now if the charge Q is given the electric field inside is given as $E = \sigma/\varepsilon_0$ Also we know that $E = V/d$ or in other words $V = E.d$

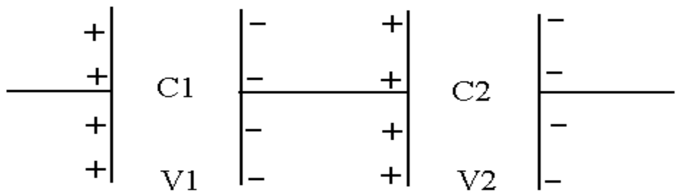
Knowing the value of electric field in terms the charge on capacitor. We get a relation between charge Q and potential V.

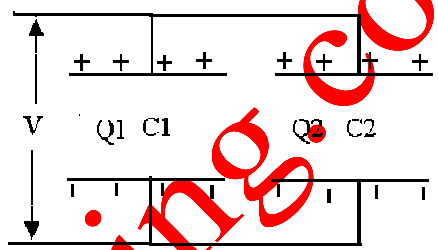
WE DIVIDE CHARGE Q by POTENTIAL V and we get the capacitance.

We see the capacitance is depending on Plate area A, distance between ‘d’ and the permittivity. And also we see that to increase the capacitance either the area is to be increased or the distance between the plates is to be decreased. Let us now analyse that, what happens when area is increased. As we increase the Area the net size of capacitor increase, then it becomes difficult to put it in desired circuit. Next as we decrease the distance there is chance of charge leaking and hence the basic purpose is being defeated. Thus we cans say the we have practical limitations in increasing the area and decreasing the distance between plates.

To increase the capacitance we do grouping of capacitors. There are 2 type of groupings: (i) Series (ii) Parallel

Series capacitance: is said when the charge on capacitors is same but potential is added. In this type of connections the one plate is connected to other plate but oppositely charged. As the charge is produced by induction the charges are equal in magnitude. *(the basic condition for*





series combination) It is to be noted that net charge stored in a capacitor is zero. As it stores equal & opposite charges.

When we connect the capacitors as shown, charge is same on both the capacitors, V_1 is the potential of capacitor C_1 and V_2 is potential of capacitor C_2,

Thus $Q = C_1V_1 = C_2V_2$

The potential of complete circuit is

$$V = V_1 + V_2$$

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

$$\Rightarrow \frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{C_{net}}$$

$$\Rightarrow \frac{1}{C_{net}} = \frac{1}{C_1} + \frac{1}{C_2}$$

In series the net capacitance is less than the least

When the capacitors are connected in parallel , Q_1 is the charge of capacitor C_1 and Q_2 is the charge of C_2 when both are connected to same potential V

Thus $Q_1 = C_1V$ and $Q_2 = C_2V$

Total charge stored in the capacitor combination is given $Q = Q_1 + Q_2$

$$= C_1V + C_2V$$

$$= (C_1 + C_2)V$$

$$\frac{Q}{V} = C_1 + C_2 = C_{net}$$

thus for capacitor in parallel $C = C_1 + C_2$

In parallel connection the net capacitance is greater than the greatest. Thus to increase we attach in series and to decrease we attach in parallel

Energy of capacitor:

To find the energy stored in capacitor, we find the work done in storing charge in capacitor. Both should be equal as per the definition of the potential energy.

When we bring first charge we do not do any work against electric force because there is no charge in the vicinity to provide electrostatic force (either repulsion/ attraction).

But when we bring second charge some work is done because of force due to first charge, as more & more charge is given more work

$$q = CV$$

work done in bringing 'dq' charge is 'dW' such that

$dW = Vdq$ $\quad (W = qV)$

$$= \frac{q}{C}dq \Rightarrow \int_0^W dW = \int_0^Q \frac{qdq}{C} \Rightarrow W = \frac{Q^2}{2C} = U \quad (PE)$$

Using relation $(Q = CV)$ other formulas are

$$U = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

It is to be understood that ‘C’ is always depending upon physical dimensions and medium, i.e. with the change in Q, V automatically is done.

We integrate this work done and equate to potential energy.

Potential of capacitor raises from zero to final V when we give charge, Thus

Q = CV (Q final charge, V final voltage

At any stage when charge is q then

change as per the relation Q = CV

As an exercise check yourself that in parallel & series combination energy is always added i.e. if U_1, U_2 are energies of individual capacitors, weather in series or parallel the net energy is $\boxed{U = U_1 + U_2 + U_3}$