Capacitor

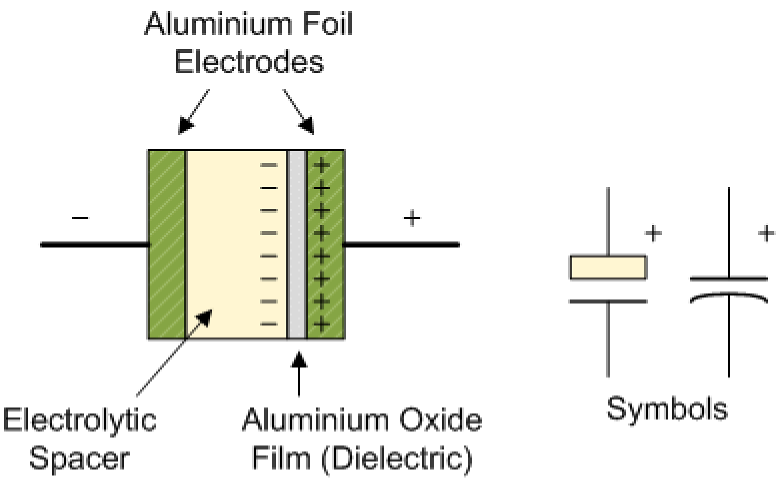
Capacitors are also known as Electric-condensers. A capacitor is a two-terminal electric component. It has the ability or capacity to store energy in the form of electric charge. Capacitors are usually designed to enhance and increase the effect of capacitance. Therefore, they take into account properties like size and shape. The storing capacity of capacitance may vary from small storage to high storage.

Capacitance

Capacitance is nothing but the ability of a capacitor to store the energy in form of electric charge. In other words, the capacitance is the storing ability of a capacitor. It is measured in farads.

Construction of Capacitor

Most capacitors usually contain two electrical conductors. These conductors are separated by metallic plates. Conductors may be in form of electrolyte, thin film, a sintered bead of metal etc.



Capacitor Rating

The capacitance value of two different capacitors may exactly be the same and the voltage rating of the two capacitors are different. Let us take two capacitors, one which has a small voltage rating and other with high voltage rating. If we substitute a smaller rated voltage capacitor in place of a higher rated voltage capacitor, the smaller capacitor.

This can happen because of the unexpected increases in voltage. The common working DC voltages of capacitors are usually 10V, 16V, 25V, 35V, 50V, 63V, 100V, 160V, 250V, 400V and 1000V.]

Question: Write about the capacitance of an isolated conductor.

Answer: When we give charge to a conductor, its potential increases. We see that for a conductor, the potential of the conductor is proportional to charge given to it.

q = charge on conductor

V = potential of the conductor. Therefore, the charge will be proportional to the potential, and we may write:

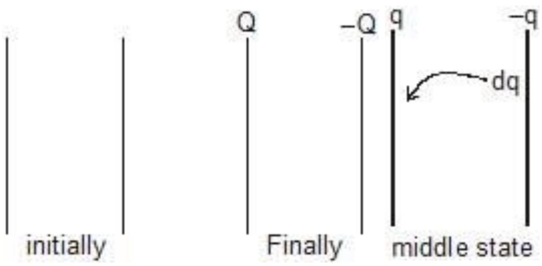
$q \propto V$

Hence, $q = CV$

Where C is the proportionally constant or the capacitance of the conductor. If the value of C is large, the capacitor can store more 'q' and if the value of C is small, q will be small. Hence, this constant gives us a measure of the amount of charge that a capacitor can store.

Energy Stored in a Capacitor

Work has to be done to transfer charges onto a conductor, against the force of repulsion from the already existing charges on it. This work is stored as a potential energy of the electric field of the conductor.



Suppose a conductor of capacity C is at a potential V_0 and let q_0 be the charge on the conductor at this instant. The potential of the conductor when (during charging) the charge on it was q (< q_0) is,

$V \propto q$ or $V = Cq$; where 'C' is a constant of proportionality that depends on the nature of the material of the conductor. This constant is known as the capacitance.

$$dW = Vdq = \left(\frac{q}{C}\right)dq$$

The total work done in charging it from 0 to q_0 is now easy to calculate. All we have to do is to take an integral of the above equation between the relevant limits as shown below:

$$W = \int_0^{q_0} dW = \int_0^{q_0} \frac{q}{C} dq = \frac{1}{2}\frac{q_0^2}{C}$$

This work is stored as the potential energy and we have:

$$U = \frac{1}{2}\frac{q_0^2}{C}$$

Further by using $q_0 = CV_0$ we can write this expression also as,

$$U = \frac{1}{2}CV_0^2 = \frac{1}{2}q_0V_0$$

In general, if a conductor of capacity C is charged to a potential V by giving it a charge q, then

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

Energy Density of a Charged Capacitor

This energy is localized on the charges or the plates but is distributed in the field. Since in case of a parallel plate capacitor, the electric field is only between the plates, i.e., in a volume (A × d), the energy density =

U_E = U/Volume; using the formula C = ε_0A/d, we can write it as:

$$U_E = \frac{1}{2}\varepsilon_0\left(\frac{V}{d}\right)^2 = \frac{1}{2}\varepsilon_0 E^2 \left[\because \frac{v}{d} = E\right]$$

Capacitors in Series and Parallel

Capacitance in Series

When the alternate end of all the capacitors are connected together then such type of grouping is called series grouping.

In series grouping the charge on each capacitor is same but P.D is differ

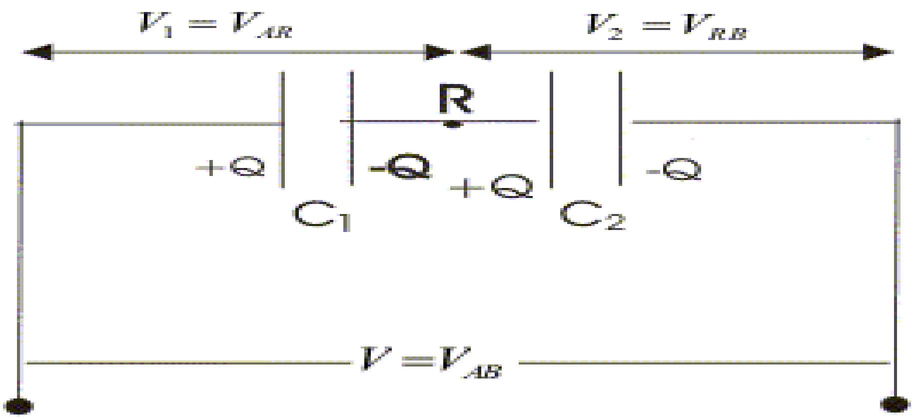


Figure 7

- Now potential difference across individual capacitors are given by
  $V_{AR}=Q/C_1$
  and,
  $V_{RB}=Q/C_2$
- Sum of V_{AR} and V_{RB} would be equal to applied potential difference V so,
  $V=V_{AB}=V_{AR}+V_{RB}$
  $=Q(1/C_1 + 1/C_2)$
  or,

$$\frac{V}{Q}=\frac{1}{C_1}+\frac{1}{C_2}=\frac{Q}{C}$$

where

$$\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}$$

i.e., resultant capacitance of series combination C=Q/V, is the ratio of charge to total potential difference across the two capacitors connected in series.

Parallel combination

When the same end of all thw capacitors are connected together then such type of grouping is called parallel grouping

i) Parallel combination of capacitors

- Figure below shows two capacitors connected in parallel between two points A and B

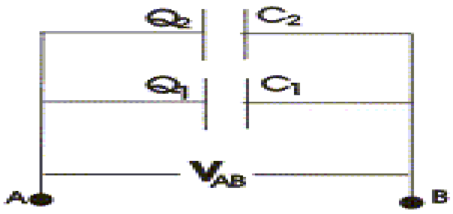


Figure 6

- Right hand side plate of capacitors would be at same common potential V_A. Similarly left hand side plates of capacitors would also be at same common potential V_B.
- Thus in this case potential difference $V_{AB}=V_A-V_B$ would be same for both the capacitors, and charges Q_1 and Q_2 on both the capacitors are not necessarily equal. So,

  $Q_1=C_1V$ and $Q_2=C_2V$
- Thus charge stored is divided amongst both the capacitors in direct proportion to their capacitance.
- Total charge on both the capacitors is,

  $Q=Q_1+Q_2$

  $=V(C_1+C_2)$

  and

  $Q/V=C_1+C_2$

  So system is equivalent to a single capacitor of capacitance

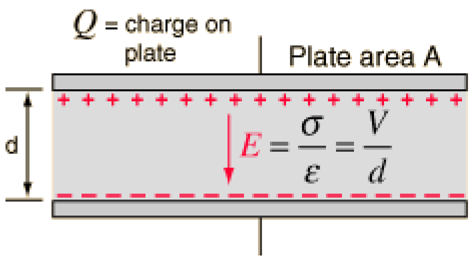
  $C=Q/V$

  where,
- When capacitors are connected in parallel their resultant capacitance C is the sum of their individual capacitances.

- The value of equivalent capacitance of system is greater than the greatest individual one.
- If there are number of capacitors connected in parallel then their equivalent capacitance would be

  $C=C_1+C_2+C_3$..........

Parallel plate capacitor



Suppose two plates of the capacitor has equal and opposite charge Q on them. If A is the area of each plate then surface charge density on each plate is

$\sigma=Q/A$

We have already calculated field between two oppositely charged plates using gauss's law which is

$E=\sigma/\varepsilon_0=Q/\varepsilon_0 A$

and in this result effects near the edges of the plates have been neglected.

Since electric field between the plates is uniform the potential difference between the plates is

$V=Ed=Qd/\varepsilon_0 A$

where , d is the separation between the plates.

Thus, capacitance of parallel plate capacitor in vacuum is

$C=Q/V=\varepsilon_0 A/d$

we see that quantities on which capacitance of parallel plate capacitor depends i.e.,ε_0 , A and d are all constants for a capacitor.