PHYSICS

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01. Electrical Capacitance

Electrical capacitance of a conductor is related to its ability to store the electric charge. When a conductor is given some electric charge, it is raised to some potential. As more and more charge is given, its potential increases accordingly. If charge q is given to the conductor so that its potential increases by an amount V, then it is found that

$$q \propto V$$

or $$q = C\,V, \qquad ...(i)$$

where the constant of proportionality C is called the ***capacitance*** of the conductor. Its value depends upon the *shape* and *dimensions* of the conductor. It may be pointed out that the capacitance of a conductor does not depend upon the material of the conductor but depends upon the nature of the medium (its relative permittivity or dielectric constant) in which the conductor is located.

From the equation (i), we have

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

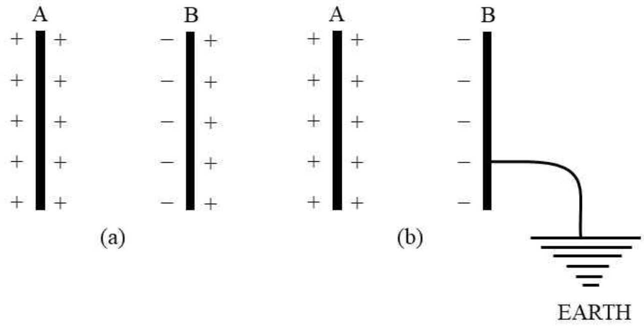
Thus, *capacitance of a conductor may be defined as the ratio of the electric charge on it to its electric potential due to that charge.*

02. Principle of a Capacitor

A capacitor is a device for string a large quantity of electric charge.

A conductor can store a small amount of charge and hence it possesses a small capacitance. To store a large amount of charge, two (or more) conductors are arranged to form a capacitor. Thus, a capacitor posseses a large capacitance to store charge and that too in a small space.

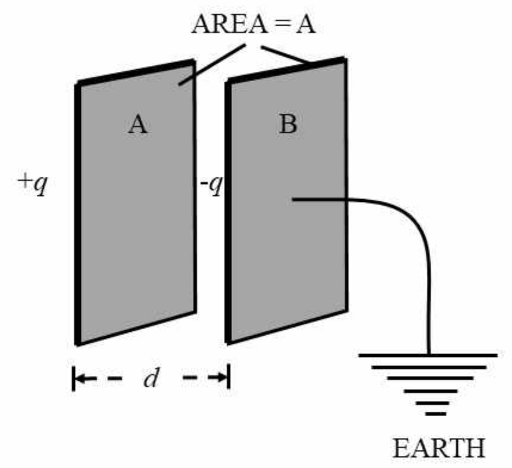
Principle : To understand the principle of a capacitor, consider an insulated metal plate A. Suppose that it is given positive charge, till its potential becomes maximum. The metal plate will not hold any more charge over it. If charge is given to the metal plate A, it will leak to the surroundings. Now, place another metallic plate B near plate A. Due to induction, negative charge will be induced on the nearer face of plate B and positive charge on its farther face as shown in Fig. (a). The potential of plate A gets lowered due to induced negative charge on plate B and a bit raised due to the induced positive charge. Since the metal plates have finite thickness, induced negative charge is nearer to the plate A than the induced positive charge on plate B is. Therefore, on the whole, the potential of plate A gets lowered, though by a very small amount. In order to make the potential of the metal plate A again the same, an additional small amount of charge has to be given to plate A. It indicates that the capacitance of a conductor increases by a small amount, when another uncharged conductor is placed near it.



Now, connect the metal plate B to the earth as shown in Fig (b). The induced positive charge on plate B will immediately flow to the earth as it is repelled by positive charge on plate A. However, the induced negative charge on plate B will stay on it. It does not flow to earth as it is attracted by the positive charge on plate A. Thus, the metal plate B will have only negative charge on plate B, the potential of A will get lowered by a large amount. In order to raise the metal plate A again to the same potential, a large amount of charge has to be given to it. Thus, it follows that the capacitance of a conductor gets increased greatly, when an earth connected conductor is placed near it. It forms the principle of a capacitor and such an arrangement of two metal plates is called **capacitor**.
An arrangement of two metallic conductors, so that when one conductor is connected to the earth ; the other conductor has the ability to store a large amount of charge on it, is called a capacitor.

03. Parallel Plate Capacitor

It is most commonly used capacitor. It consists of two conducting plates placed parallel to each other as shown in Fig. below. The separation d between the plates is very small as compared to the area of the plates. Due to small separation between the plates, the fringing of electric field at the boundaries is negligible.
If charge $+q$ is given to plate A, then charge $-q$ is induced on the left face of plate B and charge $+q$ on its right face. When plate B is earthed, the charge $+q$ on its right face flows to earth. Due to charge $+q$ on plate A and $-q$ on plate B, electric field is set up between the two plates.



The electric field between the plates is related to the potential gradient as

$$E = \frac{dV}{dr} \qquad \text{(in magnitude)}$$

Between the two parallel plates, the electric field is uniform and perpendicular to the plates. Therefore, if V is potential difference between the two plates, then

$$E = \frac{V}{d} \qquad \left(\text{For uniform field, } \frac{dV}{dr} = \frac{V}{d}\right)$$

or

$$V = Ed \qquad ...(i)$$

If σ is surface charge density of the plates, then the electric field between the two plates is given by

$$E = \frac{\sigma}{\varepsilon_0},$$

Where ε_0 is absolute permittivity of the free space. (It is assumed that medium between the plates is vacuum or air).

In the equation (i), substituting for E, we have

$$V = \frac{\sigma}{\varepsilon_0} d$$

If A is the area of each plate, then

$$\sigma = \frac{q}{A}$$

$$\therefore \qquad V = \frac{q\,d}{\varepsilon_0 A}$$

If C is the capacitance of the parallel plate capacitor, then

$$C = \frac{q}{q\,d/\varepsilon_0 A}$$

or

$$C = \frac{\varepsilon_0 A}{d} \qquad ...(ii)$$

It gives the capacitance of a parallel plate capacitor, when its plates are held in air or vacuum.