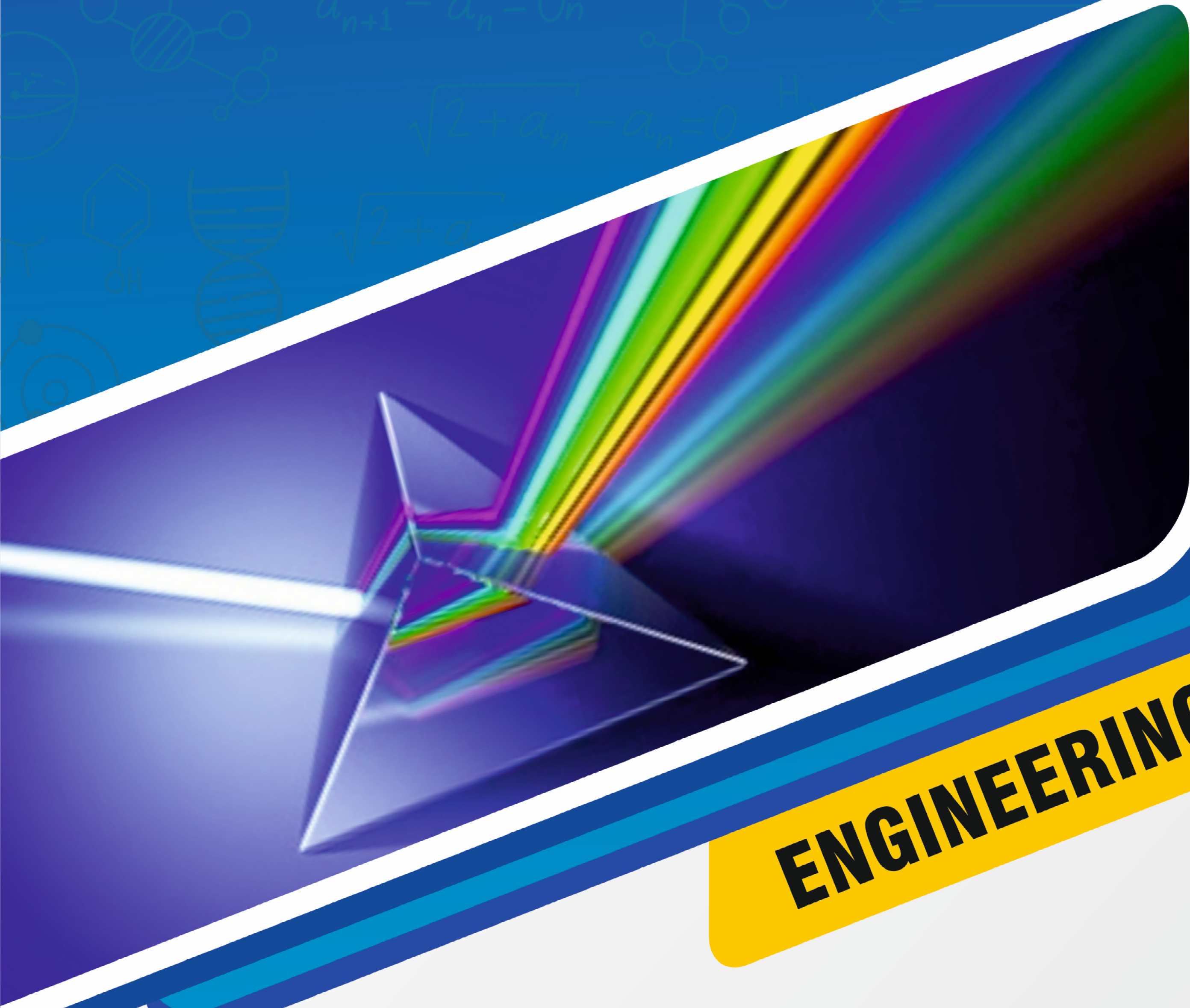
PHYSICS



ENGINEERING

CAPACITANCE

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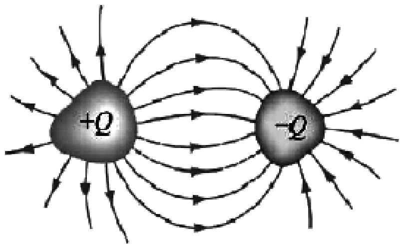
CAPACITANCE

CONTENT

Capacitance

Introduction

Capacitor is an arrangement of two conductors generally carrying charges of equal magnitudes and opposite sign and separated by an insulating medium.



When charges are pulled apart, energy is associated with the pulling apart of charges, just like energy is involved in stretching a spring. Thus, some energy is stored in capacitors.

In the *uncharged* state, the charge on either one of the conductors in the capacitor is zero. During the charging process, a charge Q is moved from one conductor to the other one, giving one conductor a charge $+Q$, and the other one a charge –Q. A potential difference ΔV is created, with the positively charged conductor at a higher potential than the negatively charged conductor. Note that whether charged or uncharged, the net charge on the capacitor as a whole is zero.

Note :

1. The net charge on the capacitor as a whole is zero. When we say that a capacitor has a charge Q, we mean that the positively charged conductor has charge +Q and negatively charged conductor has a charge –Q.

2. In a circuit, a capacitor is represented by the symbol : ——| |——

Limitations on charging a conductor

How much electric charge can be placed on a conductor?

As more air is pumped into the tank, the pressure opposing the flow of additional air becomes greater so it becomes further difficult to pump more air. . Similarly, as more charge Q is transferred to the conductor, the potential V of the conductor becomes higher, making it increasingly difficult to transfer more charge. Suppose we try to place an indefinite quantity of charge Q on a spherical conductor of radius r. The air surrounding the conductor is an insulator, sometimes called a dielectric, which contains few charges free to move. The electric field intensity E and the potential V at the surface of the sphere are given by

$$E = \frac{kQ}{r^2} \quad \text{and} \quad V = \frac{kQ}{r}$$

Since the radius r is constant, both the field intensity and the potential at the surface of the sphere increase in direct proportion to the charge Q. There is a limit, however, to the field intensity that can exist on a conductor without ionizing the surrounding air. When this occurs, the air essentially becomes a conductor, and any additional charge placed on the sphere will “leak off” to the air. This limiting value of electric field intensity for which a material loses its insulation properties is called the dielectric strength of that material.

The dielectric strength for dry air at 1 atm pressure is around 3MN/C. Since the dielectric strength of a material varies considerably with environmental conditions, such as pressure and humidity, it is difficult to compute accurate values.

Note that the amount of charge that can be placed on a spherical conductor decreases with the radius of the sphere. Thus, smaller conductors can usually hold less charge. But the shape of a conductor also influences its ability to retain charge. Consider the charged conductors. If these conductor are tested with an electroscope, it will be discovered that the charge on the surface of a conductor is concentrated at points of greatest curvature. Because of the greater charge density in these regions, the electric field intensity is also greater in regions of higher curvature. If the surface is reshaped to a sharp point, the field intensity may become great enough to ionize the surrounding air. A show leakage of charge sometimes occurs at these locations, producing a corona discharge, which is often observed as a faint violet glow in the vicinity of the sharply pointed conductor. It is important to remove all sharp edges from electrical equipment to minimize this leakage of charge.

Capacitance

We can say that the increase in potential V is directly proportional to the charge Q placed on the conductor. Symbolically: $V \propto Q$

Therefore, the ratio of the quantity of charge Q to the potential V produced will be a constant for a given conductor. This ratio reflects the ability of a conductor to store charge and is called its capacitance C.

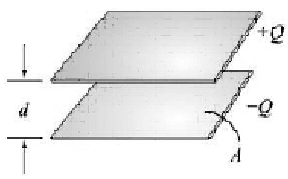
$$C = \frac{Q}{V}$$

The unit of capacitance is the coulomb per volt, which is redefined as a farad (F). Thus, if a conductor has a capacitance of 1 farad, a transfer of 1 coulomb of charge to the conductor will raise its potential by 1 volt.

The value of C for a given conductor is not a function of either the charge placed on a conductor or the potential produced. In principle, the ratio Q/V will remain constant as charge is added indefinitely, but the capacitance depends on the size and shape of a conductor as well as on the nature of the surrounding medium.

The capacitor

The simplest example of a capacitor consists of two conducting plates of area *A*, which are parallel to each other, and separated by a distance *d*, as shown in Figure.



A parallel-plate capacitor

Experiments show that the amount of charge *Q* stored in a capacitor is linearly proportional to $|\Delta V|$, the electric potential difference between the plates. Thus, we may write

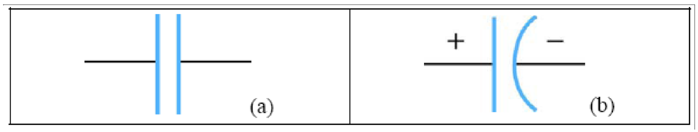
$$Q = C\,|\Delta V|$$

where *C* is a positive proportionality constant called *capacitance*. Physically, capacitance is a measure of the capacity of storing electric charge for a given potential difference ΔV. The SI unit of capacitance is the *farad* (F) :

$$1\text{ F} = 1\text{ farad} = 1\text{ coulomb / volt} = 1\text{C/V}$$

A typical capacitance is in the picofarad (1pF = 10^{-12} F) to millifarad range, (1 mF = 10^{-3} F = 1000 μF ; 1μF = 10^{-6} F).

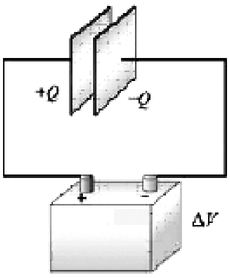
Figure (a) shows the symbol which is used to represent capacitors in circuits. For a polarized fixed capacitor which has a definite polarity, Figure (b) is sometimes used.



Capacitor symbols.

Capacitors in Electric Circuits

A capacitor can be charged by connecting the plates to the terminals of a battery, which are maintained at a potential difference ΔV called the ***terminal voltage.***

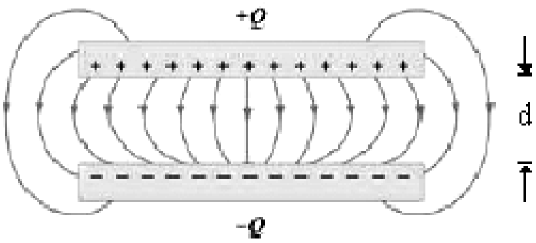


Charging a capacitor.

The connection results in sharing the charges between the terminals and the plates. For example, the plate that is connected to the (positive) negative terminal will acquire some (positive) negative charge. The sharing causes a momentary reduction of charges on the terminals, and a decrease in the terminal voltage. Chemical reactions are then triggered to transfer more charge from one terminal to the other to compensate for the loss of charge to the capacitor plates, and maintain the terminal voltage at its initial level. The battery could thus be thought of as a charge pump that brings a charge Q from one plate to the other.

Parallel-Plate Capacitor

Consider two metallic plates of equal area A separated by a distance d, as shown in Figure below. The top plate carries a charge $+Q$ while the bottom plate carries a charge $-Q$. The charging of the plates can be accomplished by means of a battery which produces a potential difference. Find the capacitance of the system.



The electric field between the plates of a parallel-plate capacitor

To find the capacitance C, we first need to know the electric field between the plates. A real capacitor is finite in size. Thus, the electric field lines at the edge of the plates are not straight lines, and the field is not contained entirely between the plates. This is known as *edge effects*, and the non-uniform fields near the edge are called the *fringing fields*. In Figure the field lines are drawn by taking into consideration edge