Static Electricity Lesson 4, March 26, 2020

Your Tasks

Task 1: Read the content and take the quiz on Scorative: RENU1RAJAS

Task 2: Complete the quiz at https://play.howstuffworks.com/quiz/capacitor-quiz

Capacitors

READ THE CONTENT & TAKE SOCRATIVE QUIZ: RENU1RAJAS

The capacitor is a component which has the ability or "capacity" to store Static Electrical Energy. It works much like a small rechargeable battery. Leyden Jar is the first capacitor to be invented. There are many different kinds of capacitors available from very small capacitor beads used in resonance circuits to large power factor correction capacitors, but they all do the same thing, they store charge.

In its basic form, a capacitor consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but are electrically separated either by air or by some form of a good insulating material such as waxed paper, mica, ceramic, plastic or some form of a liquid gel as used in electrolytic capacitors. The insulating layer between a capacitors plates is commonly called the Dielectric.

A Typical Capacitor

Due to this insulating layer, DC current can not flow through the capacitor as it blocks it allowing instead a voltage to be present across the plates in the form of an electrical charge.

The conductive metal plates of a capacitor can be either square, circular or rectangular, or they can be of a cylindrical or spherical shape with the general shape, size and construction of a parallel plate capacitor depending on its application and voltage rating.

When used in a direct current or DC circuit, a capacitor charges up to its supply voltage but blocks the flow of current through it because the dielectric of a capacitor is non-conductive and basically an insulator. However, when a capacitor is connected to an alternating current or AC circuit, the flow of the current appears to pass straight through the capacitor with little or no resistance.

The amount of potential difference present across the capacitor depends upon how much charge was deposited onto the plates by the work being done by the source voltage and also by how much capacitance the capacitor has. Capacitors are chosen in such a way that it is able to store al the electrical energy it was given.

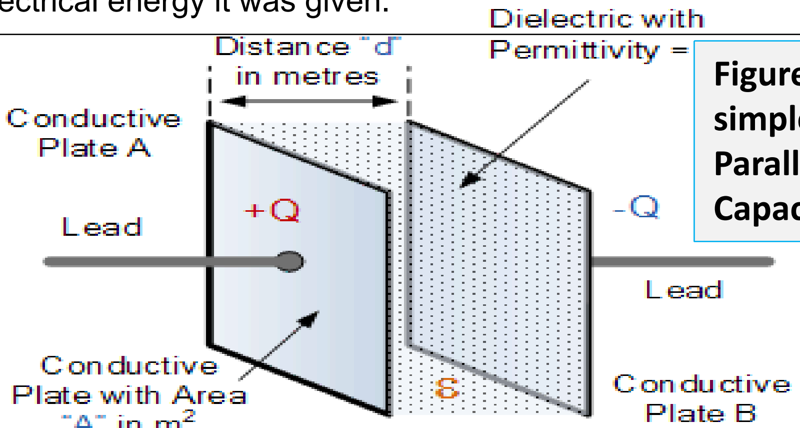


Figure 1: A simple Parallel Plate Capacitor

There is content on next slide as well

Standard Units of Capacitance

- •Microfarad (μF) $1\mu F = 1/1{,}000{,}000 = 0.000001 = 10^{-6}$ F
- •Nanofarad (nF) $1nF = 1/1{,}000{,}000{,}000 = 0.000000001 = 10^{-9}$ F
- •Picofarad (pF) $1pF = 1/1{,}000{,}000{,}000{,}000 = 0.000000000001 = 10^{-12}$ F

The various insulating materials used as the dielectric in a capacitor differ in their ability to block or pass an electrical charge.

This dielectric material can be made from a number of insulating materials or combinations of these materials with the most common types used being: air, paper, polyester, polypropylene, Mylar, ceramic, glass, oil, or a variety of other materials.

The factor by which the dielectric material, or insulator, increases the capacitance of the capacitor compared to air is known as the **Dielectric Constant**, **k** and a dielectric material with a high dielectric constant is a better insulator than a dielectric material with a lower dielectric constant. Dielectric constant is a dimensionless quantity since it is relative to free space.

The actual permittivity or "complex permittivity" of the dielectric material between the plates is then the product of the permittivity of free space (ε_o) and the relative permittivity (ε_r) of the material being used as the dielectric and is given as:

$$\varepsilon = \varepsilon_o \times \varepsilon_r$$

If we take the permittivity of free space, ε_o as our base level and make it equal to one, when the vacuum of free space is replaced by some other type of insulating material, their permittivity of its dielectric is referenced to the base dielectric of free space giving a multiplication factor known as "relative permittivity", ε_r. So the value of the complex permittivity, ε will always be equal to the relative permittivity times one.

Typical values of dielectric permittivity, ε or dielectric constant for common materials are: Pure Vacuum = 1.0000, Air = 1.0006, Paper = 2.5 to 3.5, Glass = 3 to 10, Mica = 5 to 7, Wood = 3 to 8 and Metal Oxide Powders = 6 to 20 etc.

Note that the permittivity of air, and especially of dry air, as being the same value as a vacuum as they are very close.

https://www.electronics-tutorials.ws/capacitor/cap_1.html

Determination of Capacitance: The amount of electrical charge that a capacitor can store on its plates is known as its **Capacitance** value. It can be calculated using the formula $\text{Capacitance, } C = \frac{\varepsilon_o \varepsilon_r A}{d} \text{ Farads}$

Example

A capacitor is constructed from two conductive metal plates 30cm x 50cm which are spaced 6mm apart from each other, and uses dry air as its only dielectric material. Calculate the capacitance of the capacitor.

Formula to be used:

$$\text{Capacitance, } C = \frac{\varepsilon_o \varepsilon_r A}{d} \text{ Farads}$$

Process

$$\text{Using: } C = \varepsilon_0 \frac{A}{d}$$

$$\text{where: } \varepsilon_0 = 8.84 \times 10^{-12}$$

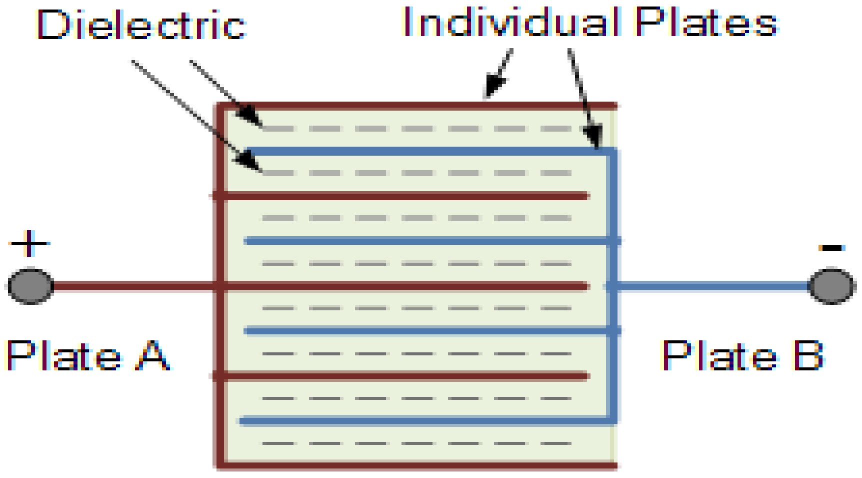
$$A = 0.3 \times 0.5\, m^2 \quad \text{and} \quad d = 6 \times 10^{-3}\, m$$

$$C = \frac{8.84 \times 10^{-12} \times (0.3 \times 0.5)}{6 \times 10^{-3}} = 0.221 nF$$

When you solve problems on socrative, you need to show complete work

Multi-plate Capacitors

One method used to increase the overall capacitance of a capacitor while keeping its size small is to "interleave" more plates together within a single capacitor body. Instead of just one set of parallel plates, a capacitor can have many individual plates connected together thereby increasing the surface area, A of the plates.



8 mini capacitors in one

The capacitance of a multiplate capacitor is determined by the following equation

$$\text{Capacitance, } C = \frac{\varepsilon_0 \varepsilon_r (n-1)A}{d} \text{ Farads}$$

Now we have five plates connected to one lead (A) and four plates to the other lead (B). Then BOTH sides of the four plates connected to lead B are in contact with the dielectric, whereas only one side of each of the outer plates connected to A is in contact with the dielectric. Then as above, the useful surface area of each set of plates is only eight and its capacitance is therefore given as:

$$C = \frac{\varepsilon_0 \varepsilon_r (n-1)A}{d} = \frac{\varepsilon_0 \varepsilon_r (9-1)A}{d} = \frac{\varepsilon_0 \varepsilon_r 8A}{d}$$