El-Manzala Higher Institute of Engineering and Technology

Fundamentals of Electrical Engineering

First YEAR

By

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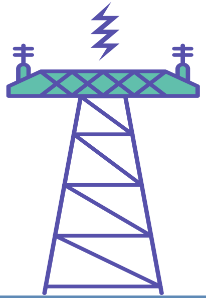

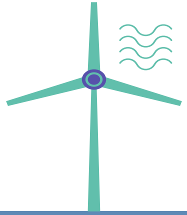

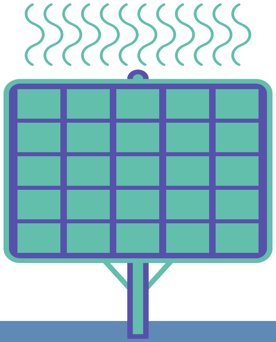

Capacitors and Inductor

Chapter 6

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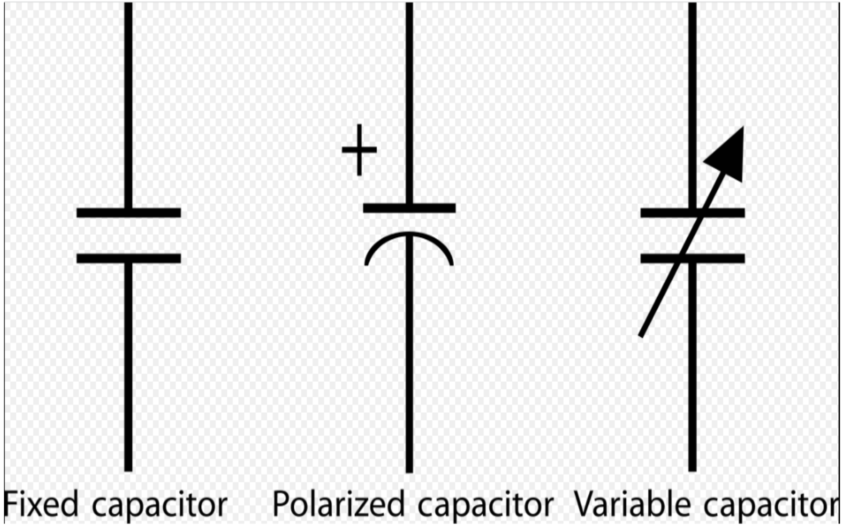
Chapter Content

CH6: Capacitors and Inductor

1 Capacitors and Capacitance
2 Total Capacitance
3 Inductance and Inductor Construction
4 Total Inductance

1. Capacitors and Capacitance

- A **capacitor** consists of two conductors separated by an insulator.
- The chief feature of a capacitor is its ability to store electric charge, with negative charge on one of its two conductors and positive charge on the other.
- Accompanying this charge is energy, which a capacitor can release.

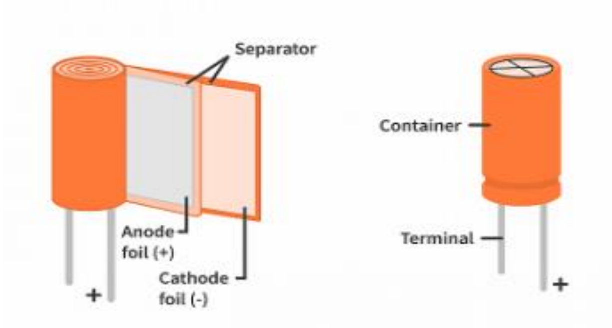


1. Capacitors and Capacitance

- **Capacitance**: the electrical property of capacitors, is a measure of the ability of a capacitor to store charge on its two conductors.
- if the potential difference between the two conductors is V volts when there is a positive charge of Q coulombs on one conductor and a negative charge of the same amount on the other, the capacitor has a capacitance of

$$C = Q/V$$

where C is the quantity symbol of capacitance

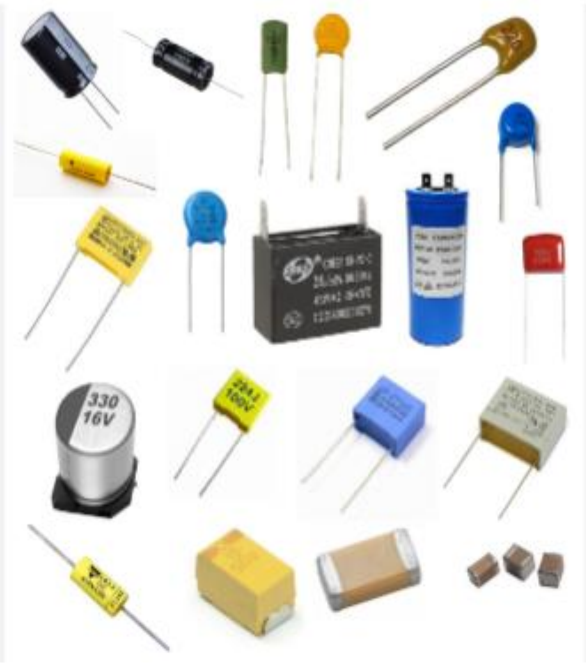


1. Capacitors and Capacitance

EX1 :What is the charge stored on a 2-pF capacitor with 10 V across it'?

SOL:

$$Q = CV = (2 \times 10^{-6})(10)\ C = 20\ \mu C$$



- The SI unit of capacitance is the furad, with symbol (F).

- Unfortunately, the farad is much too large a unit for practical applications, and the microfarad (pF) and picofarad (pF) are much more common.

Milli: 10^-3 Micro:10^-6

Nano: 10^-9 Pico: 10^-12

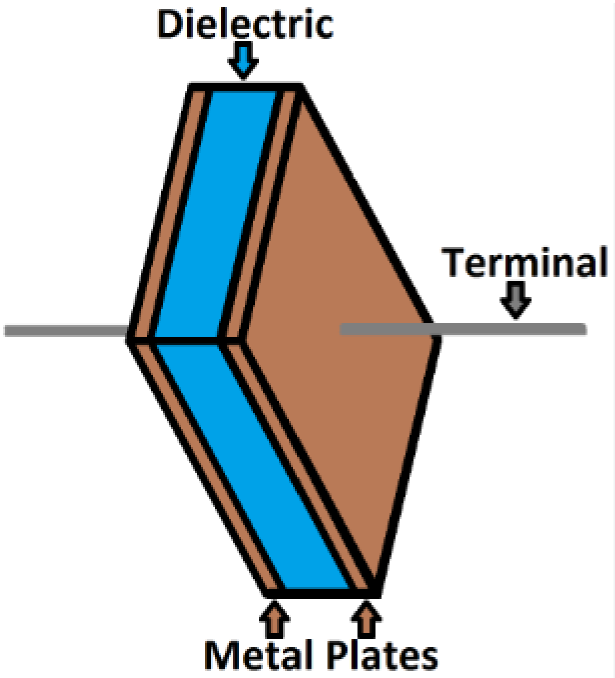
1. Capacitors and Capacitance

- One common type of capacitor is the **parallel-plate** capacitor.
- This capacitor has two spaced conducting plates that can be **rectangular**, as shown, but that often are **circular**.
- The insulator between the plates is called a <u>**dielectric.**</u>
- For the parallel-plate capacitor, the capacitance in farads is

$$C = \varepsilon_0 A/d$$

A is the area of either plate in square meters

d is the separation in meters



1. Capacitors and Capacitance

- ε_0 is the **permittivity** in farads per meter (**F/m**) of the dielectric.
- The <u>larger the plate area</u> or the <u>smaller the plate separation</u>, or <u>the greater the dielectric permittivity</u>, the **greater the capacitance**.

- The permittivity of vacuum, designated by col is 8.85 pF,/m.
- Permittivity of other dielectrics are related to that of vacuum by a factor called the dielectric constant or relative permittivity, designated by ε_r

$$\varepsilon = \varepsilon_0 \, \varepsilon_r$$

- The dielectric constants of some common dielectrics are 1.0006 for air, 2.5 for paraffined paper, 5 for mica, 7.5 for glass, and 7500 for ceramic.

EX2

EX2: A capacitor has a disk-shaped dielectric of ceramic that has a 0.5-cm diameter and is 0.521 mm thick. The disk is coated on both sides with silver, this coating being the plates. Find the capacitance.(ceramic dielectric constant of 7500)

SOL:

With the ceramic dielectric constant of 7500 in the parallel-plate capacitor formula,

$$C = \varepsilon \frac{A}{d} = \frac{7500(8.85 \times 10^{-12})[\pi \times (0.25 \times 10^{-2})^2]}{0.521 \times 10^{-3}} \text{ F} = 2500 \text{ pF}$$

ENERGY STORAGE

The energy stored in a capacitor is:

$$W = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV = \frac{1}{2}CV^2$$

where **W** is in joules, **C** is in farads, and **V** is in volts.

- Notice that this stored energy does not depend on the capacitor current.

2. TOTAL CAPACITANCE

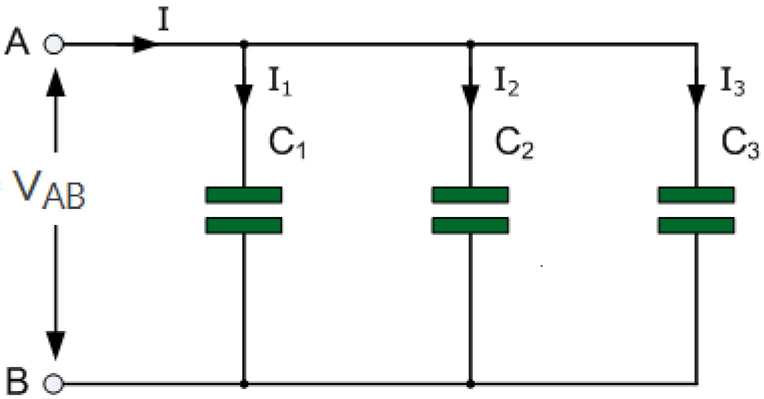
Parallel Combination

- The total or equivalent capacitance (C_T or C_{eq}) of parallel capacitors the charge stored in a capacitor is:

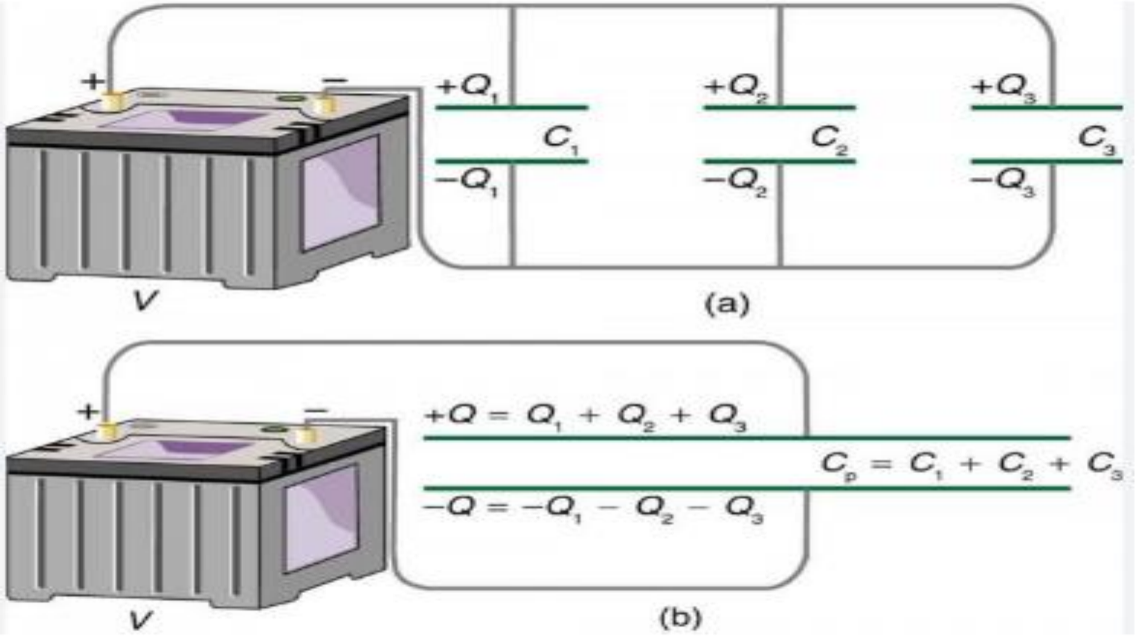
$$Q_T = Q_1 + Q_2 + Q_3 \qquad \text{but, } Q = CV$$

$$\therefore Q_T = CV_T = CV_1 + CV_2 + CV_3$$

$$\text{or} \quad C_T = C_1 + C_2 + C_3$$



Parallel Combination



2. TOTAL CAPACITANCE

Series Combination

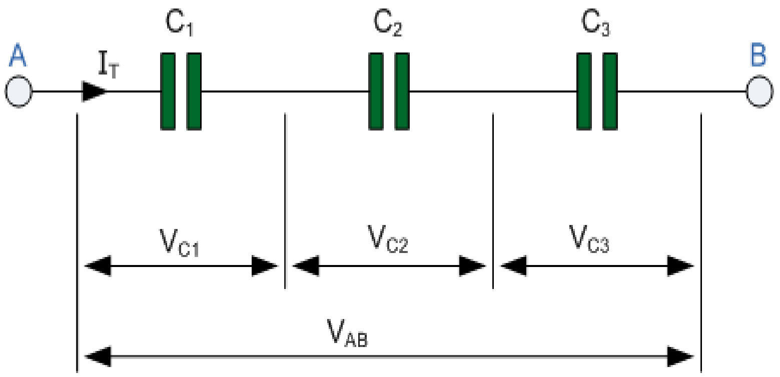
- For series capacitors, The Q in each term is the same.
- The total or equivalent capacitance (C_T or C_{eq}) of series capacitors the charge stored in a capacitor is:

$$V_{AB} = V_{C1} + V_{C2} + V_{C3}$$

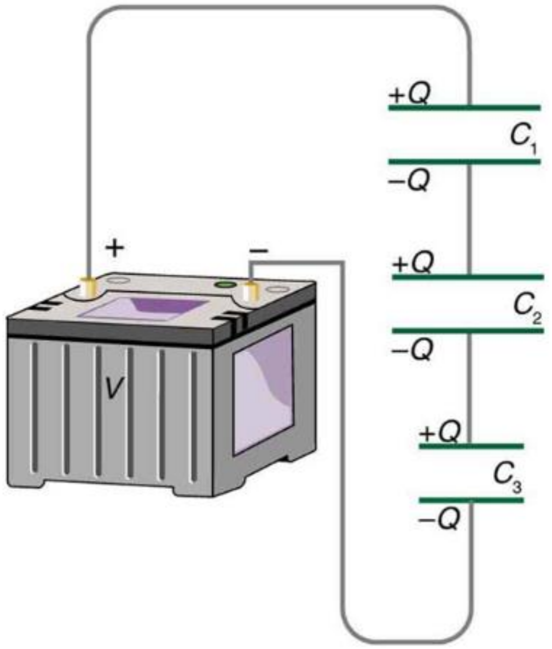
$$V_{C1} = \frac{Q_T}{C_1},\quad V_{C2} = \frac{Q_T}{C_2},\quad V_{C3} = \frac{Q_T}{C_3}$$

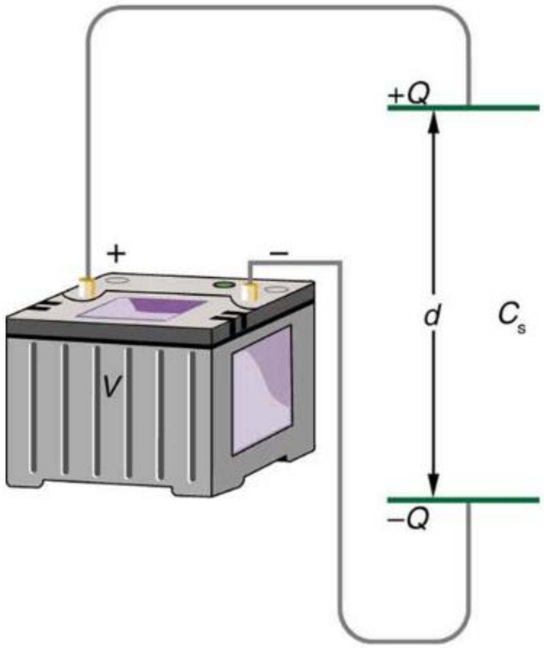
$$V_{AB} = \frac{Q_T}{C_T} = \frac{Q_T}{C_1} + \frac{Q_T}{C_2} + \frac{Q_T}{C_3}$$

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots.etc$$



Series Combination





EX3

EX3: What are the different capacitances that can be obtained with a 1- and a 3-pF capacitor?

SOL: The capacitors can produce 1 and 3 μF individually;
1 + 3 = 4 μF in parallel; and
(1 x 3)*(1 + 3) = 0.75 μF in series

EX4

EX4: A 24-V source and two capacitors are connected in series. If one capacitor has 20 μF of capacitance and has 16 V across it, what is the capacitance of the other capacitor?

SOL: By KVL, the other capacitor has 24 - 16 = 8 V across it.

Also, the charge on it is the same as that

$Q = C\,V = (20 \times IO_{-6})(16)\ C = 320\mu C$

So, $C = Q\ V = 320 \times 10_{-6} \times 8 = 40\ \mu F$

End of Lecture 6