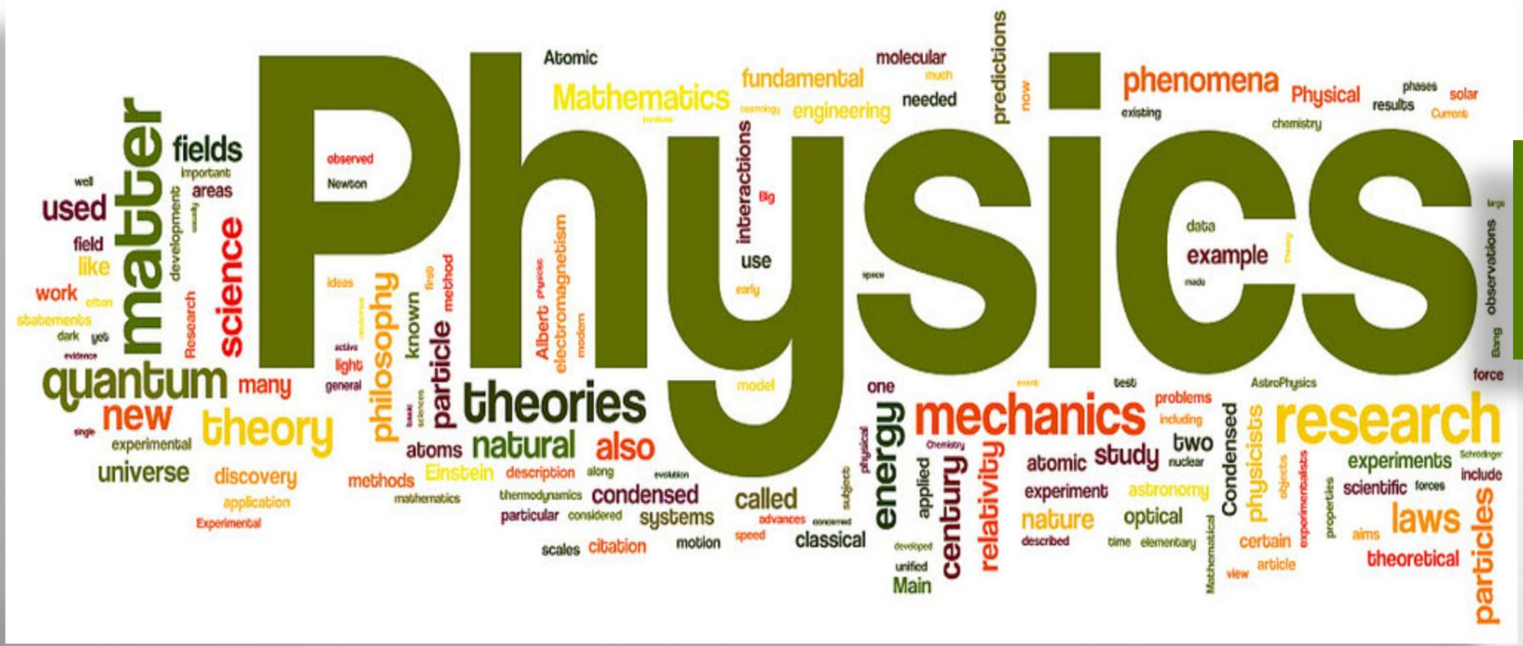


B

(PHY 002)

DR. MOHAMED NABIL

13 April 2020

Chapter 5

Capacitors and Capacitance

Outlines

What is capacitor

Definition of capacitance

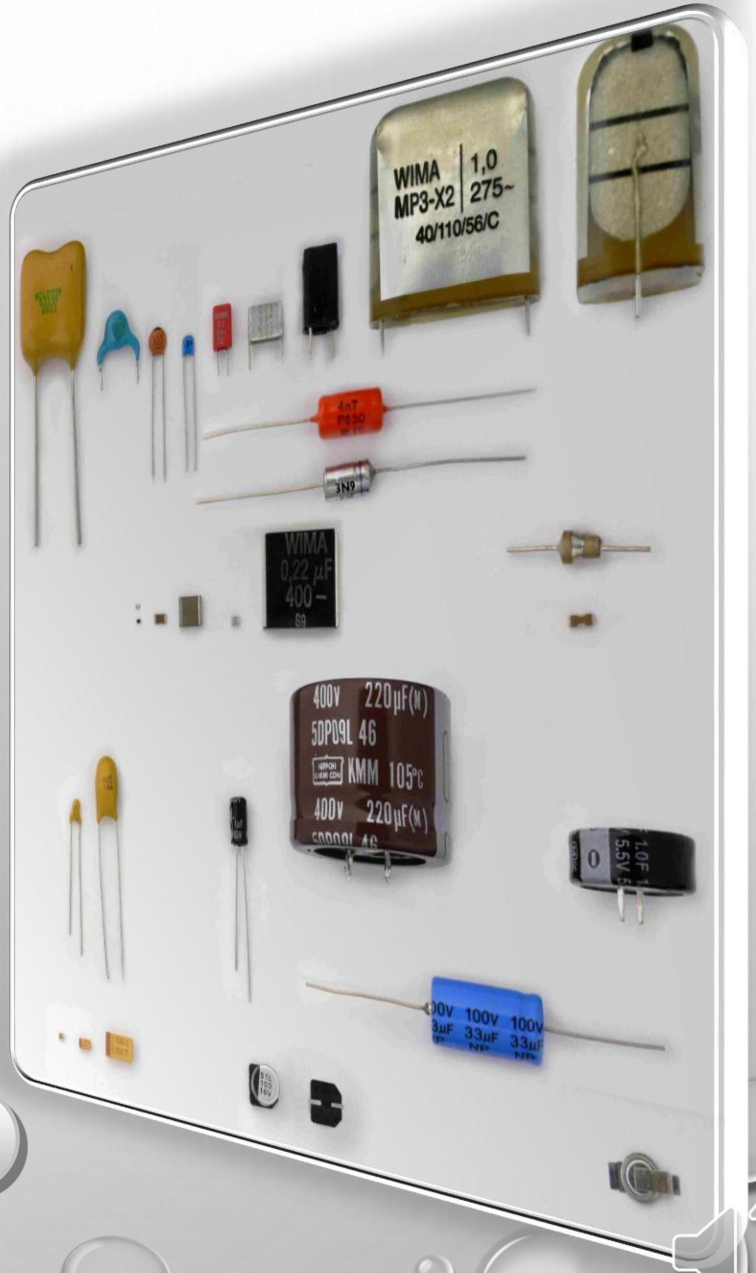
Types of Capacitors

Calculation of capacitance

Factors affecting capacitance

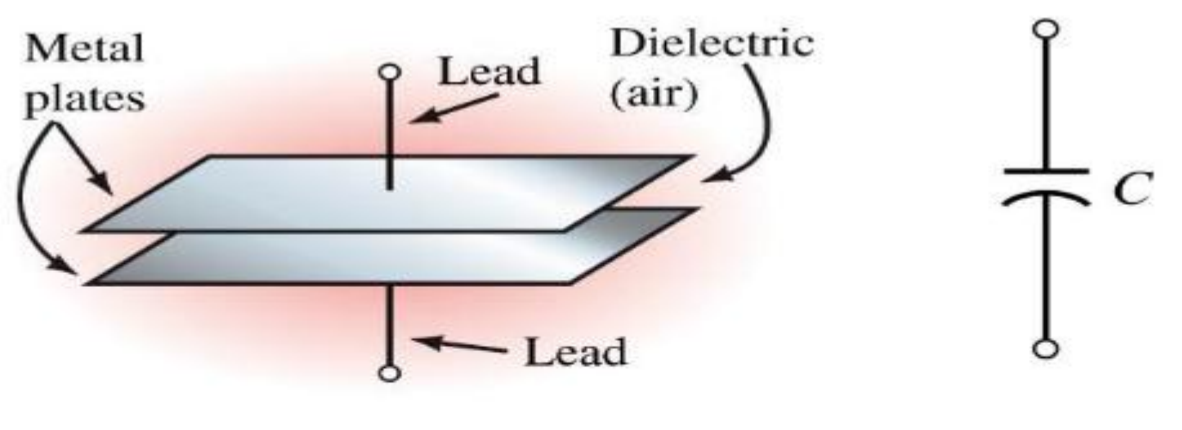
Combination of capacitors

Energy stored in a charged capacitor



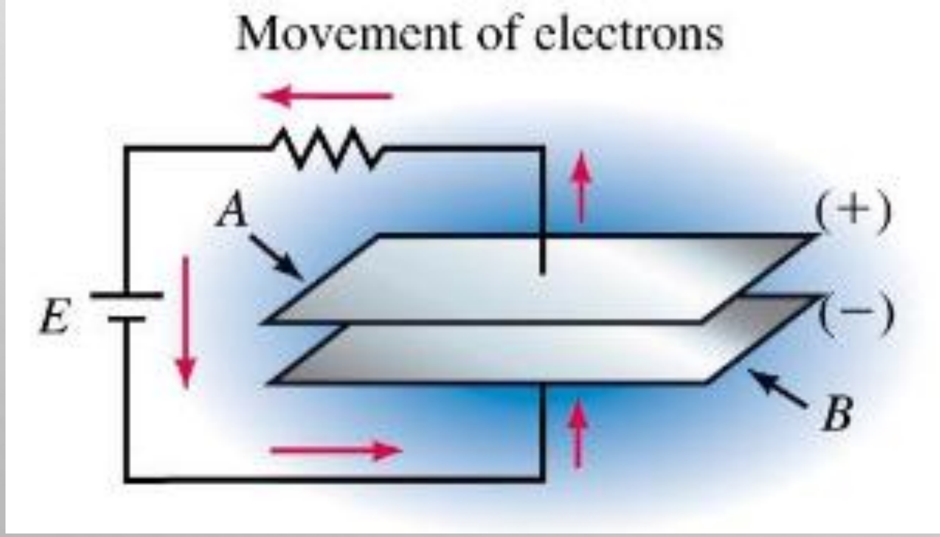
What is the capacitors

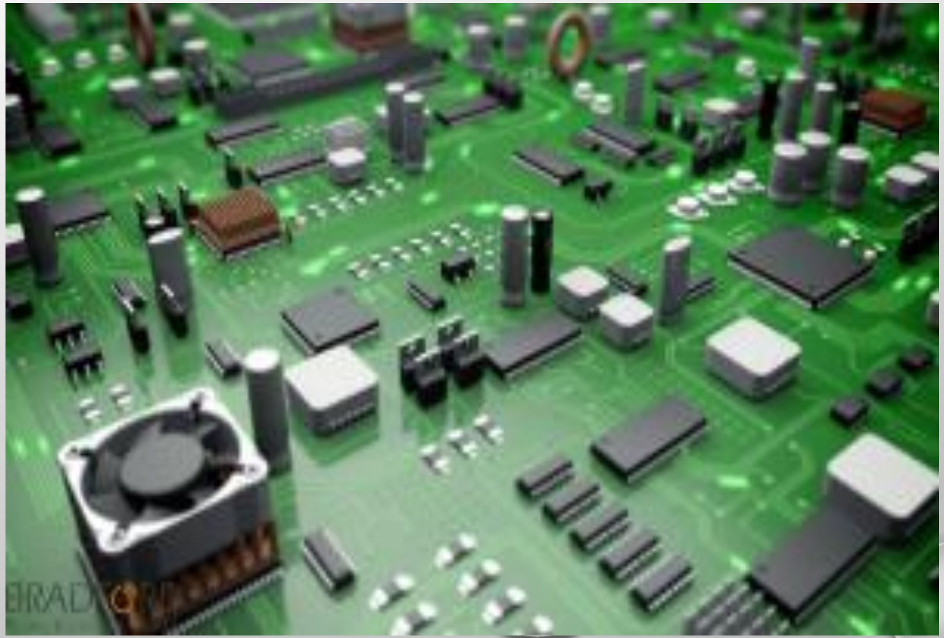
- Capacitor
  - Two conductors' plates separated by insulator
  - Insulating material called dielectric
  - conductors' plates can become charged with equal opposite charges +q and -q.



▪Capacitor

- Capacitor can store charge
- Capacitors are used as sensors
- Capacitors for Signal Processing





Definition of Capacitance

- Amount of charge Q that a capacitor can store depends on applied potential difference V
- the ratio of the magnitude of the charge Q on either conductor to the magnitude of the potential difference V between them

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

The Capacitance *C* has a Unit of *C/v*, which is called *farad F*

▪Definition of Capacitance

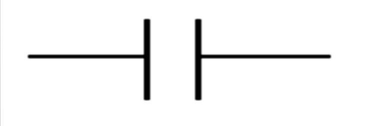
The farad is very big unit and hence we use submultiples of farad

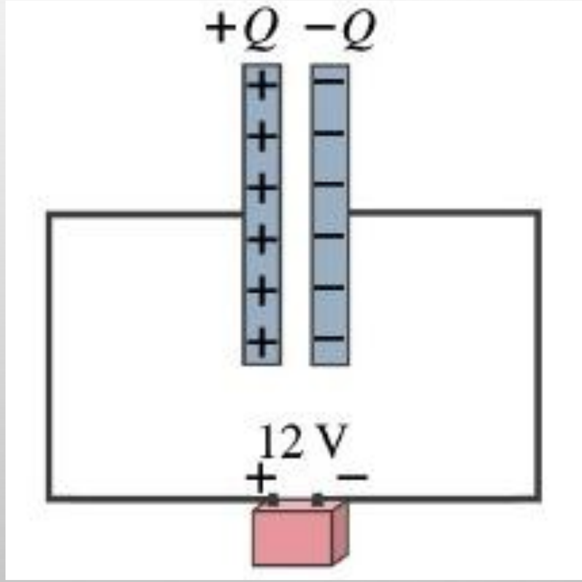
$1\mu F = 10^{-6} F$

$1nF = 10^{-9} F$

$1pF = 10^{-12} F$

The capacitor in the circuit is represented by the symbol shown in Figure





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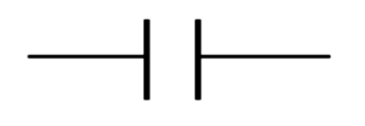
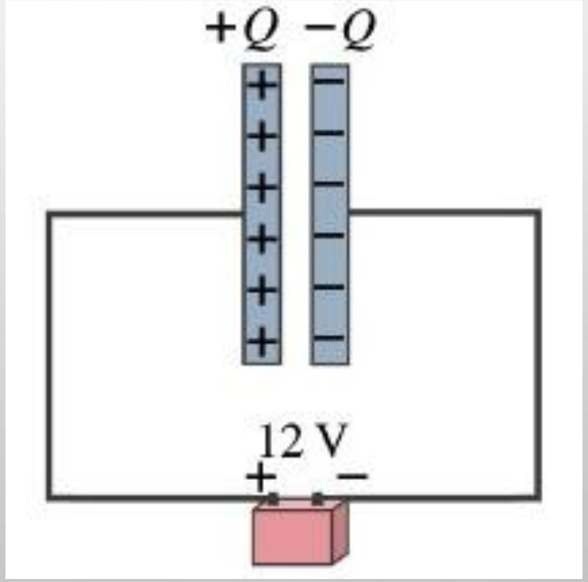




▪Types of Capacitor

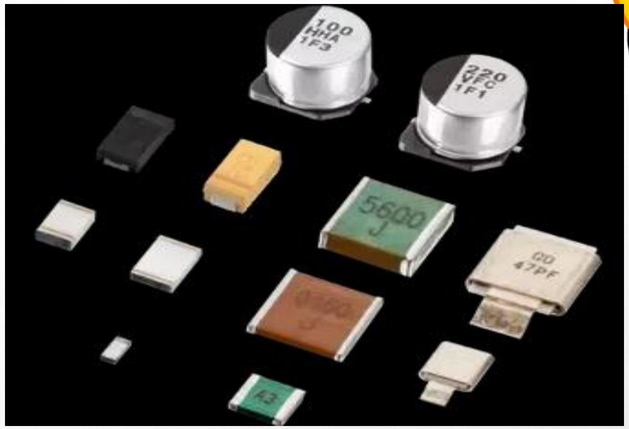
➢ <u>Fixed capacitors</u>:– often identified by their dielectrics.

Ceramic, Plastic, Mica, Aluminum and Tantalumoxide

➢ <u>Electrolytic capacitors:-</u>

Large capacitance at low cost and have a shelf life

▪Types of Capacitor



➢ Surface Mount Capacitors

- Soldered directly onto printed circuit boards
- Extremely small: High packaging density

➢ Variable capacitors:-

➢ Supercapacitors:-

▪Calculation of capacitance C

➢ The most common type of capacitors are:-

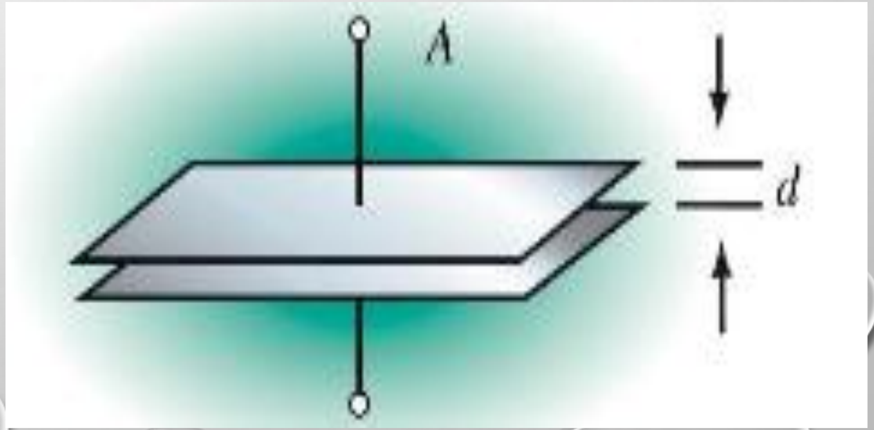
- a Parallel-Plate Capacitor

- Cylindrical Capacitor

- Spherical Capacitor

✓ a Parallel-Plate Capacitor

Two parallel plates of equal area *A* are separated by distance *d* as shown in the figure bellow. One plate charged with +*q*, the other -*q*.

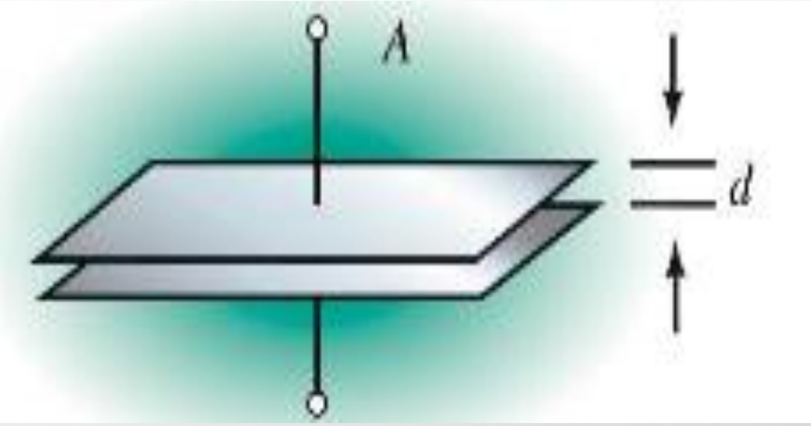


The capacitance is given by $C = \frac{V}{q}$ (1)

✓ a Parallel-Plate Capacitor

The **charge per unit area** on either plate is

$\sigma = q/A$ $\quad\quad$ $q = \sigma A$ $\quad\quad$ (2)



The **electric field due to conducting Surface**

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

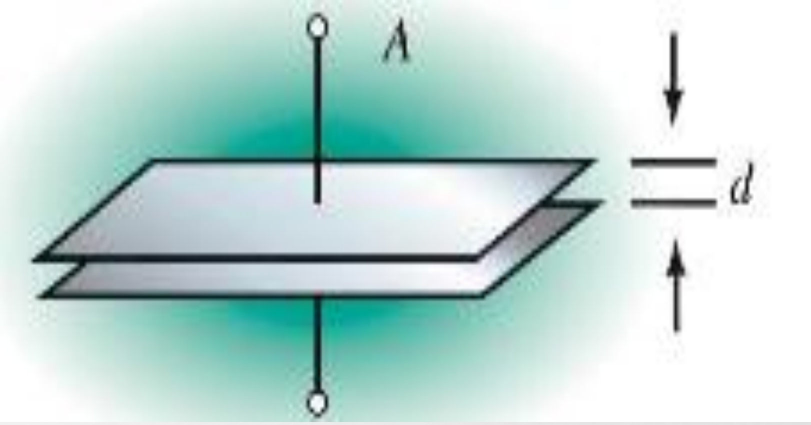
The **potential difference** between the plates is equal to $V = Ed$

$$\therefore V = \frac{qd}{A\varepsilon_o} \quad (3)$$

✓ a Parallel-Plate Capacitor

- From eq. 3 in eq 1

$$\because C = \frac{V}{q} = \frac{\frac{qd}{A\varepsilon_o}}{q}$$

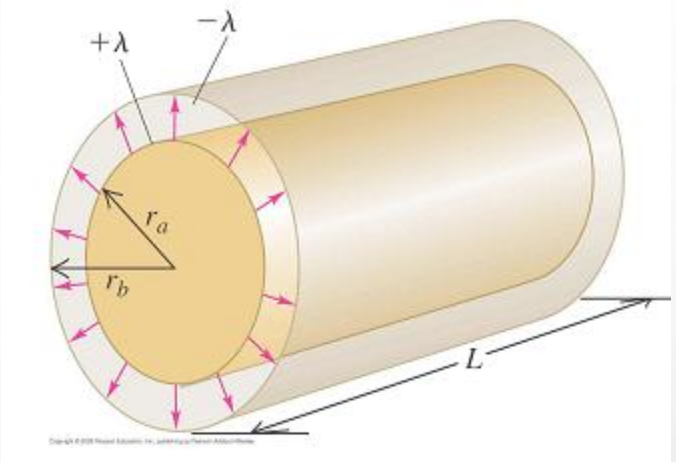


$$\therefore C = \varepsilon_o \frac{A}{d}$$

- The capacitance of the parallel plates capacitor is depends on the geometrical dimensions of the capacitor.
- The capacitance C is proportional to the area A of the plates and inversely proportional to distance between the plates.

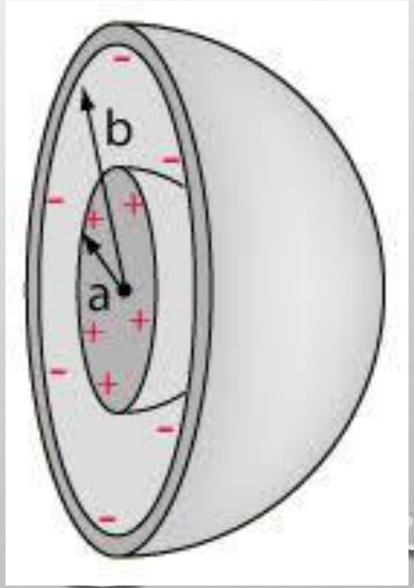
✓ - Cylindrical Capacitor

$$\therefore C = 2\pi\varepsilon_o \frac{L}{\ln b/a}$$



✓ - spherical Capacitor

$$\therefore C = 4\pi\varepsilon_o \frac{ab}{b-a}$$



Factors affecting capacitance

1. **Effect of Area:-** Capacitance, C is directly proportional to plate area A

2. **Effect of Spacing:-** Capacitance, C inversely proportional to distance between plates d

3. **Effect of Dielectric:-** The capacitance, C increases if the dielectric Constant (relative permittivity ε_o) is large

Combination of capacitors

1. Capacitors in Series

Same charge appears on all capacitors Q =Q1 =Q2=Q3

Total V = Sum of individual voltages

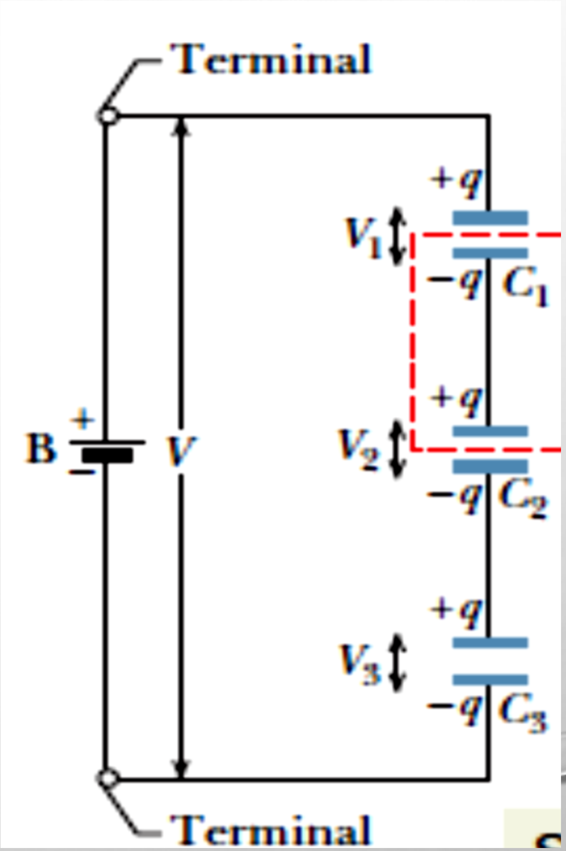
Vt =V1 + V2+ V3

$$V_t = V_1 + V_2 + V_3 = \frac{Q}{C_{eq}}$$

$$\frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

The total capacitance Ct is given by

$$\therefore \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$



Combination of capacitors

1. Capacitors in parallel

total charge on capacitors is sum of all charges Qt =Q1+Q2+ Q3

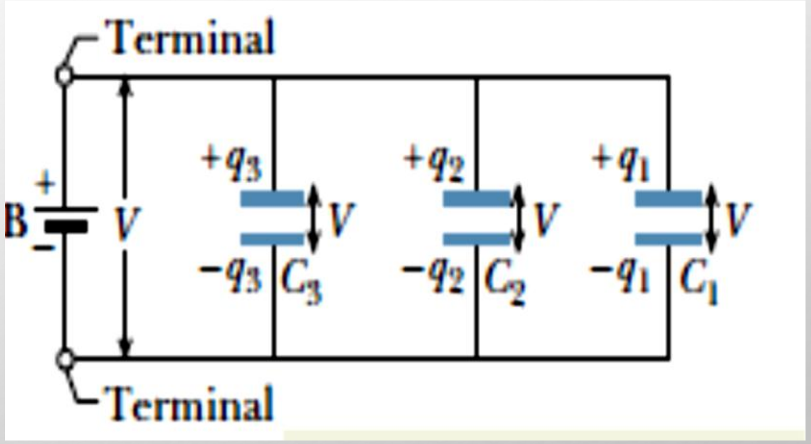
<u>All voltages are equal</u>

Vt =V1 =V2= V3

The total capacitance Ct is given by

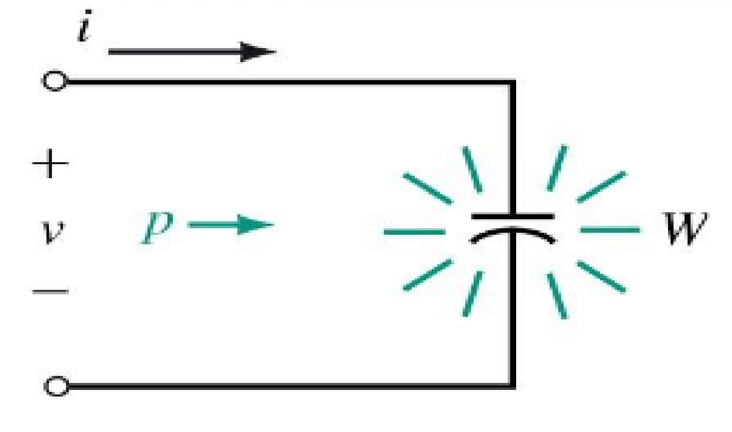
$$\therefore C_{eq}V_t = C_1V_1 + C_2V_2 + C_3V_3$$

$$\therefore C_{eq} = C_1 + C_2 + C_3$$



Energy stored in a charged capacitor

A capacitor :- does not dissipate power



- **the Stored potential energy U** :-

When power is transferred to a capacitor

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

$$U = \frac{Q^2}{2C}$$

$$U = \frac{1}{2} Q V$$

S.I unit of potential energy U = Joule

Energy stored in a charged capacitor

energy density u *:- is the energy per unit volume*

$$\boldsymbol{\upsilon} = \frac{1}{2}\boldsymbol{\varepsilon_o}\boldsymbol{E}^2$$

the electric energy density is proportional with square of the electric field

S.I unit of energy density u = Joule/ m³

problems from the book

Example .1 in details shown in page 78

Example .2 in details shown in page 80

Example .3 in details shown in page 83

Example .4 in details shown in page 86

MULTIPLE CHOICE QUESTIONS

No	Solution	No.	Solution
1	E	8	B
2	C	9	B
3	C	10	D
4	C	11	D
5	A	12	A
6	D	13	B
7	C		


Thank
You