Basic Electrical Technology

LECTURE 2 – 23 OCTOBER 2021

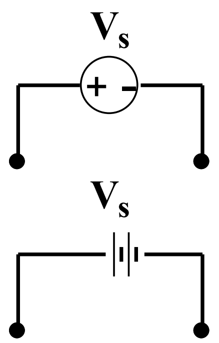
- ACTIVE & PASSIVE ELEMENTS

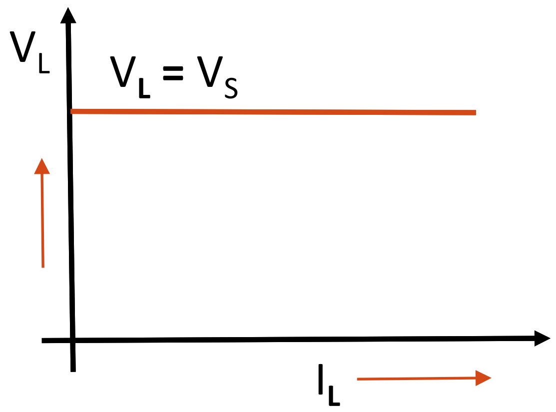
Active Elements - Sources

Voltage Source

- **Ideal:**
  - Maintains constant voltage irrespective of connected load
  - Internal resistance $\boldsymbol{R_s = 0}$

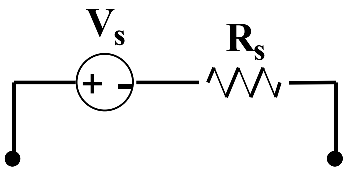
Ideal Voltage Source (DC)

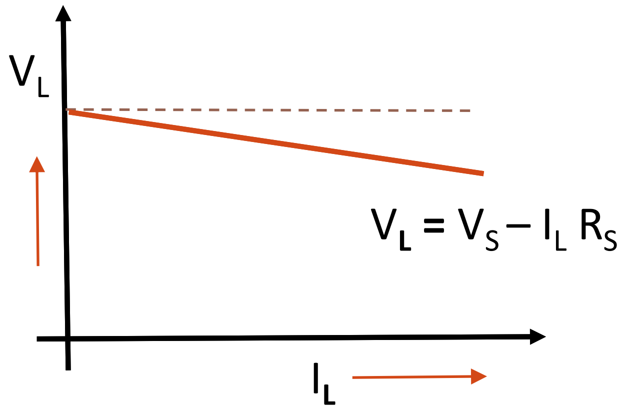




- **Practical:**
  - Terminal voltage changes based on the connected load
  - Internal resistance $\boldsymbol{R_s \neq 0}$

Practical Voltage Source

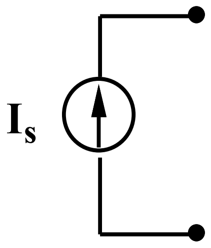


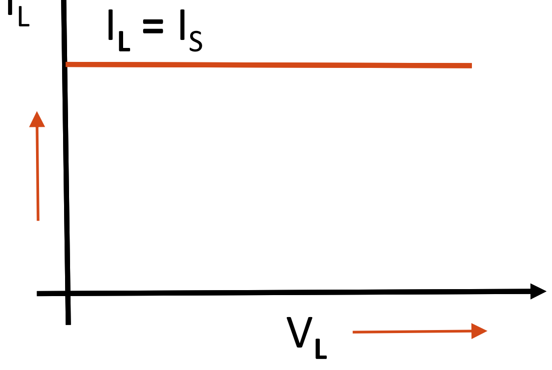


Active Elements - Sources

Current Source

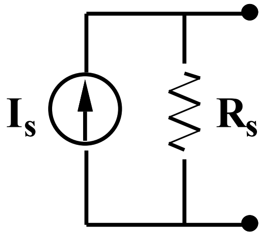
Ideal Current Source (DC)

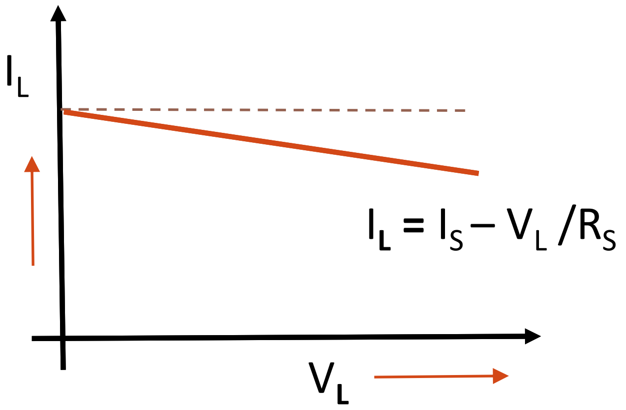




- **Ideal:**
  - Maintains constant current irrespective of the load connected
  - Internal resistance $\boldsymbol{R_s} = \infty$

Practical Current Source





- **Practical:**
  - Output current changes based on the connected load
  - Internal resistance $\boldsymbol{R_s} < \infty$

Resistor

Energy Consuming Element

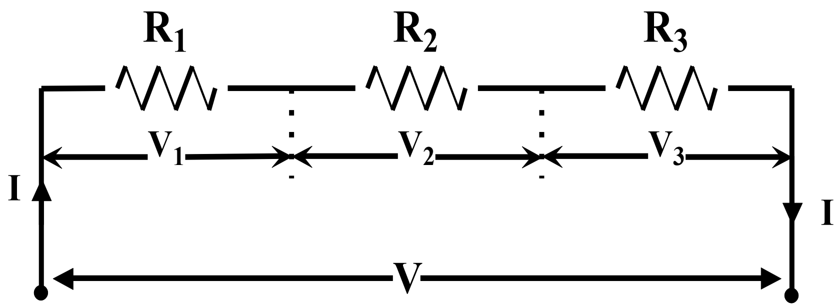
Resistor

- **Passive electric device** that **dissipates energy**
- **Resistance:** property which opposes flow of current
  - Symbol: **R**
  - Unit: Ohms (Ω)
  - Power Consumed $= \boldsymbol{I^2 R}$

- **Conductance**
  - Reciprocal of resistance
  - Symbol: G
  - Unit – Siemens (S)

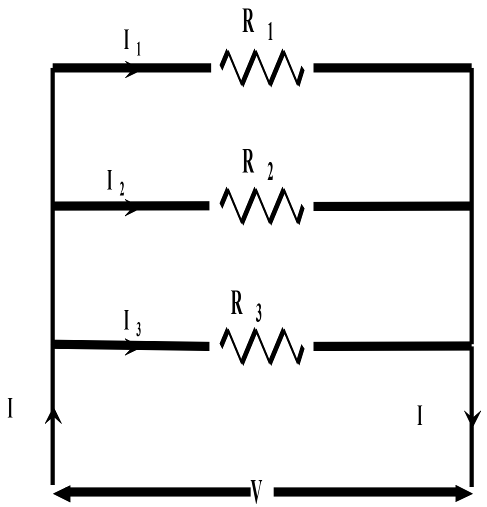
Resistors

Series connection of Resistors



- Current (I) in the all the resistors remains same
- $V = V_1 + V_2 + V_3$
- $R_{eq} = R_1 + R_2 + R_3$

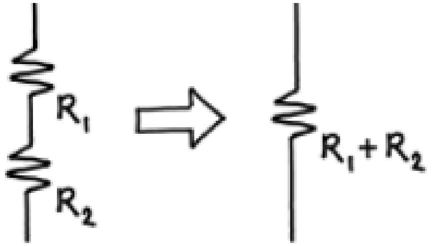
Parallel connection of Resistors



- Voltage (V) is same
- $I = I_1 + I_2 + I_3$
- $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

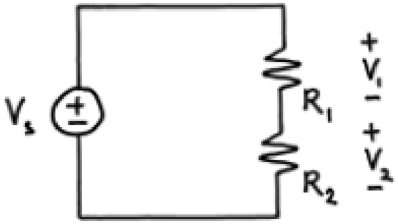
Resistors

Series Resistors



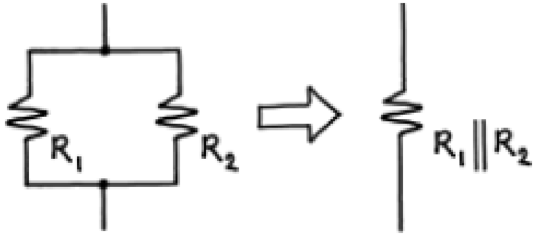
$$\text{Equivalent resistance} = R_1 + R_2$$

Voltage Divider



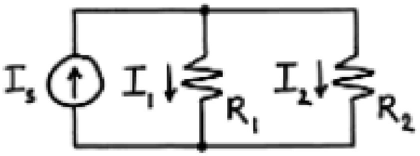
$$V_1 = \frac{R_1}{R_1 + R_2} V_s \qquad V_2 = \frac{R_2}{R_1 + R_2} V_s$$

Parallel Resistors



$$\text{Equivalent resistance} = R_1 || R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

Current Divider



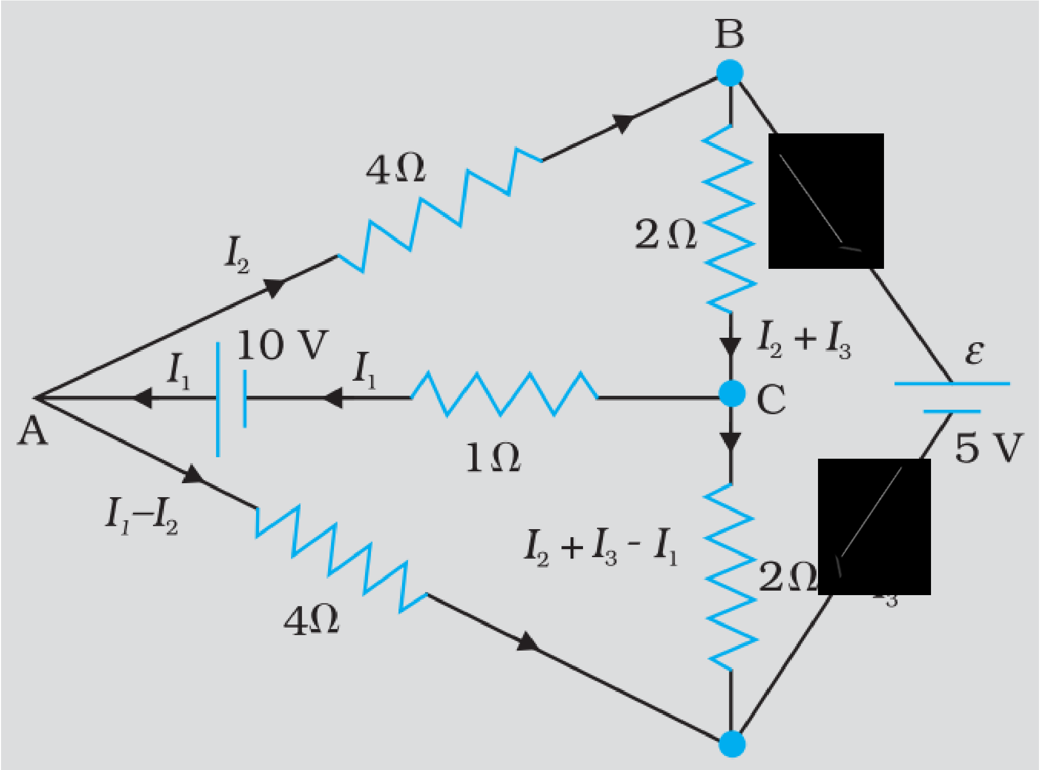
$$I_1 = \frac{R_2}{R_1 + R_2} I_s \qquad I_2 = \frac{R_1}{R_1 + R_2} I_s$$

Delivering and absorbing power by a source

- A battery is **discharging (delivering power/energy)** if,
  - **Current coming out from positive (+) terminal**

- A battery is **charging (absorbing power/energy)** if,
  - **Current flowing into positive (+) terminal**

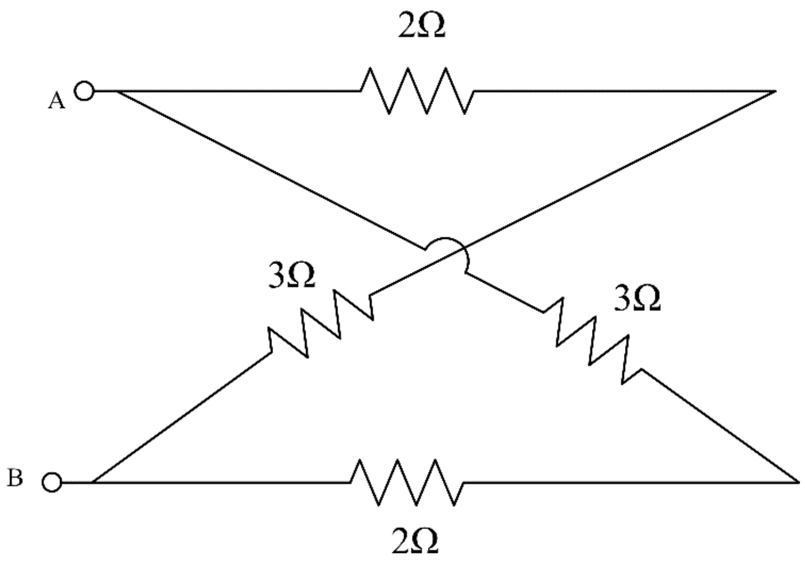
- When current flows through a resistor,
  - Power is dissipated



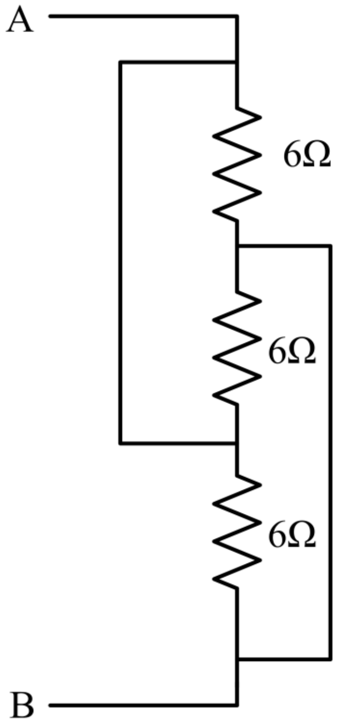
10 V battery is discharging
5V battery is charging

Illustration 1

Find the equivalent resistance of the networks given below.



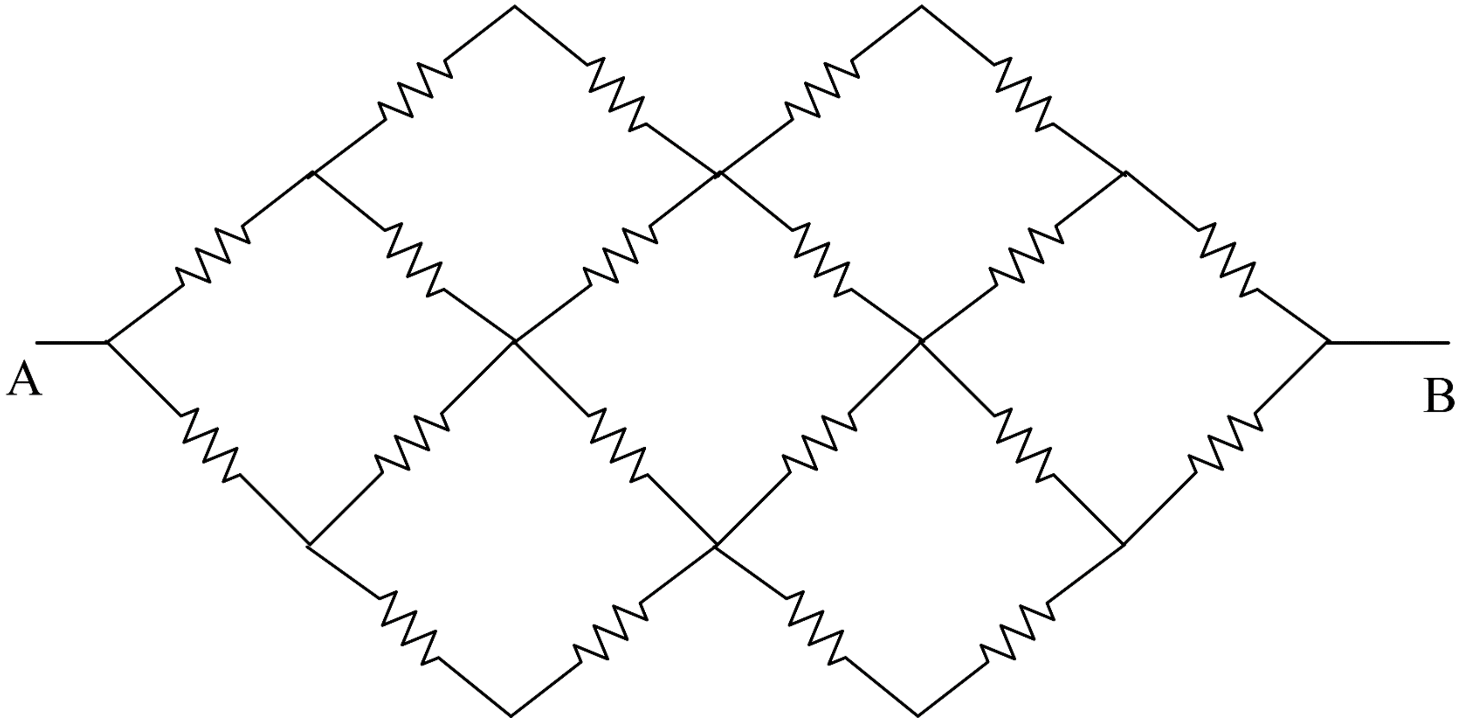
Ans: 2.5 Ohms



Ans: 2 Ohms

Illustration 2

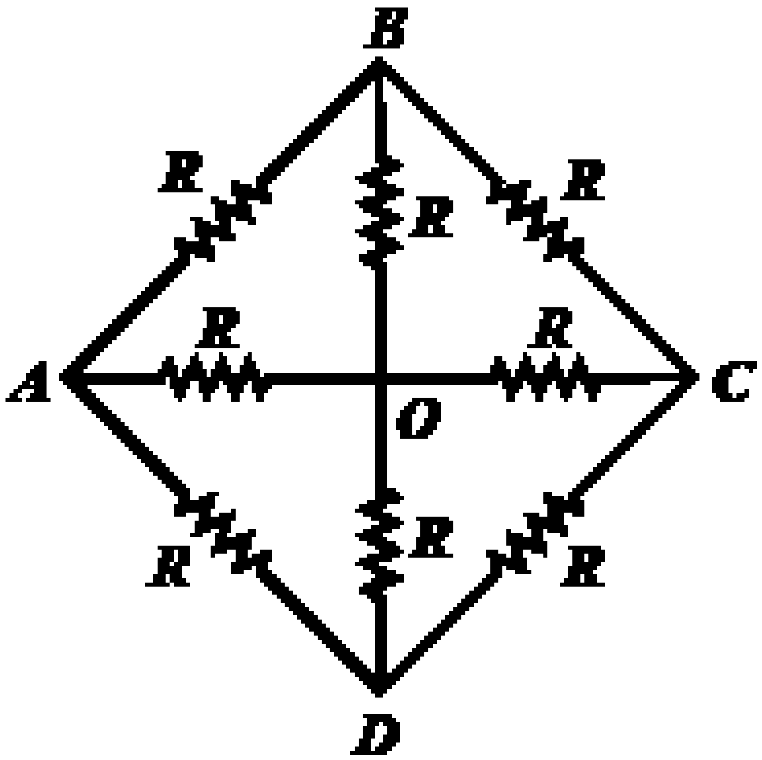
Determine the equivalent resistance between the points A and B for the given resistive network with 1 Ω resistors



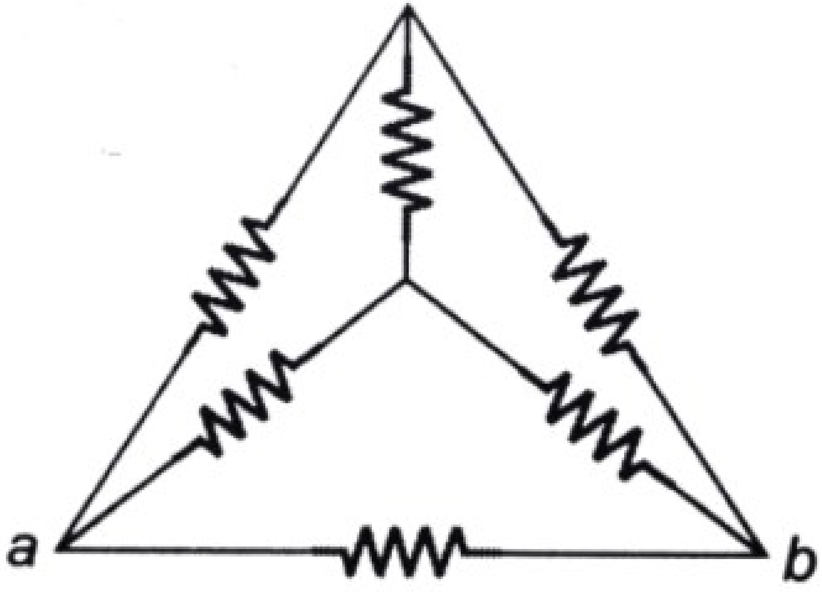
Ans: 2 Ohms

Illustration 3

Determine the equivalent resistance between the points **A & C** and **a** & **b,** respectively for the given resistive network. Each resistance is R Ohms.



Ans: 2R/3 Ohms



Ans: R/2 Ohms

Inductor

Energy Storing Element

Inductor

- **Passive** electric device that **stores energy in its magnetic field** when current flows through it

- A coil of wire wound on a core
  - Example: Air core Inductor, iron core inductor

- **Inductance**: property which opposes rate of change of current
  - Symbol: **L**
  - Unit: Henry (H)

- The voltage across inductor is proportional to the rate of change of current through it

$$v_L = L\frac{di}{dt}$$

Inductive Circuit

For a coil uniformly wound on **a non-magnetic core** of uniform cross section, self-inductance is given by

$$L = \frac{\mu_0 A N^2}{l}$$

where,

$l =$ length of the magnetic circuit in meters

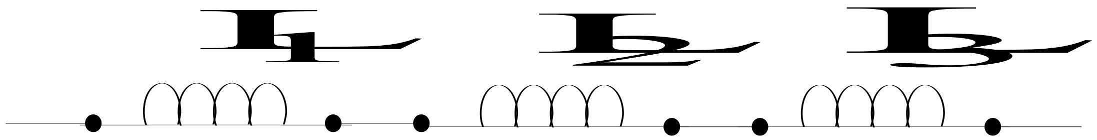
$A =$ cross sectional area in square meters

$\mu_o =$ Permeability of air $= 4\pi \times 10^{-7}$

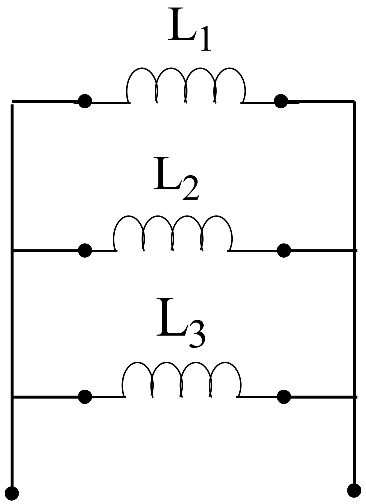
$N = No. of\ turns\ in\ the\ coil$

Equivalent Inductance

Inductors in series



$$L_{eq} = L_1 + L_2 + \dots \dots + L_n$$



Inductors in Parallel

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \dots \dots . + \frac{1}{L_n}$$

Energy Stored in an Inductor

- Instantaneous power,

$$\boldsymbol{p = \ v_L . i = L\, i \frac{di}{dt}}$$

- Energy absorbed in '$\boldsymbol{dt}$' time is

$$\boldsymbol{dw = L\, i\, di}$$

- Energy absorbed by the magnetic field when current increases from $\mathbf{0}$ to $\boldsymbol{I}$ amperes, is

$$\boldsymbol{W = \ \int_0^I L\, i\, di = \frac{1}{2} L\, I^2}$$

Capacitor

Energy Storing Element

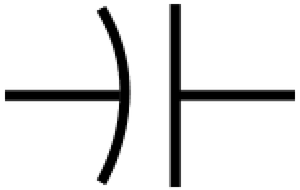
Capacitors

- **Passive electric device** that **stores energy in the electric field** between a pair of closely spaced conductors

- **Capacitance**: Property which opposes the rate of change of voltage
  - Symbol: **C**
  - Unit: Farad (F)

- The capacitive current is proportional to the rate of change of voltage across it

$$\boldsymbol{i_c = C\frac{dv_c}{dt}}$$



- Charge stored in a capacitor whose plates are maintained at constant voltage:

$$\boldsymbol{Q = CV}$$

Terminologies

- Electric field strength,

$$E = \frac{V}{d}\ volts/m$$

- Electric flux density,

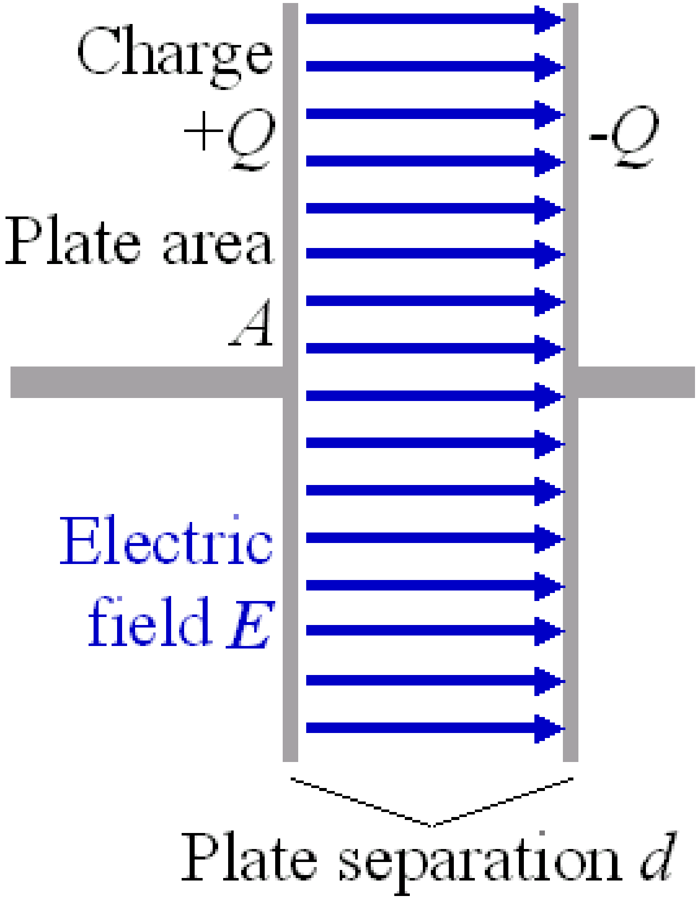
$$D = \frac{Q}{A}\ C/m^2$$

- Permittivity of free space,

$$\varepsilon_0 = 8.854 \times 10^{-12}\ F/m$$

- Relative permittivity, ε_r
- Capacitance of parallel plate capacitor

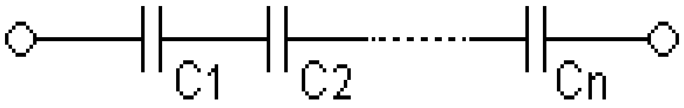
$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$



Equivalent Capacitance

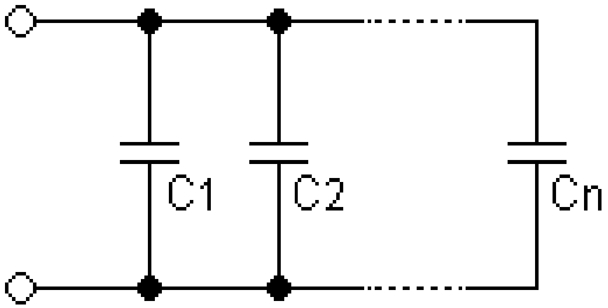
Capacitors in Series

$$\frac{1}{C_{eq}} = \frac{1}{C1} + \frac{1}{C2} + \ \dots\dots + \frac{1}{Cn}$$



Capacitors in Parallel

$$C_{eq} = C_1 + C_2 + \ \dots.. + C_n$$



Energy stored in a Capacitor

- Instantaneous power

$$p = v_c \times i = C\, v_c \frac{dv_c}{dt}$$

- Energy supplied during 'dt' time is:

$$dw = C\, v_c\, dv_c$$

- Energy stored in the electric field when potential rises from $\mathbf{0}$ to V volts is,

$$W = \int_0^V C\, v_c dv_c = \frac{1}{2} CV^2 \text{ Joules}$$

Quiz Time

UNGRADED

1

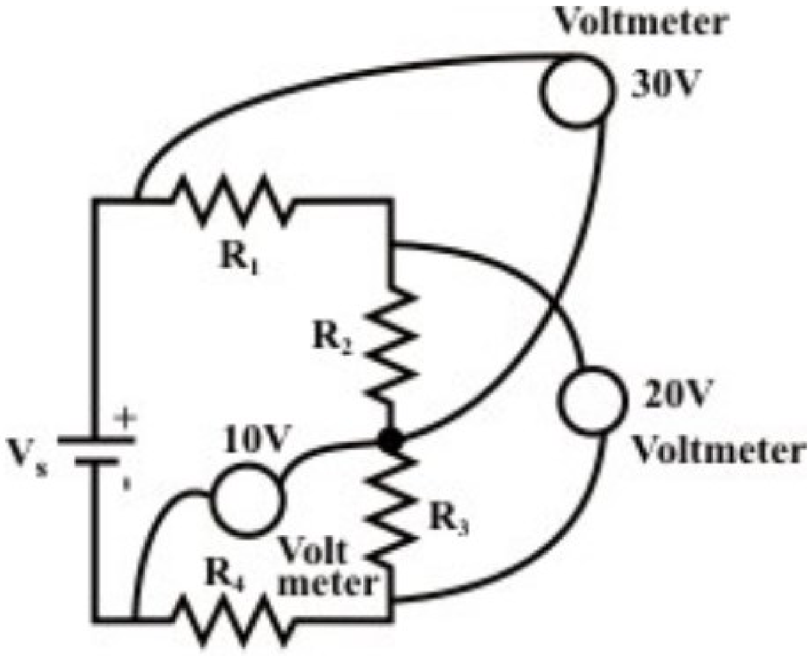
An inductor and a resistor opposes _____ & _____ respectively

a) flow of current, rate of change of current
b) rate of change of current, flow of current
c) rate of change of current, rate of change of current
d) flow of current, flow of current

2

The source voltage is ___

a) 10 V
b) 20 V
c) 30 V
d) 40 V



3

Two incandescent bulbs of 40 W and 60 W ratings are connected in series across the mains. Assuming the voltage rating of both the bulbs to be same, which of the following statement(s) is (are) correct?

a) The bulbs together will consume 100 W

b) The bulbs together will consume 50 W

c) The 60 W bulb glows brighter

d) The 40 W bulb glows brighter

4

Resistors in the following circuit are connected in

a) Series

b) Parallel

c) Combination of series and parallel

d) None of the above