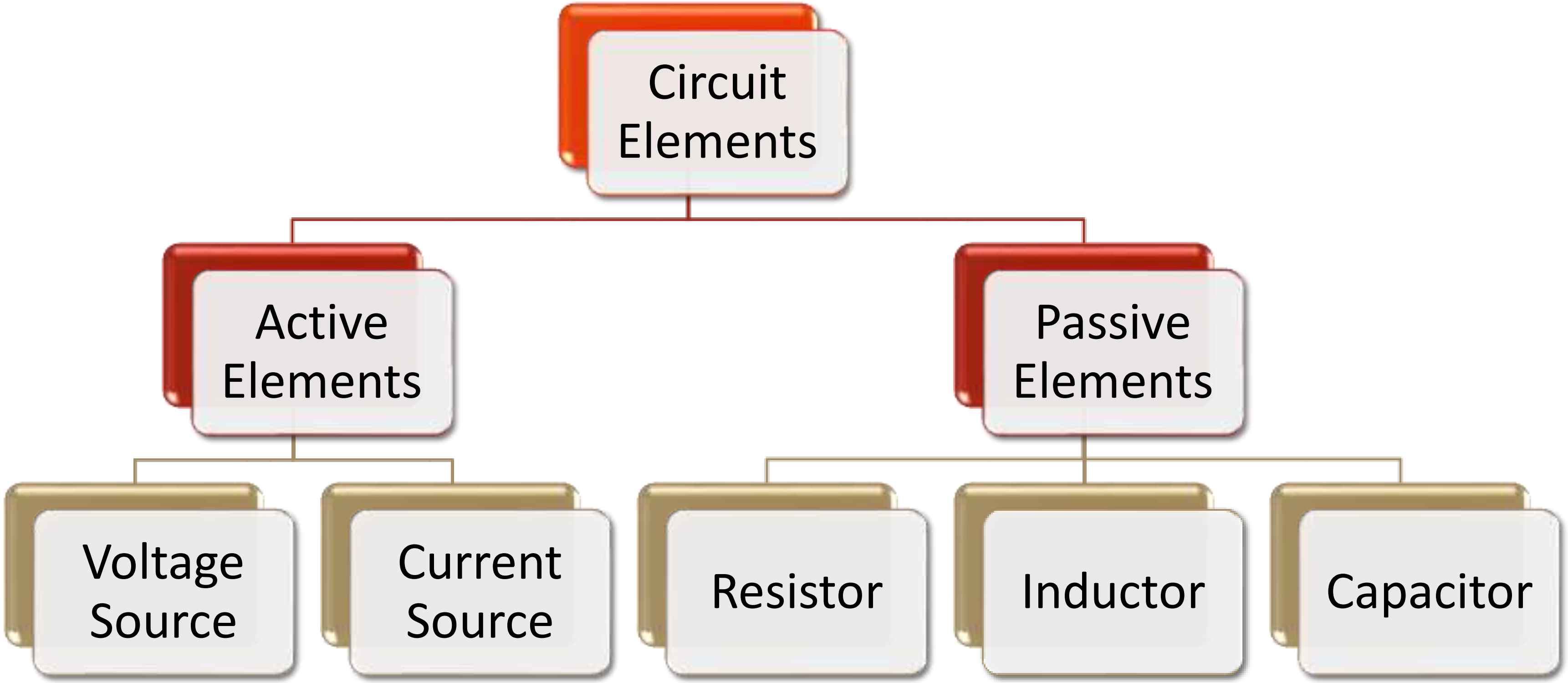
Basic Electrical Technology

Circuit Elements

Classification of Circuit Elements

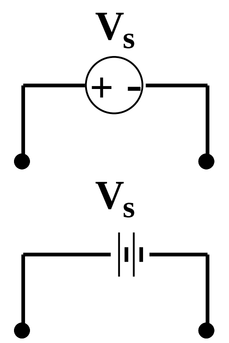


Active Elements - Sources

Voltage Source:

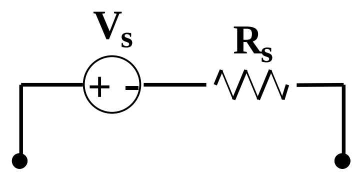
- **Ideal:**
  - Maintains constant voltage irrespective of connected load
  - Internal resistance $\boldsymbol{R_s = 0}$

Ideal Voltage Source (DC)



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

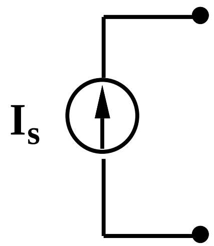
Practical Voltage Source



Active Elements - Sources

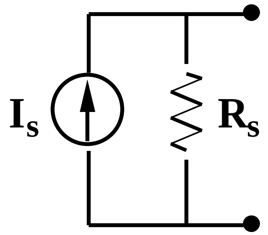
Current Source:

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 $= \boldsymbol{I^2 R}$

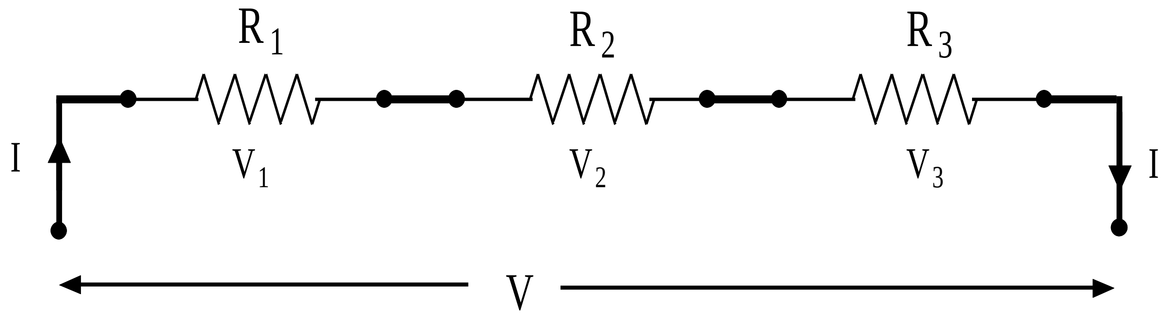
- **Conductance**
  - Reciprocal of resistance
  - Symbol: G
  - Unit – Siemens (S)

Resistors in Series

Current (I) is same

$$V = V_1 + V_2 + V_3$$

$$R_{eq} = R_1 + R_2 + R_3$$

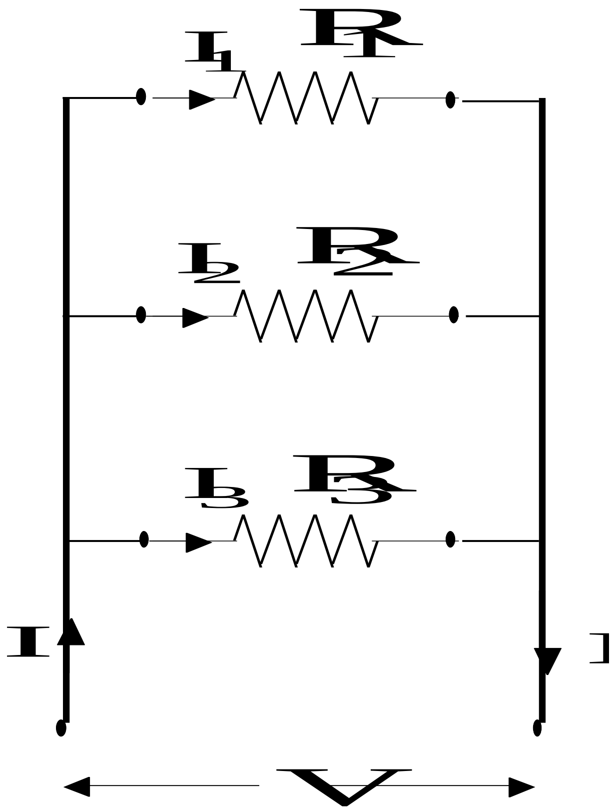


Resistors in Parallel

Voltage (V) is same

$$I = I_1 + I_2 + I_3$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



Inductor

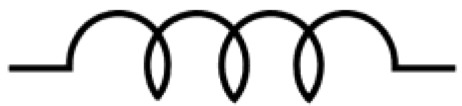
Energy Storing Element

Inductor

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

- A coil of wire wound on a core
  - Eg.: 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

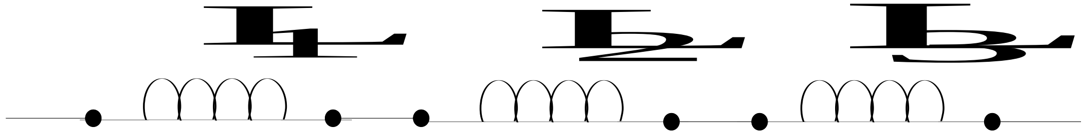
$$L = \frac{\mu_0 A N^2}{l}$$

Where,
$l =$ length of the magnetic circuit in meters
$A =$ cross sectional area in square meters
$\mu_o =$ Permeability of air $= 4 \times 10^{-7}$
$N = No. of\ turns\ in\ the\ coil$

Equivalent Inductance

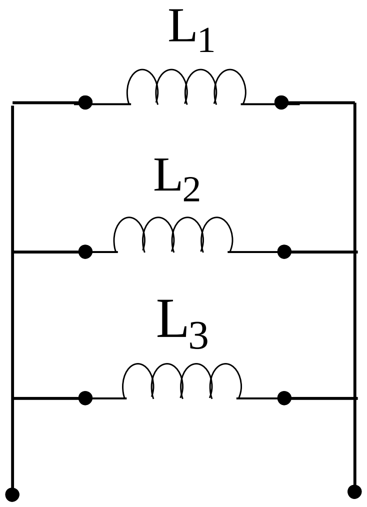
Inductors in series

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



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,

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

- Energy absorbed in 'dt' time is

$$dw = L\, i\, di$$

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

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

Capacitor

Energy Storing Element

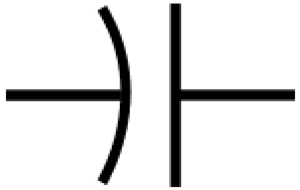
Capacitors

- **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,

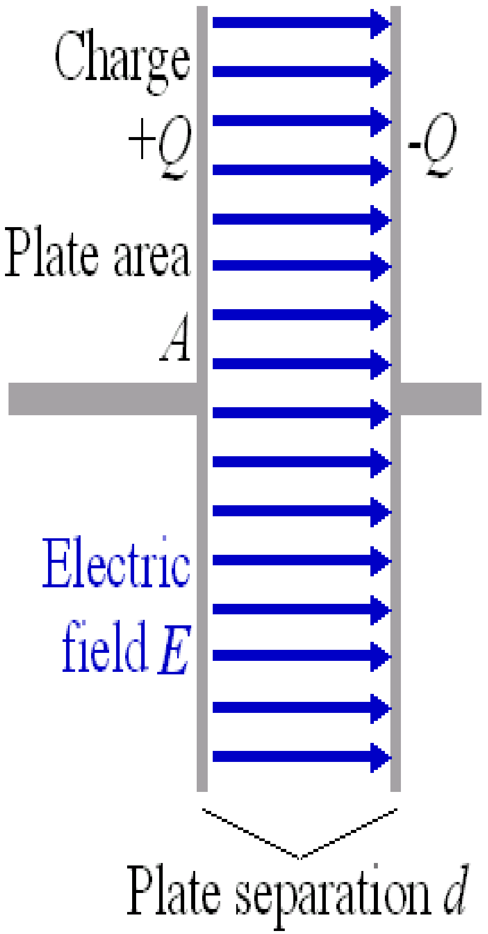
$$D = \frac{Q}{A} \, C/m^2$$

- Permittivity of free space,

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

- Relative permittivity, ε_r
- Capacitance of parallel plate capacitor

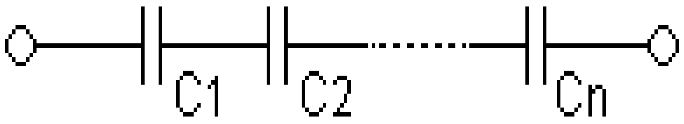
$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

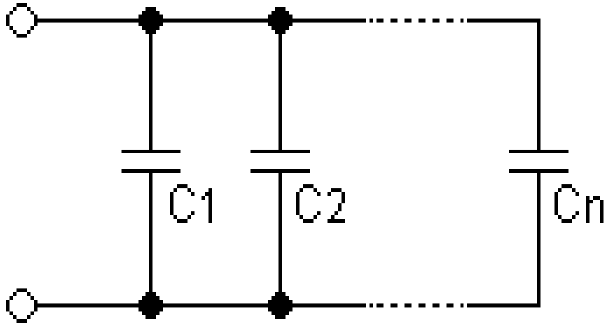


Equivalent Capacitance

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:

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

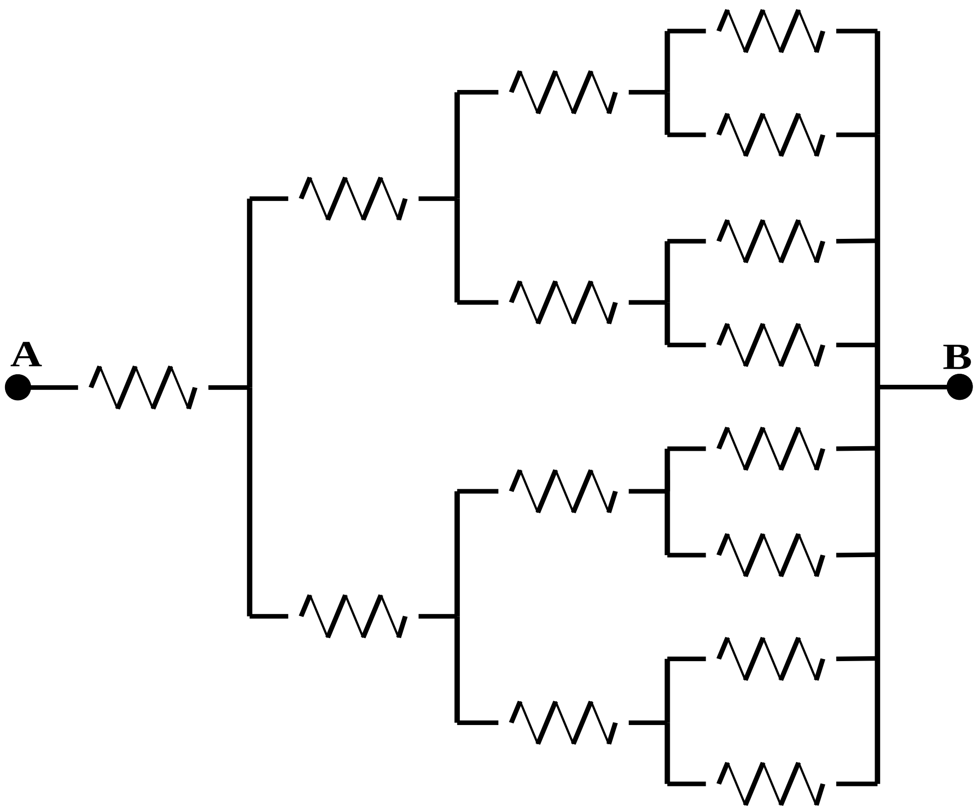
- Energy stored in the electric field when potential rises from $\mathbf{0}$ to V volts is,

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

Illustration 1

a) 15 resistors are connected as shown in the diagram. Each of the resistors has resistance 1 Ω. Find the equivalent resistance of the network between A & B.

b) What will be the equivalent resistance of this network if the resistors arranged in the sequence extends to infinity?



Ans:

a) 1.875 Ω

b) 2 Ω

Illustration 2

Two incandescent bulbs have the following ratings:

Bulb-1: 120 V, 60 W; **Bulb-2:** 240 V, 480 W

a) Both of them are connected in series with a voltage source.
   i. Which bulb will glow brighter and why?
   ii. What is the maximum voltage that can be applied so that non of the bulbs fuse?

b) Now both of them are connected in parallel with a voltage source.
   i. Which bulb will glow brighter and why?
   ii. What is the maximum voltage that can be applied so that non of the bulbs fuse?

Assume that the incandescent bulbs are purely resistive.

Ans:

a) i) Bulb-1 since it consumes more power, ii) 180 V

b) i) Bulb-2 since it consumes more power, ii) 120 V

Illustration 3

Two incandescent bulbs of 40 W and 60 W ratings are connected in series across the mains. Then which of the following statement(s) is(are) correct?

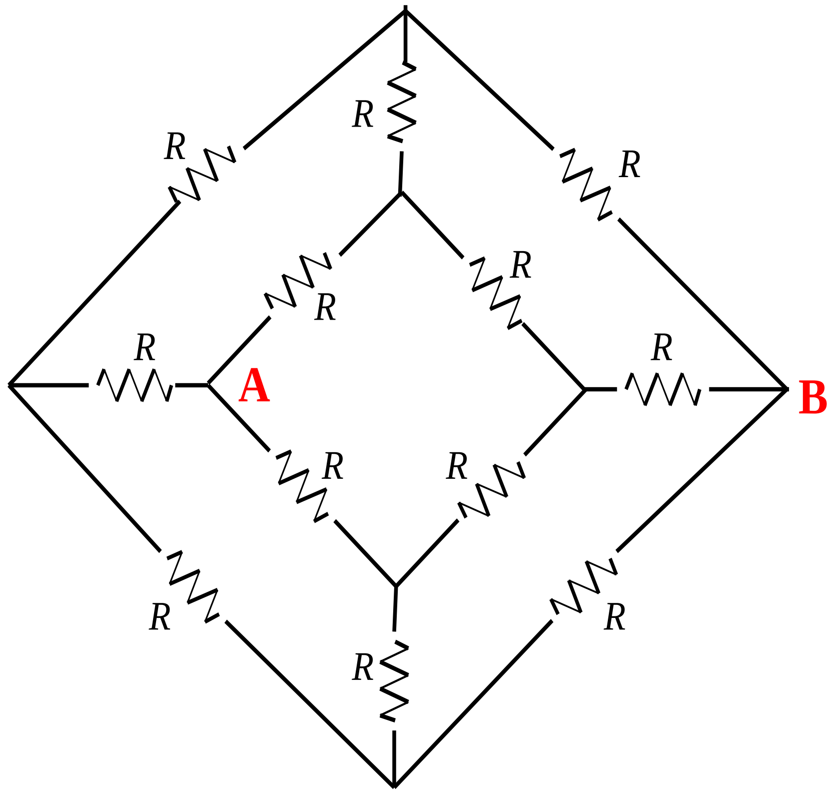
a) The bulbs together will consume 100 W
b) The bulbs together will consume 50 W
c) The 60 W bulb glows brighter
d) The 40 W bulb glows brighter

Assume the voltage rating of both the bulbs to be same.

Ans: d) The 40 W bulb glows brighter

Homework 1

Reduce the network to its equivalent resistance between terminals A and B



Ans: $\frac{5}{6}R$