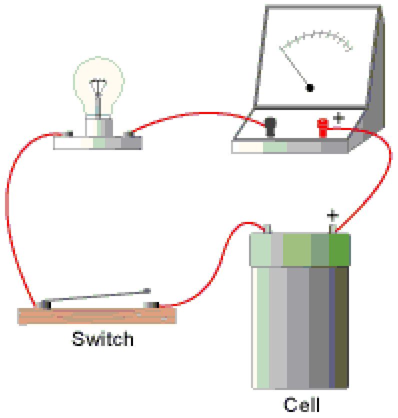
Basic Electrical Technology

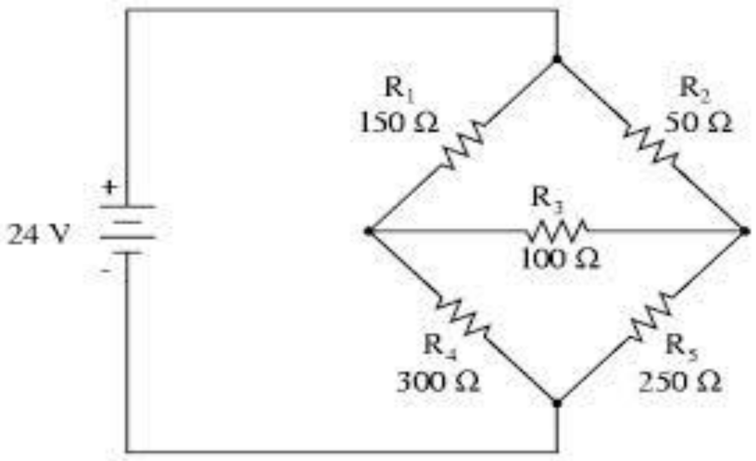
Circuit Elements

What is an Electric Circuit?

Definition:

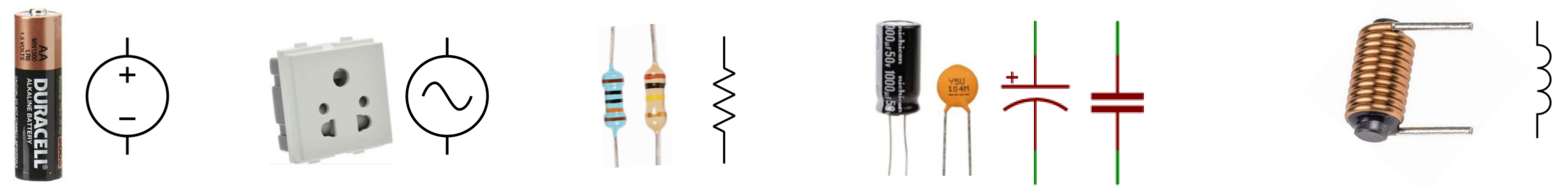
“An interconnection of simple electrical devices with at least one closed path in which current may flow”





Circuit Elements

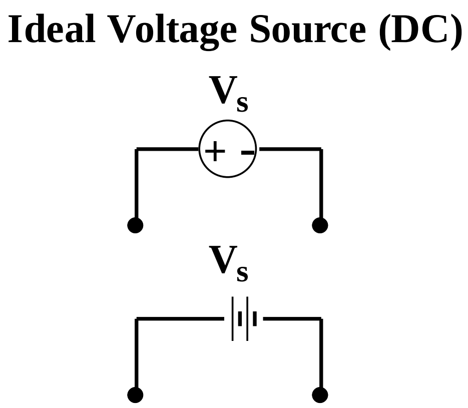
Active & Passive	• Active Elements: *Voltage & Current Sources* • Passive Elements: *Resistor, Inductor, Capacitor*
Linear & Non-linear Elements	• Linear: *Resistor, Inductor, Capacitor* • Nonlinear: *Diode, LDR (Light Dependent Resistor), Thermistor, transistor*
Unilateral & Bilateral Elements	• Unilateral (Current Flow in one direction): *Diode, Transistor* • Bilateral: *Resistor, Inductor, Capacitor**
Lumped & Distributed	• Lumped elements are simplified version of distributed elements • Discuss only ***lumped linear bilateral*** circuit elements

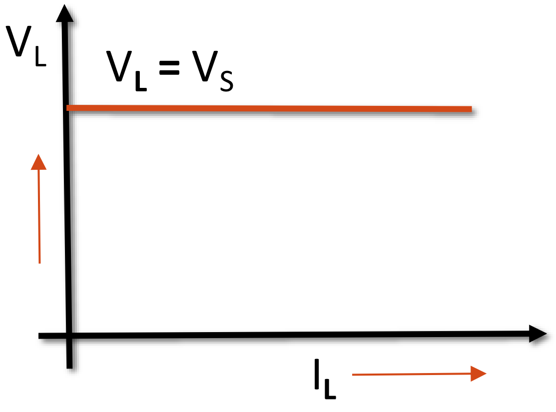


Active Elements - Sources

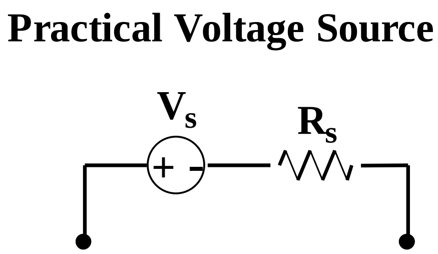
Voltage Source:

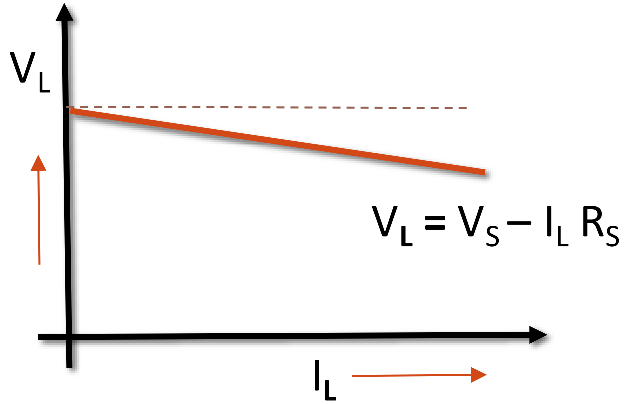
- **Ideal:**
  - Maintains constant voltage irrespective of connected load
  - Internal resistance $\boldsymbol{R_s = 0}$





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



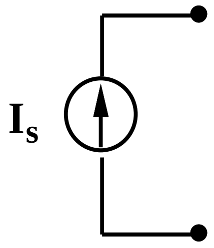


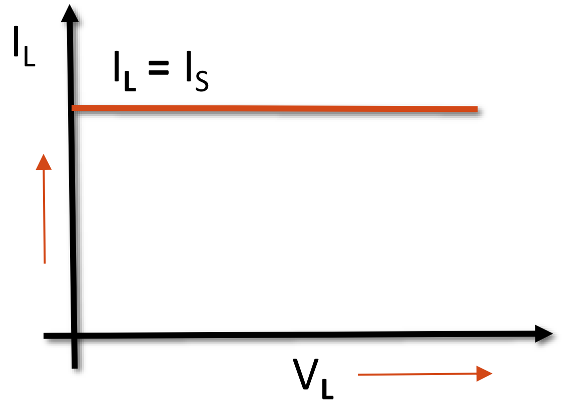
Active Elements - Sources

Current Source:

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

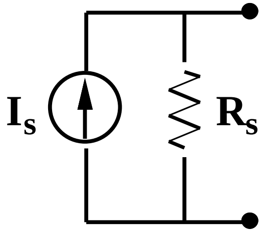
Ideal Current Source (DC)

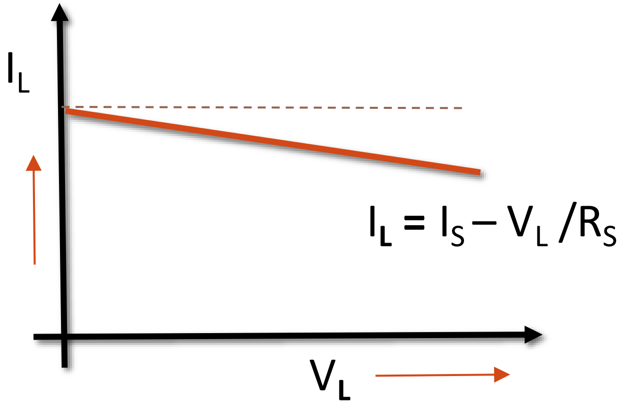




- **Practical:**
  - Output current changes based on the connected load
  - Internal resistance $\boldsymbol{R_s} < \infty$

Practical Current Source





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 $= \boldsymbol{I^2 R}$

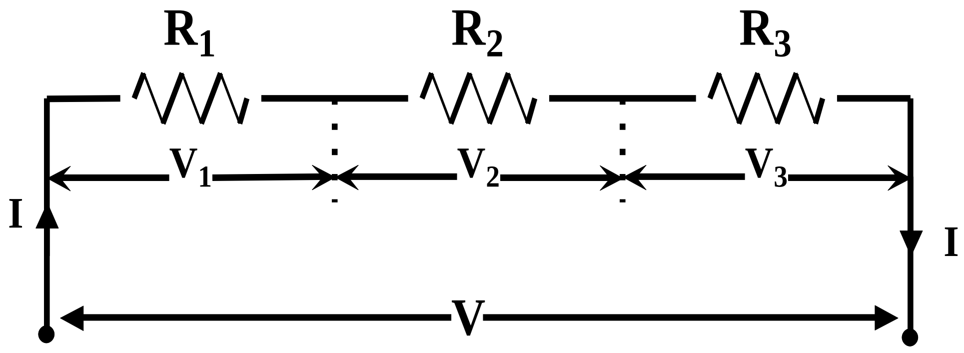
- **Conductance**
  - Reciprocal of resistance
  - Symbol: G
  - Unit – Siemens (S)

Resistors in Series

Current (I) is same

$$V = V_1 + V_2 + V_3$$

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

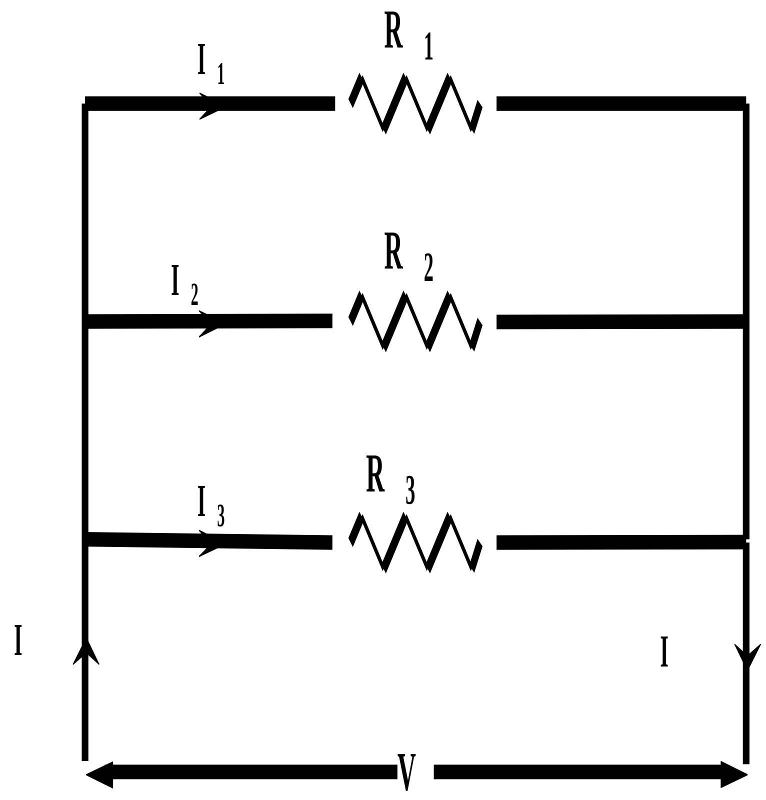


Resistors in Parallel

Voltage (V) is same

$$I = I_1 + I_2 + I_3$$

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



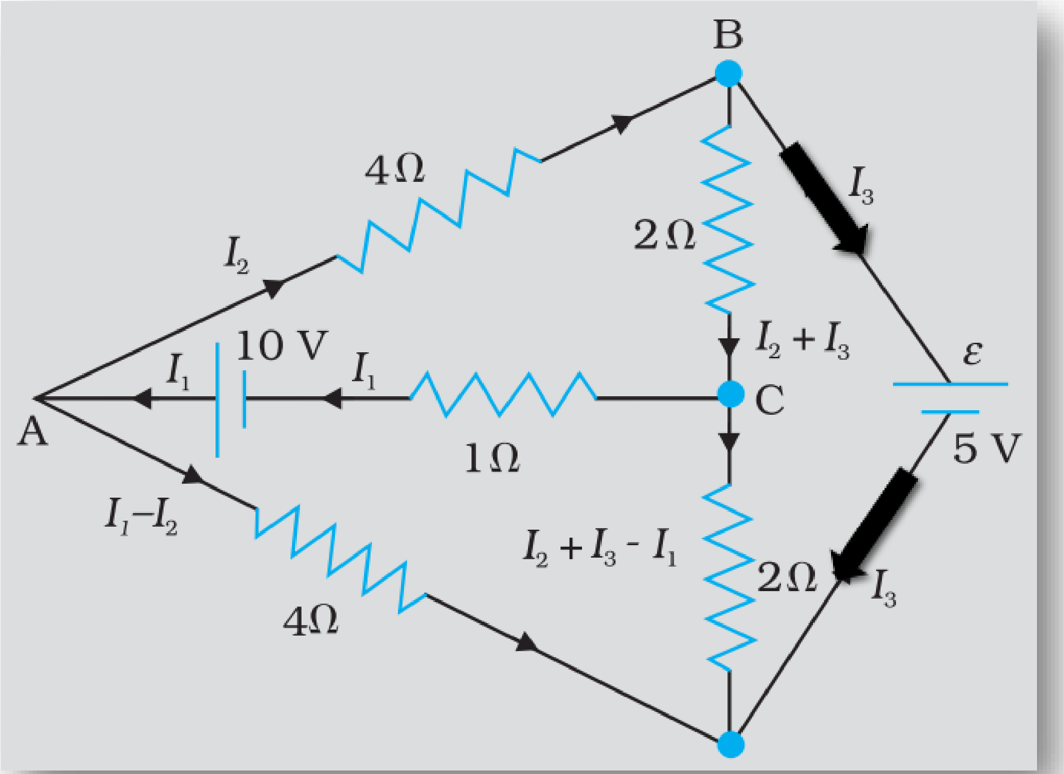
Delivering and Absorbing Power by a Source

Power is absorbed or dissipated by a circuit element if

- Current flows from the +ve terminal to –ve terminal.
- In a battery, it is said to be charging.
- In a resistance, it is absorbing/dissipating power.

In the circuit shown,

- Current I_3, is flowing from the +ve plate of the 5 V battery to the –ve plate. Therefore, **charging**
- Current I_1, is flowing from the –ve terminal to +ve terminal of 10 V. Therefore, generating power.



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

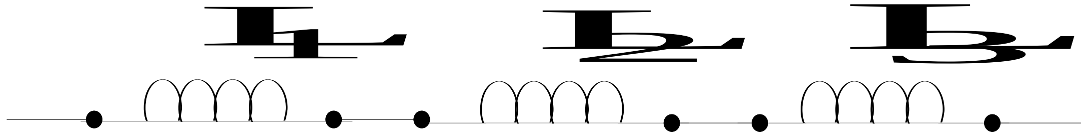
$$L = \frac{\mu_0 A N^2}{l}$$

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

Equivalent Inductance

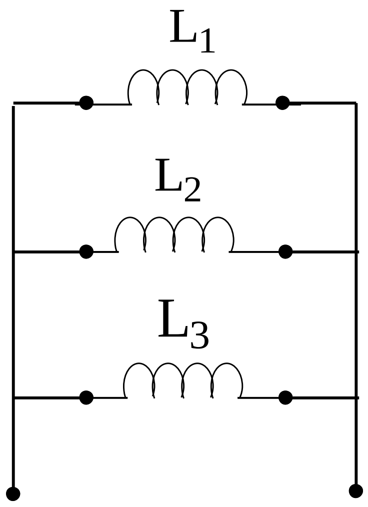
Inductors in series

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



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,

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

- Energy absorbed in 'dt' time is

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

- Energy absorbed by the magnetic field when current increases from 0 to I amperes, is

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

Capacitor

Energy Storing Element

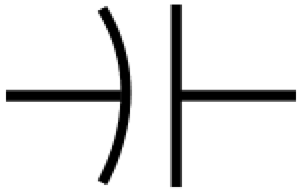
Capacitors

- **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

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



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

$$Q = CV$$

Terminologies

- Electric field strength,

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

- Electric flux density,

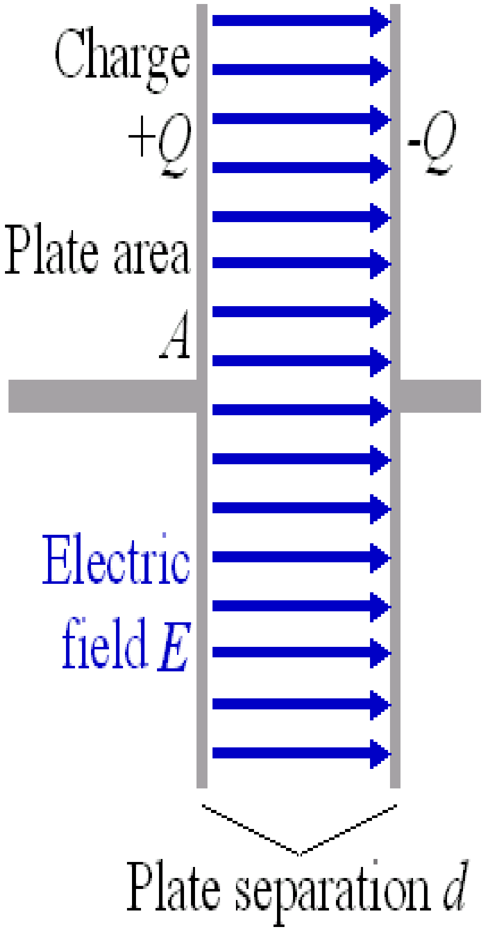
$$D = \frac{Q}{A}\ C/m^2$$

- Permittivity of free space,

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

- Relative permittivity, ε_r
- Capacitance of parallel plate capacitor

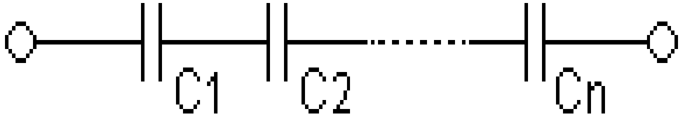
$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$



Equivalent Capacitance

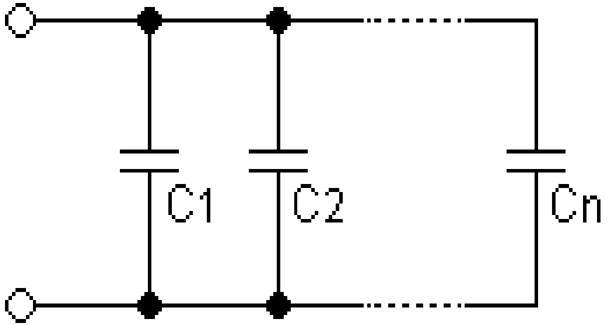
Capacitors in Series

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



Capacitors in Parallel

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



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,

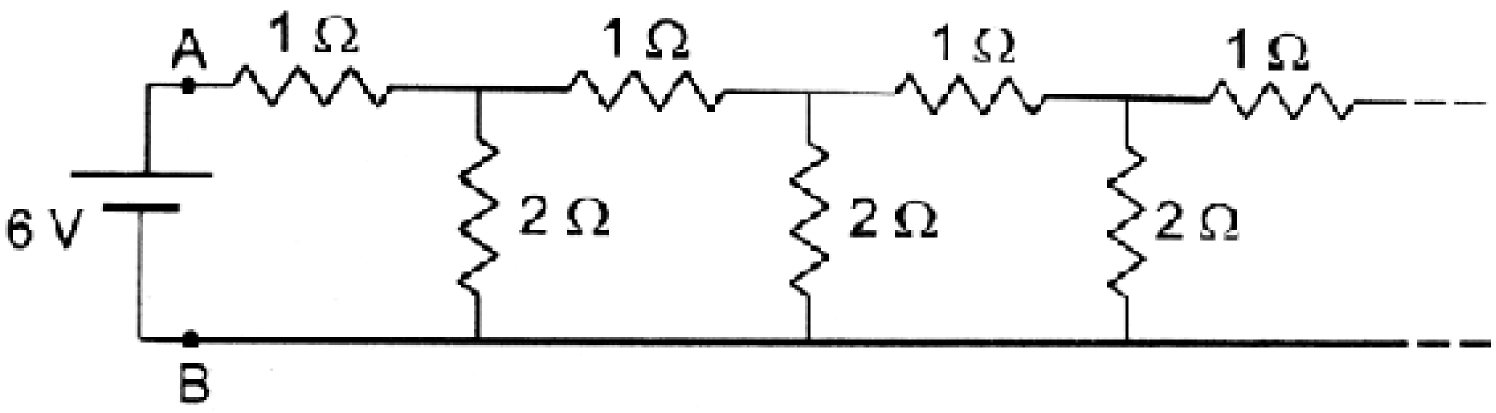
$$W = \int_0^V C\, v_c dv_c = \frac{1}{2} C V^2 \text{ Joules}$$

Quiz Time

Quick Quiz 1

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. What is the equivalent resistance across the terminals A & B in the network shown?

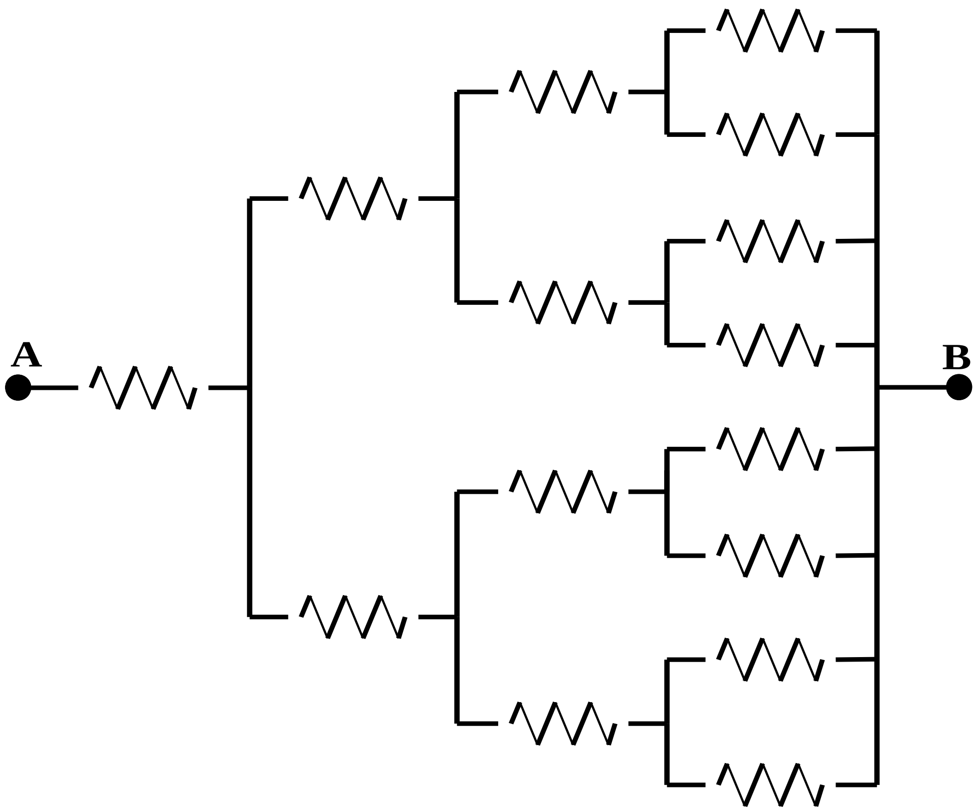


Quick Quiz 1

3.

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?



Quick Quiz 1

4. Two incandescent bulbs have the following ratings:

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

Both 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 none of the bulbs fuse?

Assume that the incandescent bulbs are purely resistive.

Quick Quiz 1

5. Two incandescent bulbs have the following ratings:

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

Now both 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 none of the bulbs fuse?

Assume that the incandescent bulbs are purely resistive.

Quick Quiz 1

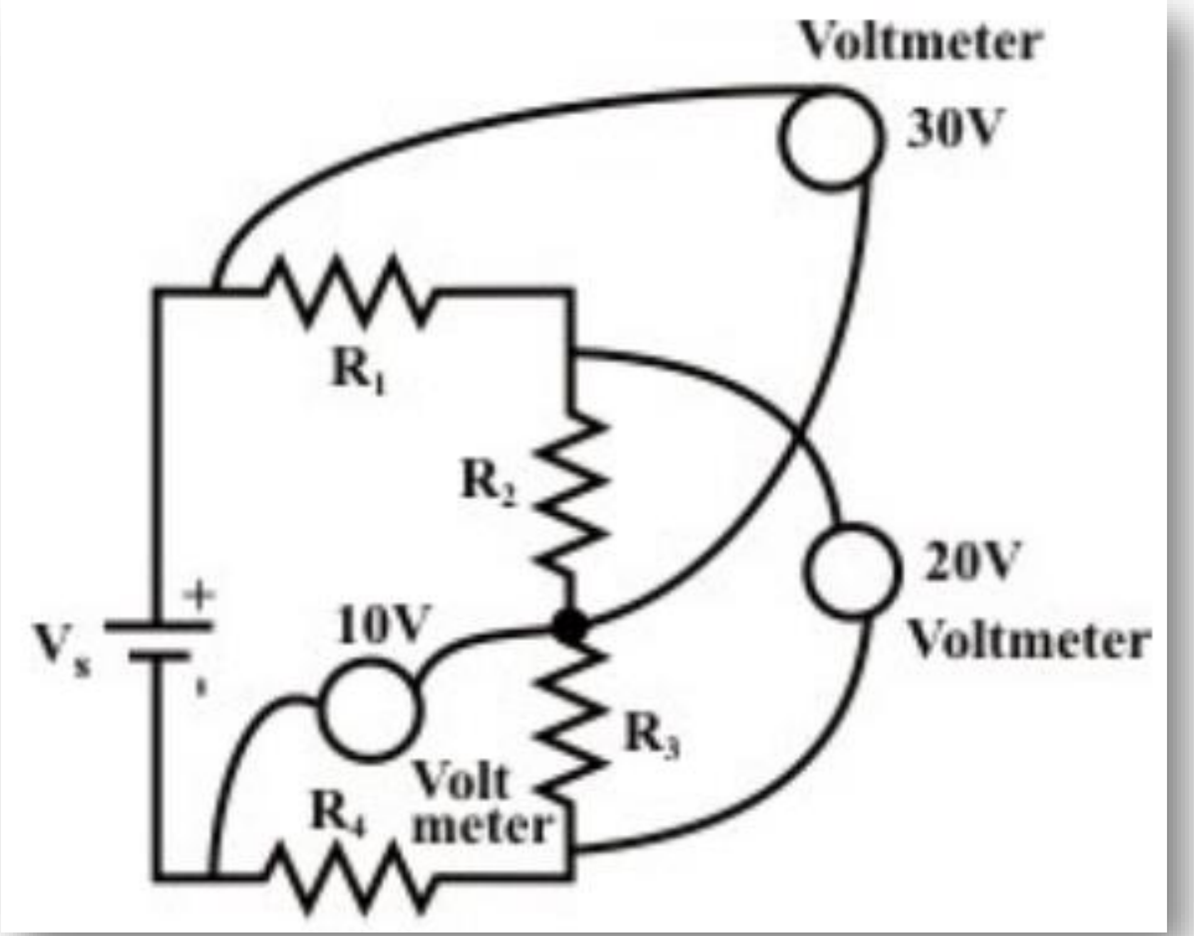
6. The source voltage is ___

A) 10 V

B) 20 V

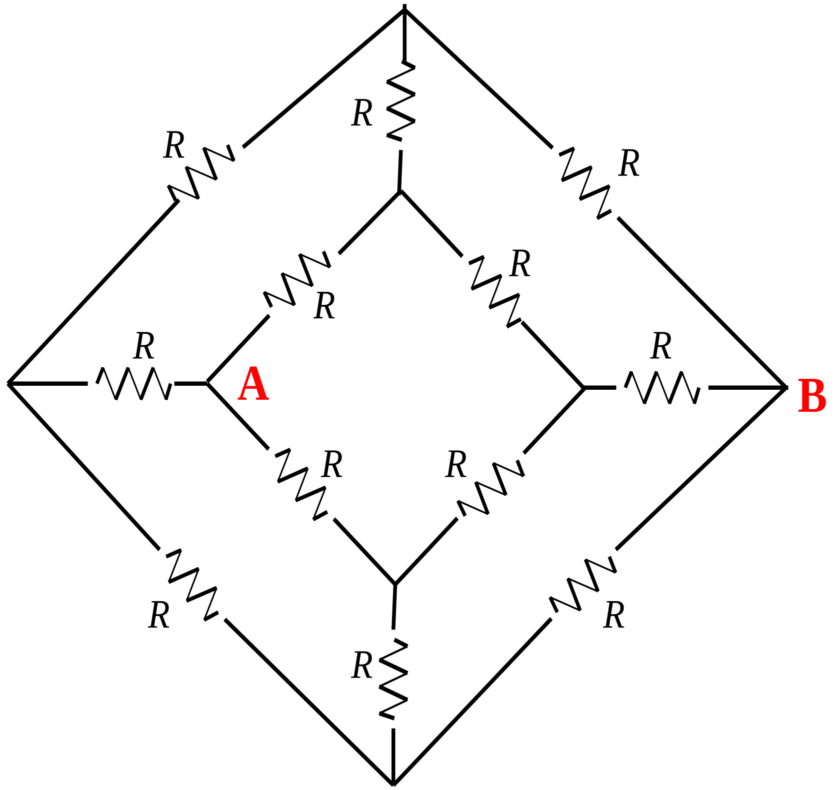
C) 30 V

D) 40 V



Homework 1

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



Answers to Quiz Questions

Answers

1. B)

2. 2 Ω

3.
   a) 1.875 Ω
   b) 2 Ω

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

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

6. 40 V

Homework 1: 5R/6