EE051IU: Principle of EE1

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About this course

EE051IU - Principles of Electrical Engineering I.

This course introduces some main principles in electricity that help students to acquire basic knowledge to continue to upper topics and designed for a 45-contact-hour teaching. In the lectures students study common circuit elements such as resistors, capacitors, inductors, and operational amplifiers, and different circuit analysis methods in DC and AC steady state. It is for students pursuing career in engineering and have had basic knowledge of mathematics and physics.

About this course (cont.)

This course comprises 7 lessons:

- Lesson 1 introduces the basic concepts in electricity and covers the characteristics of resistor.
- Lesson 2 presents basic methods of analyzing resistive circuits.
- Lesson 3 presents standardized methods for systematically analyzing circuits of common features.
- Lesson 4 presents the basic concepts and applications of the operational amplifier.
- Lesson 5 covers the characteristics of capacitors.
- Lesson 6 covers the characteristics of inductor.
- Lesson 7 presents AC circuits from basic concepts to how to analyze them based on the knowledge of the DC circuits above.

Principle of EE1

Lesson 1

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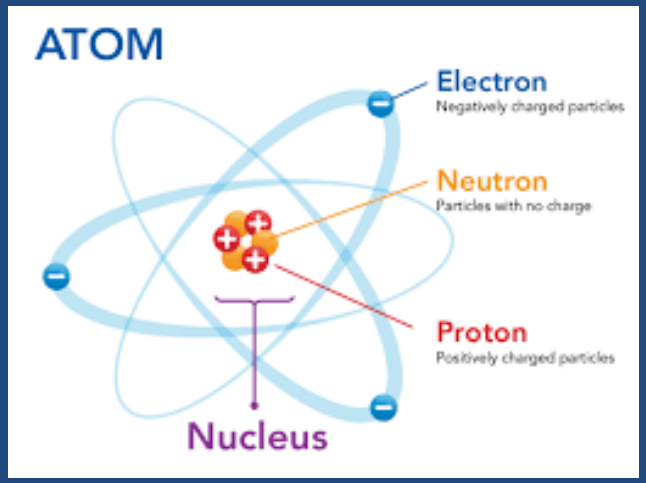
Contents

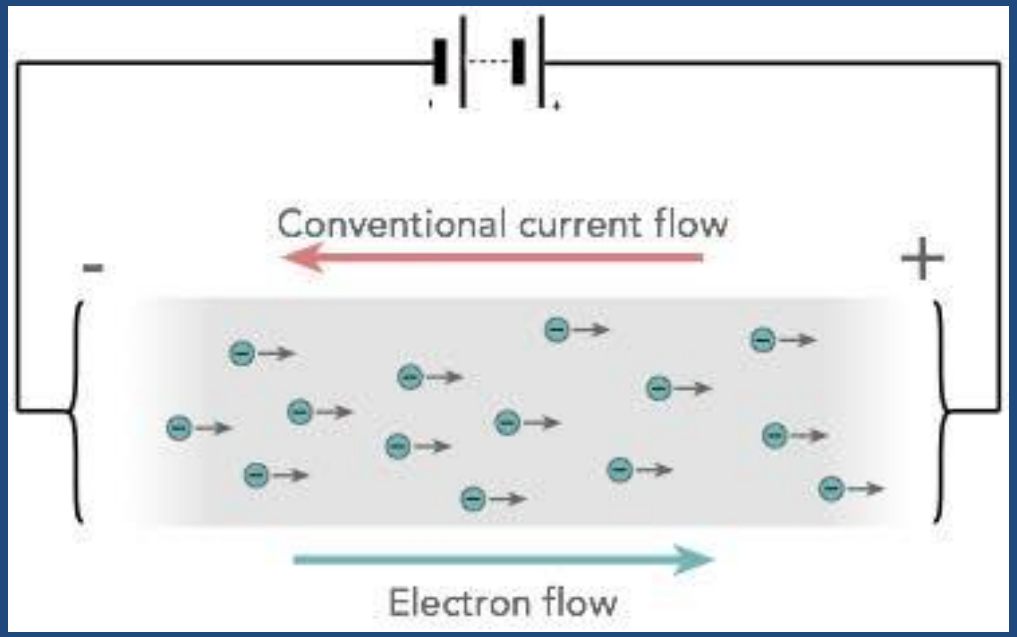
- Fundamental notions
  - Electrons and Electricity
  - Voltage and Current
  - Source and Load
  - Connections: Series, Parallel, Arbitrary
  - Switch
  - Measurement instruments
  - Modelling and simulation
  - Danger of electricity
- Basic definitions
- Resistor / resistance and Ohm’s law.

Fundamental notions

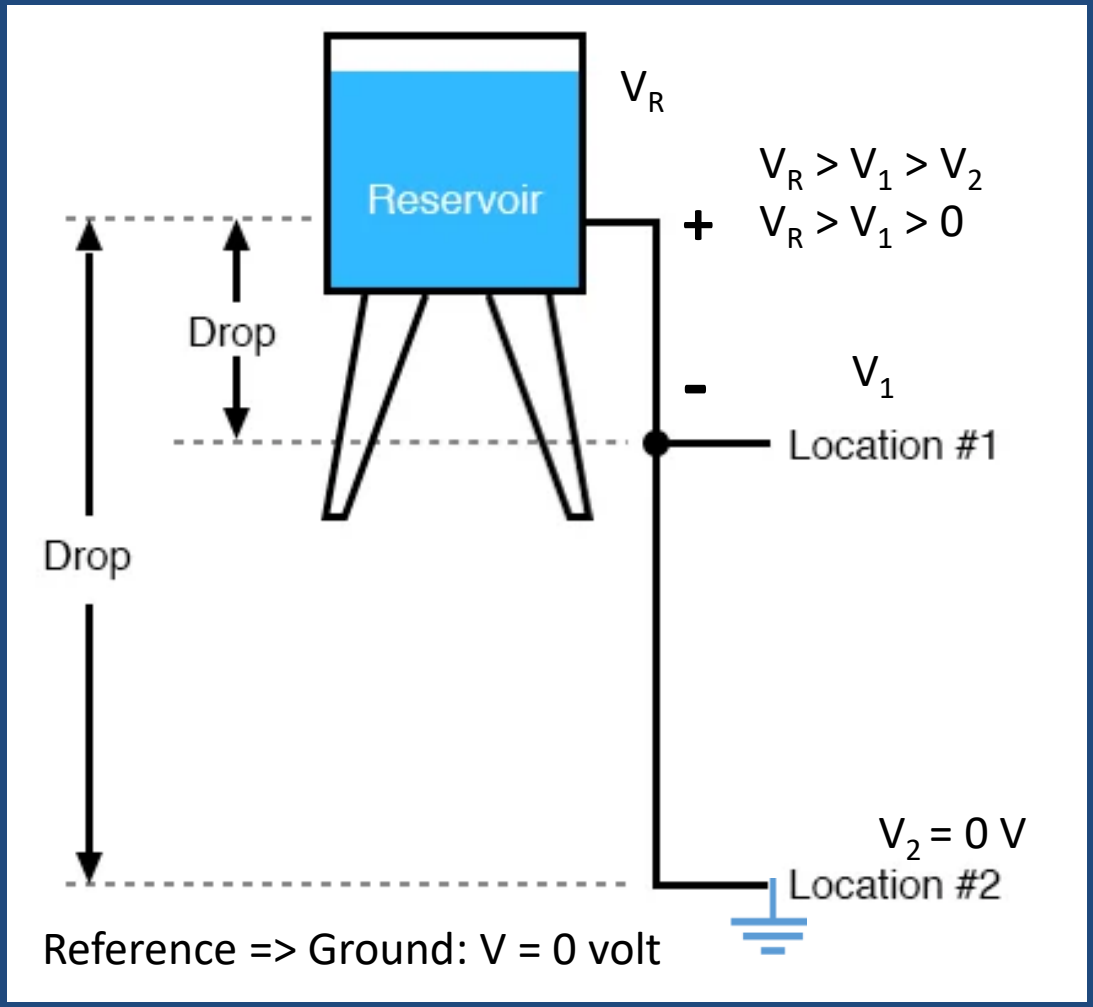
Electrons and electricity



Charge of one electron: - 1.6×10^{-19} coulombs
1 Coulomb is the charge of 6.2×10^{18} electrons

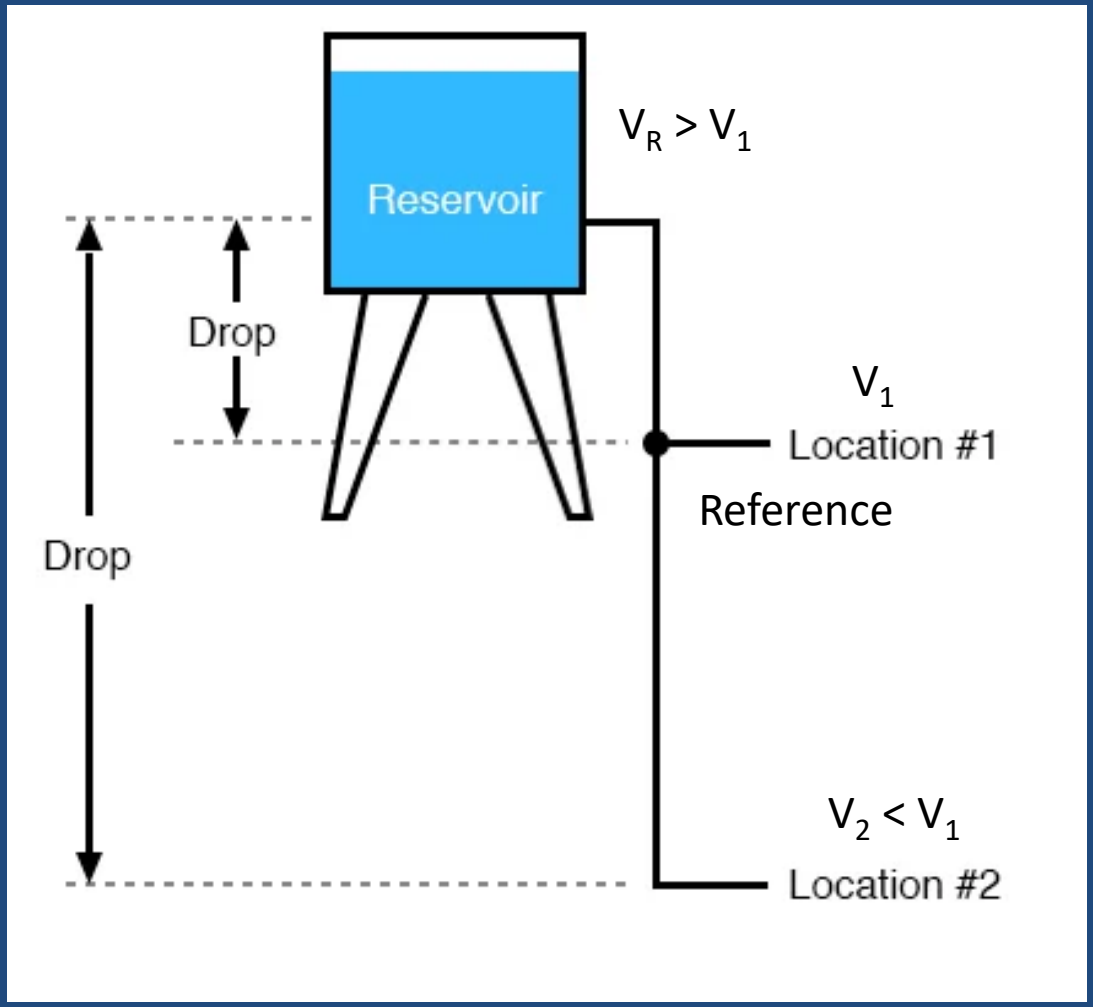


Notion of electrical voltage

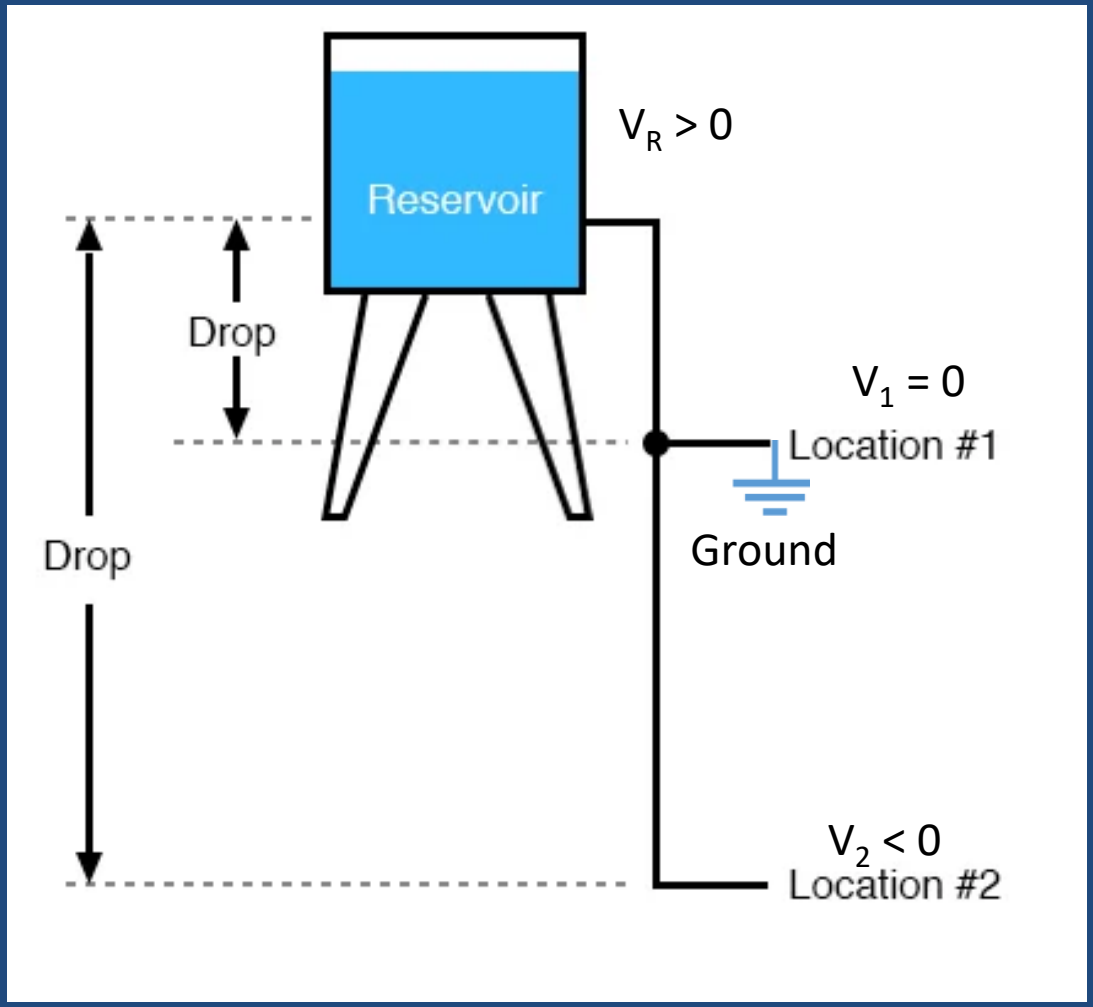


Note:
The higher voltage is +
the lower voltage is –

Notion of electrical voltage (cont.)

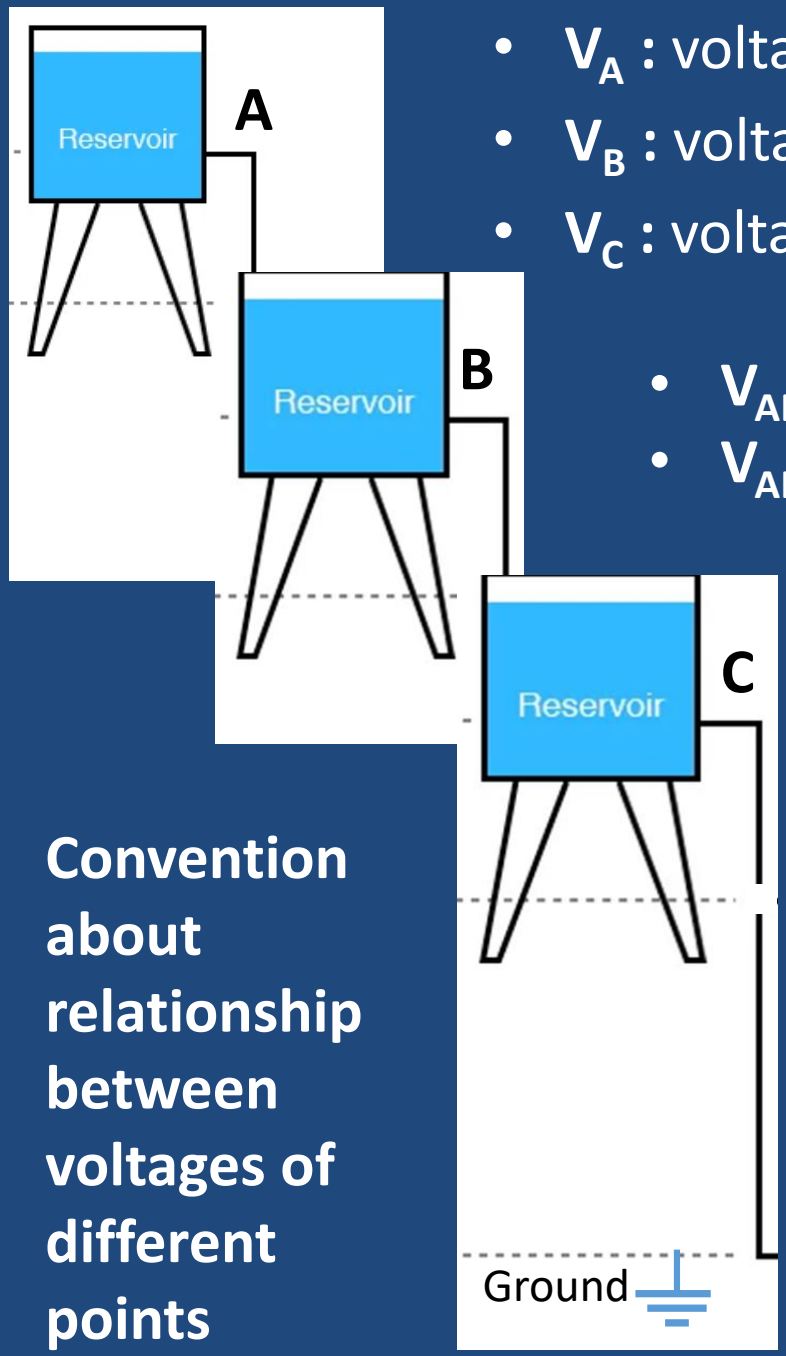


Notion of electrical voltage (cont.)



Notes:

- We can take any point as a reference; its voltage is not necessarily = 0
- When the reference is a ground; V = 0 Volt
- V can be > 0 or < 0



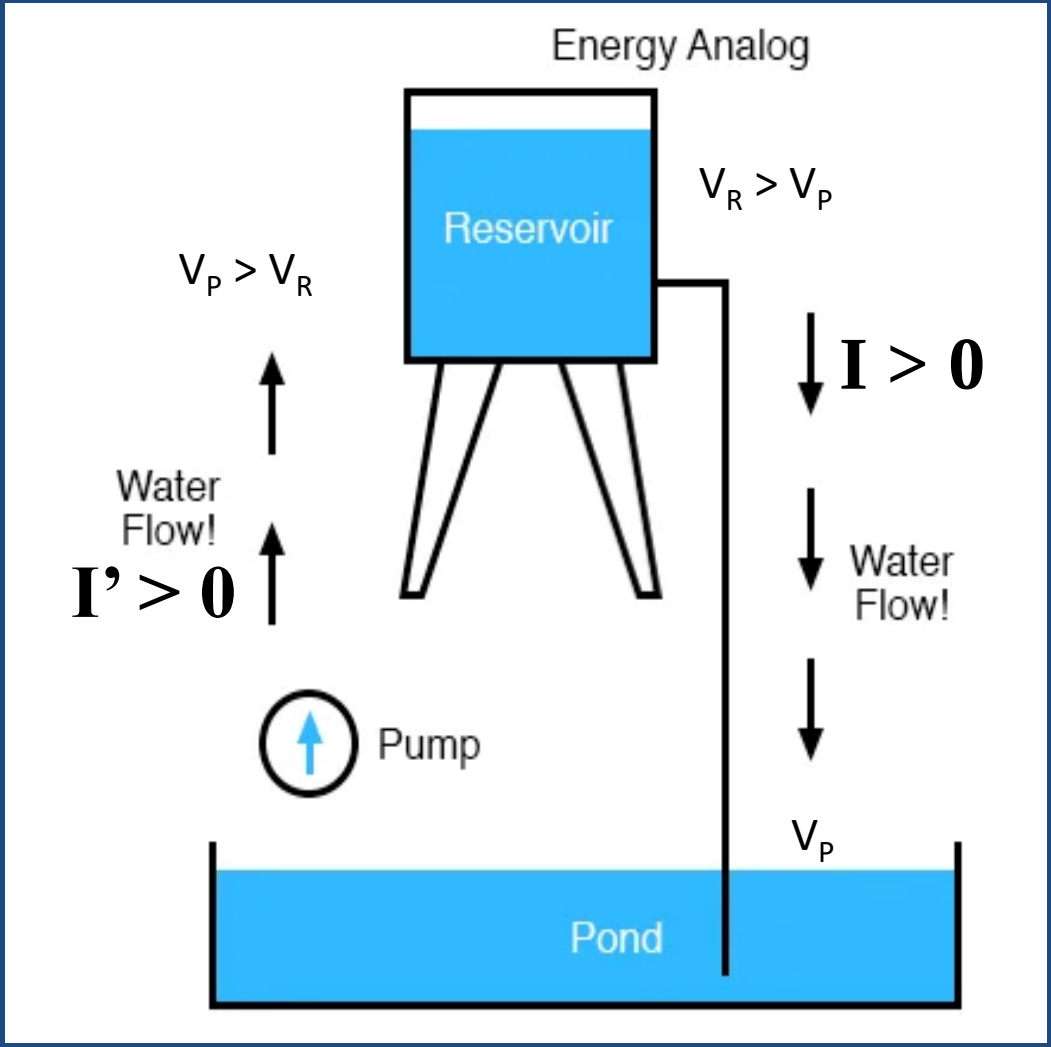
- V_A : voltage of point A with respect to the ground
- V_B : voltage of point B w/r to the ground
- V_C : voltage of point C w/r to the ground

- V_{AB}: voltage of point A w/r to point B
- $V_{AB} = V_A - V_B$

Convention about relationship between voltages of different points

- When we write V_{AB} we mean $V_A > V_B$
  - If it's true => $V_{AB} > 0$ => If $V_A > V_B$ then $V_{AB} > 0$
  - If it's false => $V_{AB} < 0$ i.e., $V_A < V_B$ => $V_{BA} > 0$ => $V_{BA} = -V_{AB}$
- $V_{AC} = V_{AB} + V_{BC}$ (1)
- $V_{AC} = V_{AB} - V_{CB}$ (2)
- In (1) B is an intermediate point
- In (2) B is a reference point

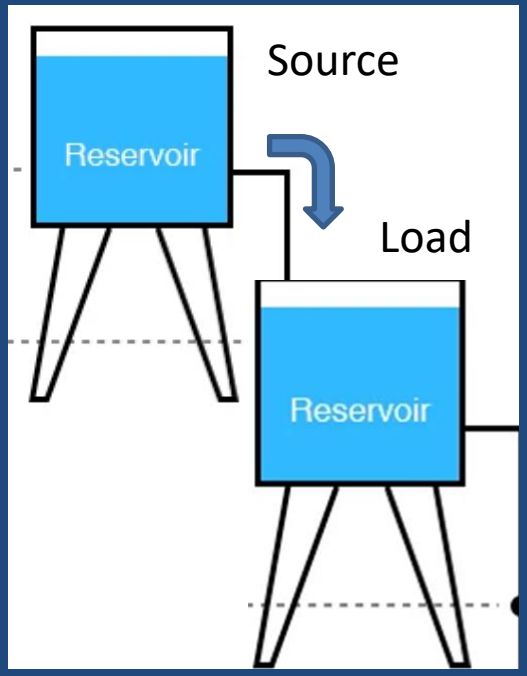
Notion of electrical current



Notes:

1. Voltage value (polarity) ⟺ Current direction
2. If we take direction of I as reference => I'< 0
   i.e., I can be > 0 or < 0

Source and Load

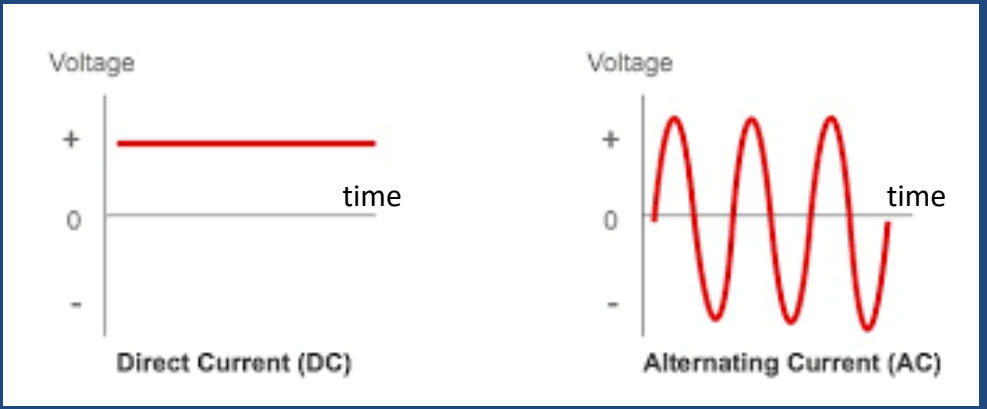


- Source: element that generates energy => active element

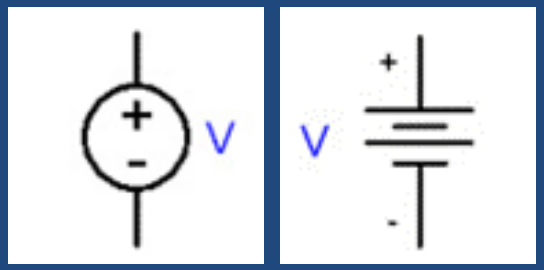
- Load: element that receives energy => passive element

Sources

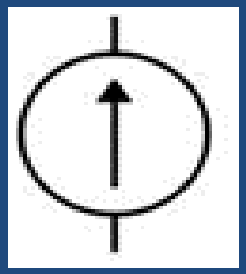
- DC versus AC sources



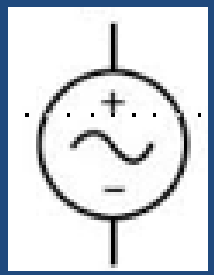
- Voltage source: always gives a <u>constant voltage</u>
- Current source: always gives a <u>constant current</u>



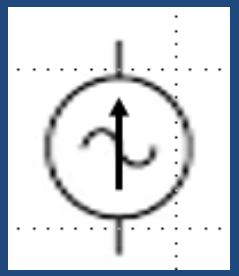
DC voltage source



DC current source

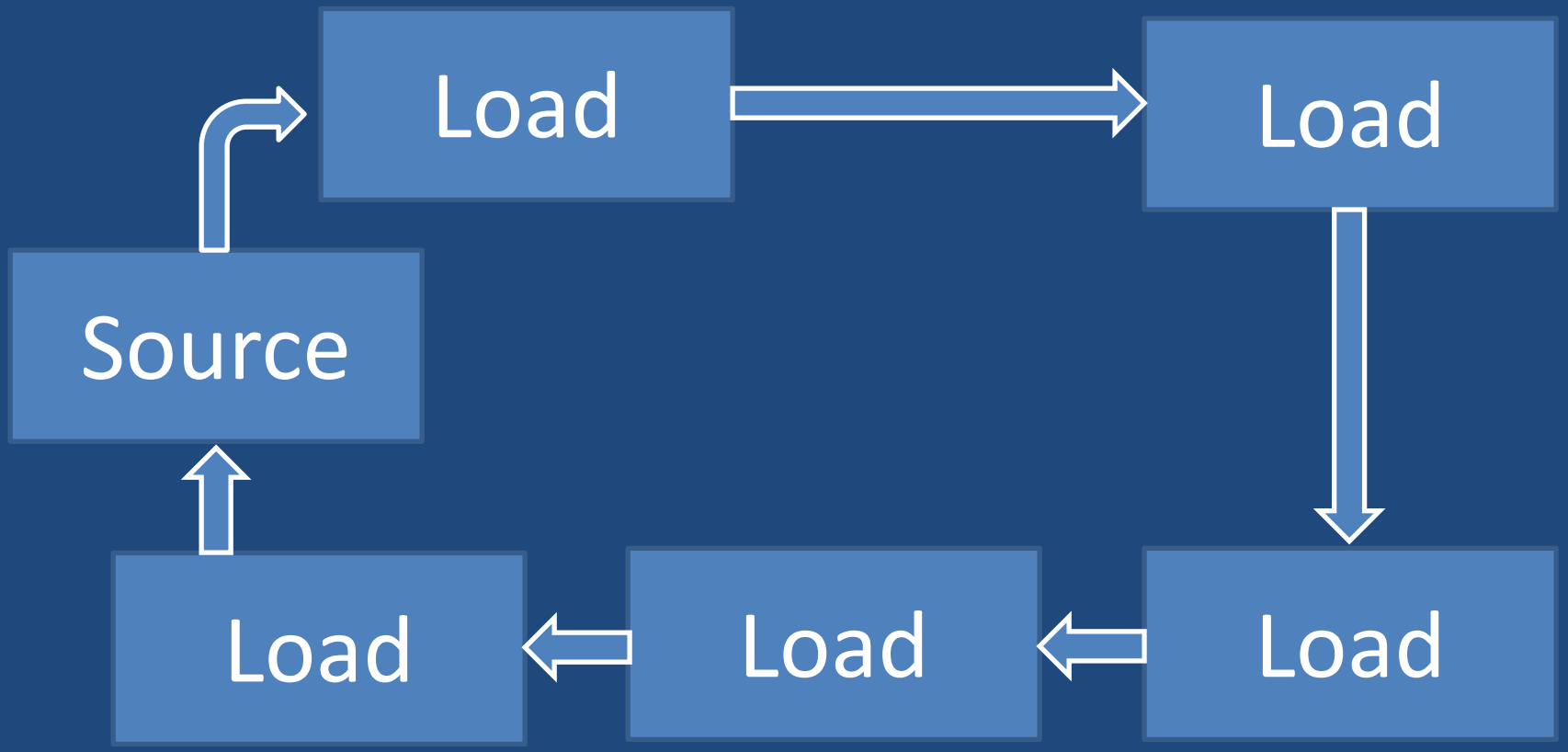


AC voltage source



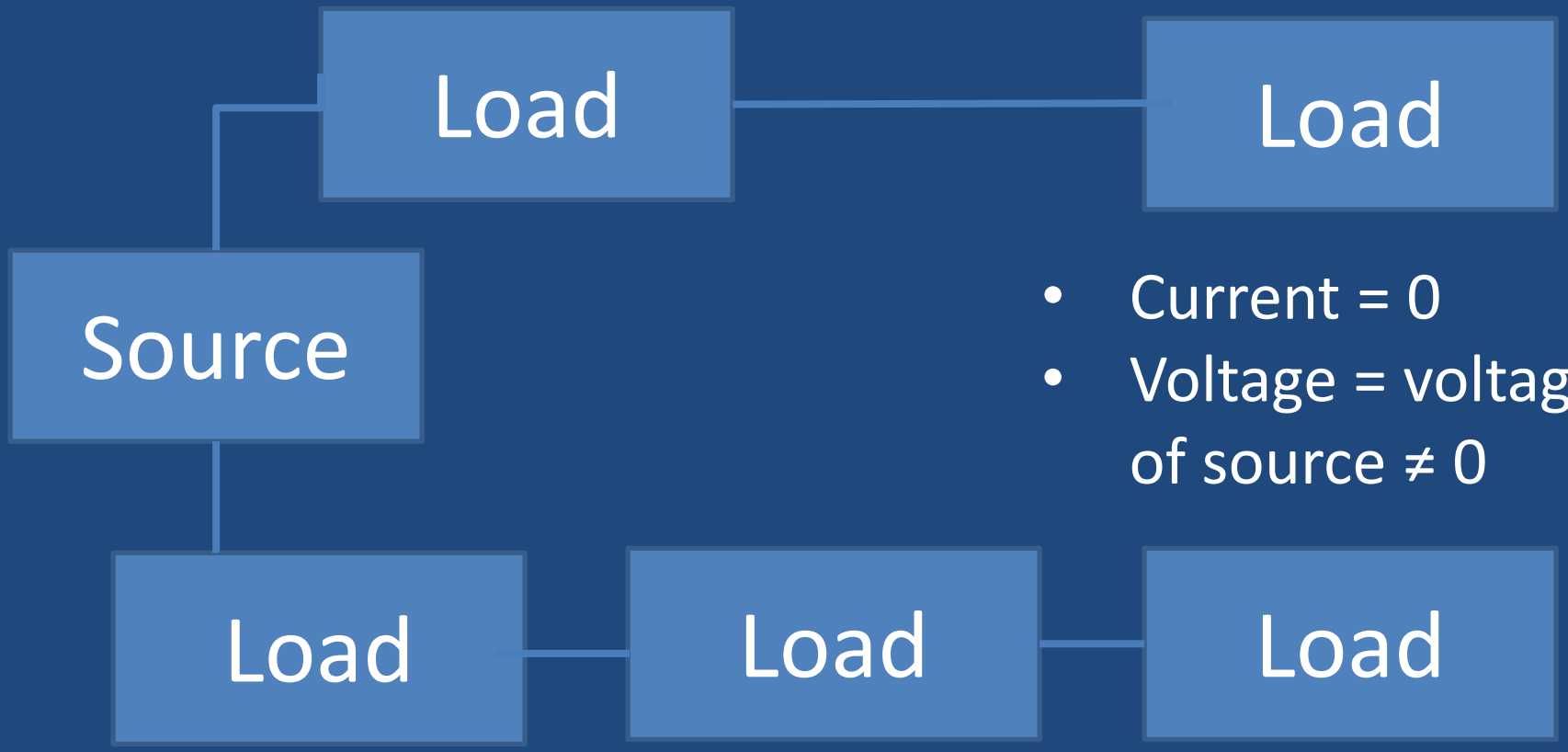
AC current source

Electrical circuit



Closed circuit => current ≠ 0

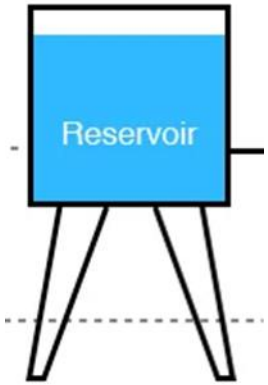
Electrical circuit



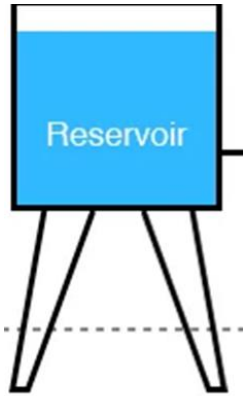
- Current = 0
- Voltage = voltage of source ≠ 0

Open circuit

Electrical circuit



No flow.
Reservoir still has water



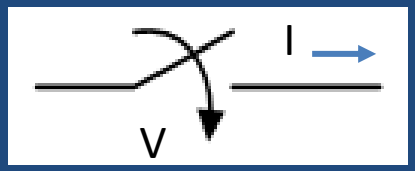
Load

- Current = 0
- Voltage = voltage of source ≠ 0

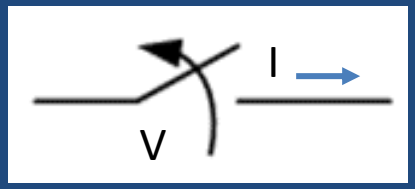
Load

Switch (circuit interrupter, breaker)

- Switch closed
  - V = 0
  - I ≠ 0

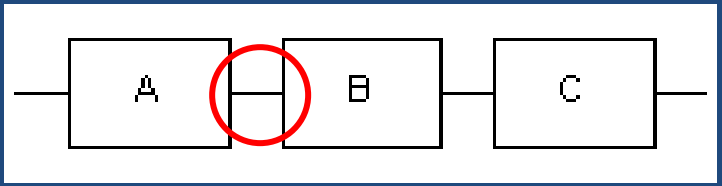


- Switch open
  - V ≠ 0
  - I =0

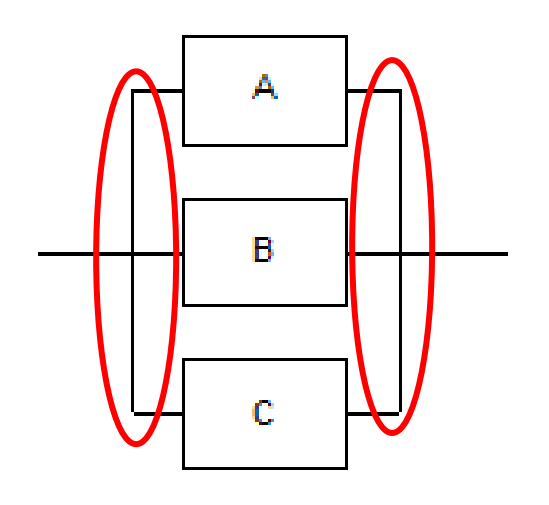


Connection of elements in a circuit

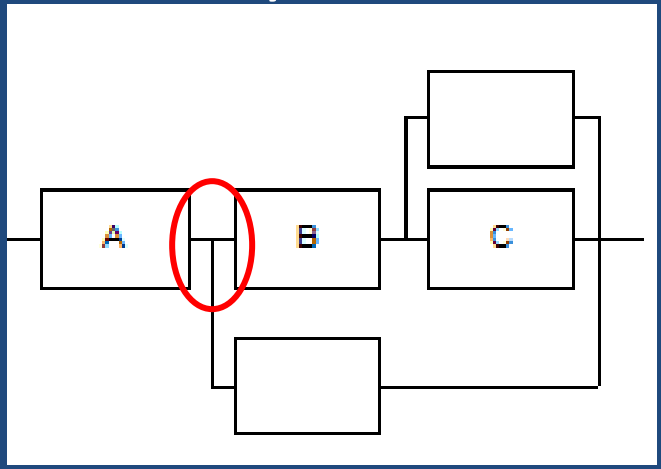
- Connection in series

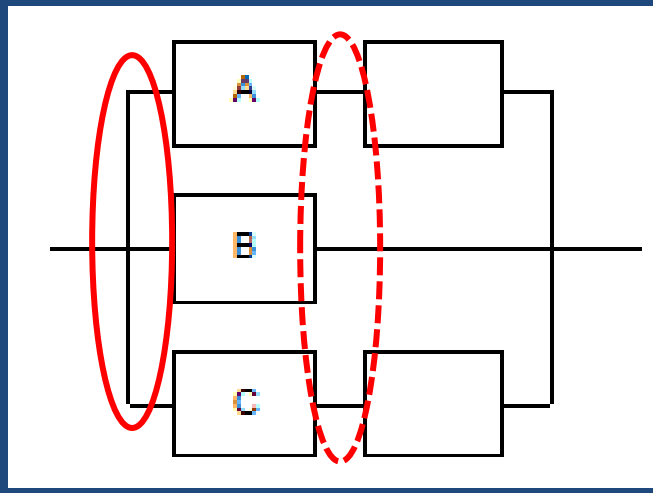


- Connection in parallel



- Arbitrary connection



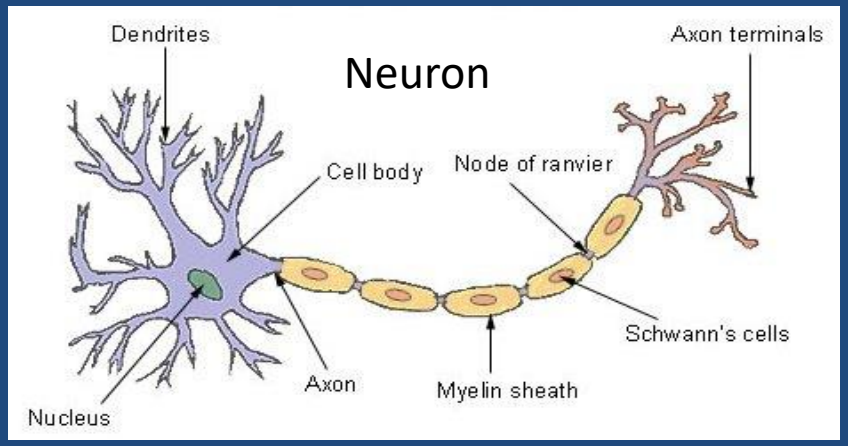


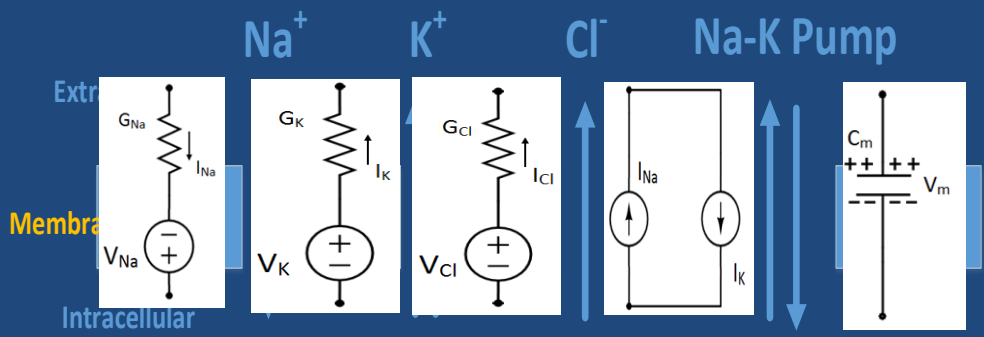
Basic electrical devices

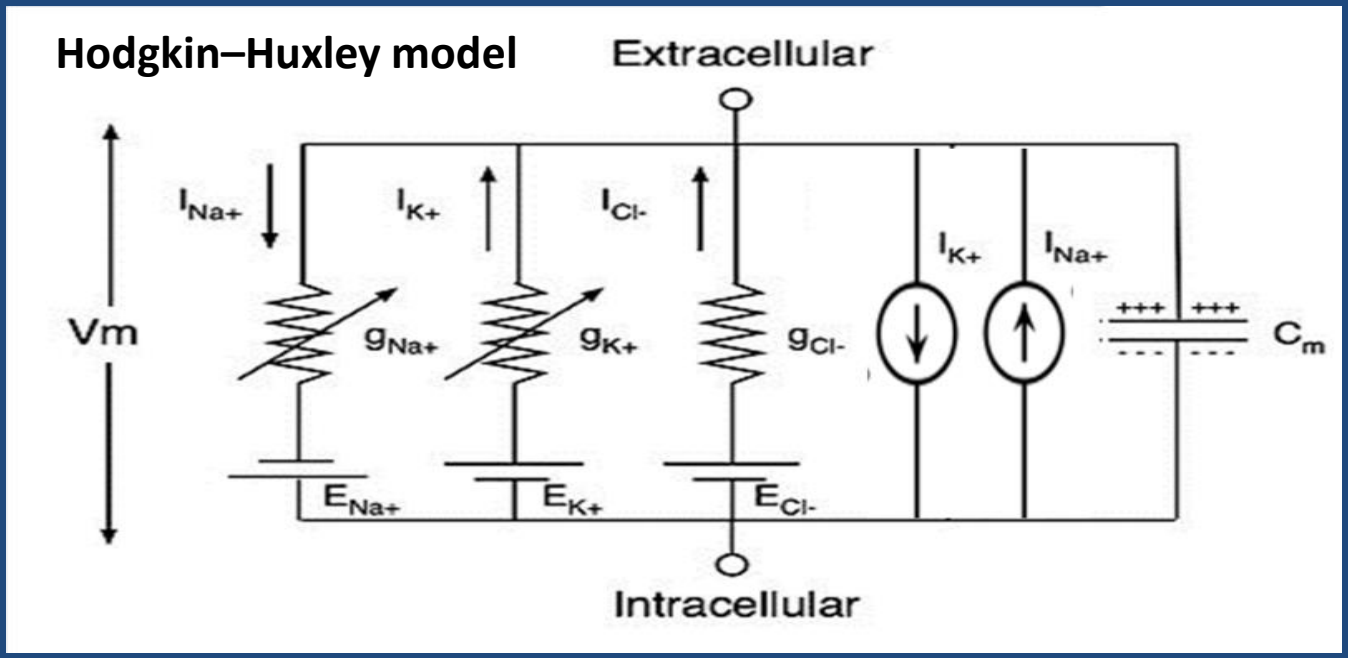
- Power supply

- Digital Multimeter

Modelling and simulation







Hodgkin-Huxley equation (Mathematical Model)

$$C_m \frac{dV_m}{dt} + \frac{E_K - V_m}{R_K} + \frac{E_{Cl} - V_m}{R_{Cl}} + I_{Na} = \frac{E_{Na} + V_m}{R_{Na}} + I_K$$

Where:

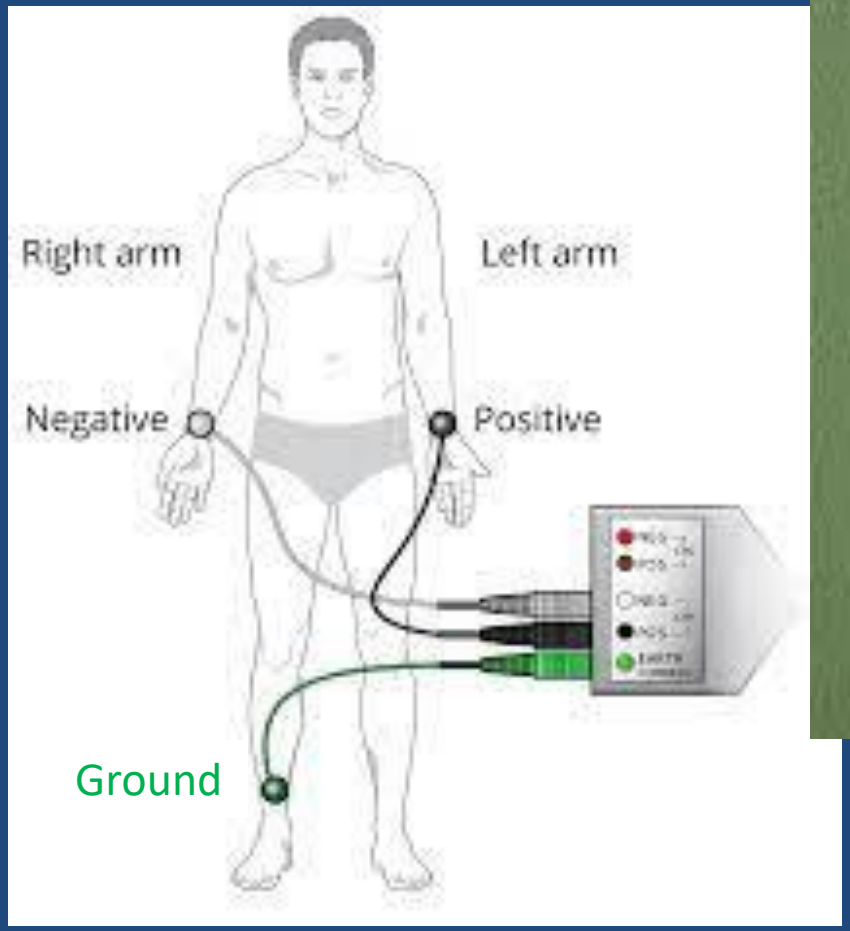
- E_{Na}, E_K, E_{Cl} : Nernst potential of Na+, K+ and Cl- channels
- R_{Na}, R_K, R_{Cl}: Resistance which represents the permeability of each corresponding channels
- I_{Na}, I_K : NA-K pump currents
- C_m: membrane capacitance.

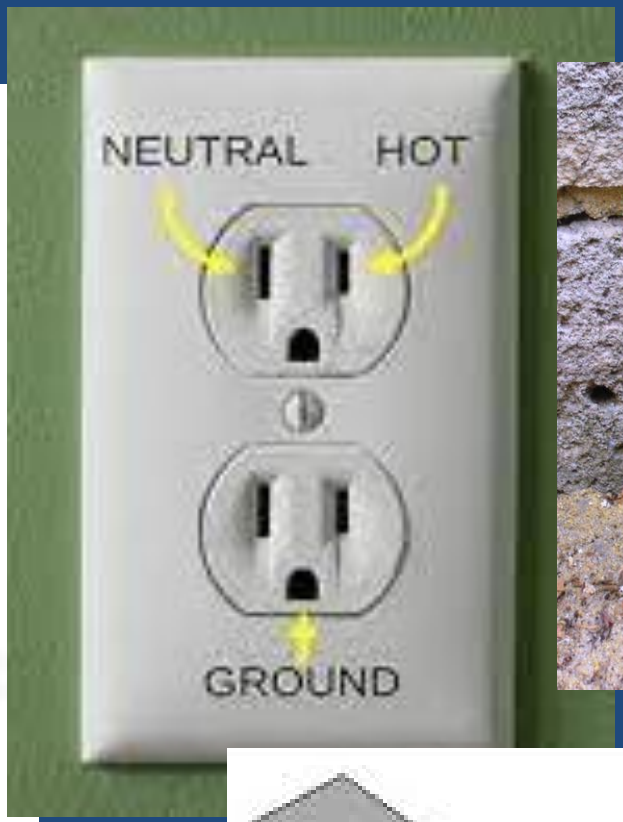
Danger of electricity

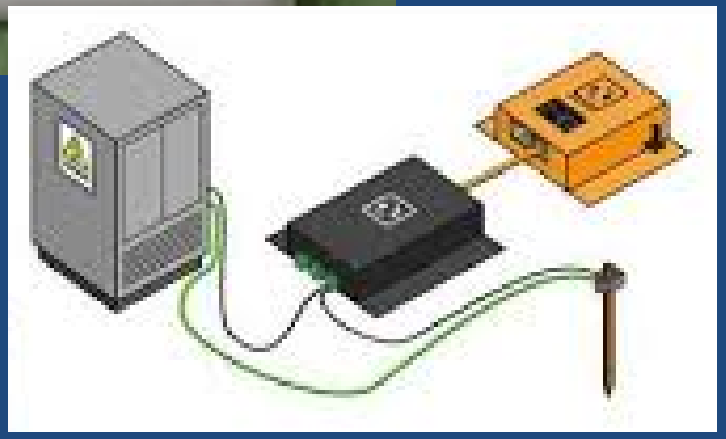
- The level of voltage
- The amount of body resistance you have to the current flow
- The path the current takes through your body
- The length of time the current flows through your body

Electric Current (1 second contact)	Physiological Effect
1 mA	Threshold of feeling, tingling sensation.
5 mA	Accepted as maximum harmless current
10-20 mA	Beginning of sustained muscular contraction ("Can't let go" current.)
100-300 mA	Ventricular fibrillation, fatal if continued. Respiratory function continues.
6 A	Sustained ventricular contraction followed by normal heart rhythm. (defibrillation). Temporary respiratory paralysis and possibly burns.

Important role of the ground







BASIC DEFINITION

and formula

Electric current

Definition: current is the rate of charge

$$i = \frac{\mathrm{d}q}{\mathrm{d}t}$$

$$\mathrm{I} = \frac{Q}{t}$$

- I: Current, unit: Ampere [A]
- Q: Charge, unit: Coulomb [C]
- t: time, unit: second [s].

Note: What is Ah? (is another unit of charge)

Q = I t (to calculate lifetime of a battery)

Ah A h

Voltage

Definition: voltage is energy per charge

$$\mathrm{v} = \frac{dw}{dq}$$

$$\mathrm{V} = \frac{W}{Q}$$

- V: voltage, unit: Volt [V]
- W: Energy, unit: Joule [J]
- Q: Charge, unit: Coulomb [C]

Power

Definition: power is the rate of energy

$$P = \frac{W}{t}$$

- P: power, unit: Watt [W]
- W: energy, unit: Joule [J]
- t: time, unit: second [s].

Notes:

- What is KWh? $W = P\,t$: Energy consumed
  KWh KW hour

- What is horsepower? hp = 746 W [E Unit] or 735.5 W [SI Unit]: is another unit of power

Efficiency

Power in = Power out + Power lost

Definition: Efficiency is the ratio of power out/power in

$$\eta\ [\%] = \frac{Power\ out}{Power\ in}\ X\ 100$$

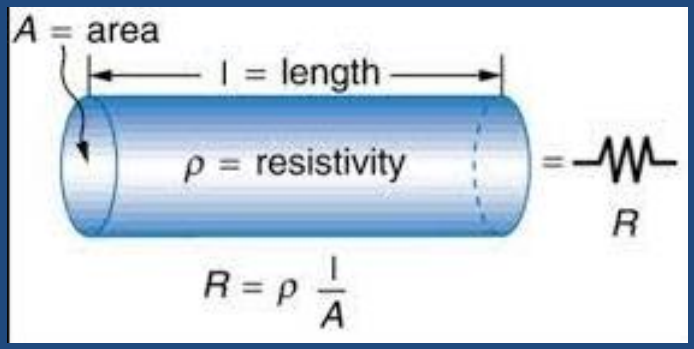
RESISTANCE AND RESISTOR

Fundamental Notions

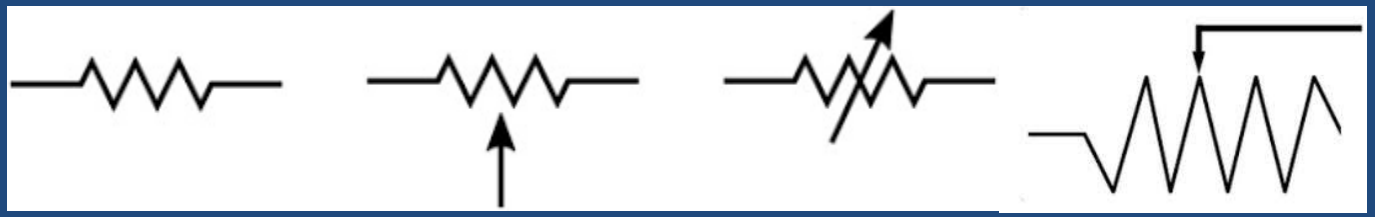
- **Resistance** of an object is a measure of its opposition to the flow of electrons i.e., current
- Resistance is measured in ohms, symbolized by the Greek letter omega (Ω).
- **Conductance** represents a material's ability to conduct electric current.
- $G = \frac{1}{R}$
- Unit of G is Mho or Ω^{-1} or ℧ or Siemens

Resistor

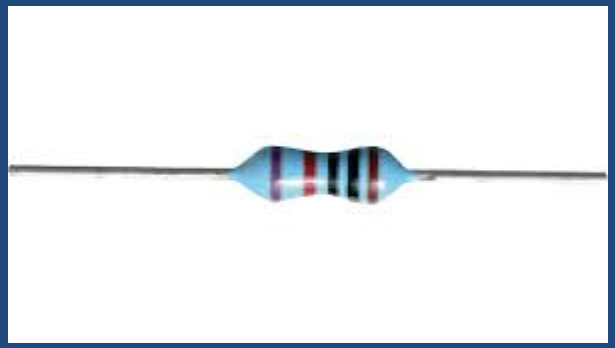
- Resistor is a device which has a specific resistance value.
- One of its roles is to limit the current in a circuit.
- Value: $R = \rho \frac{l}{A}$
  - R: Resistance, unit: Ohm [Ω]
  - ρ: Resistivity, unit: [Ωm]
  - l: Length of the material, unit: [m]
  - A: Surface area, unit: [m^2].

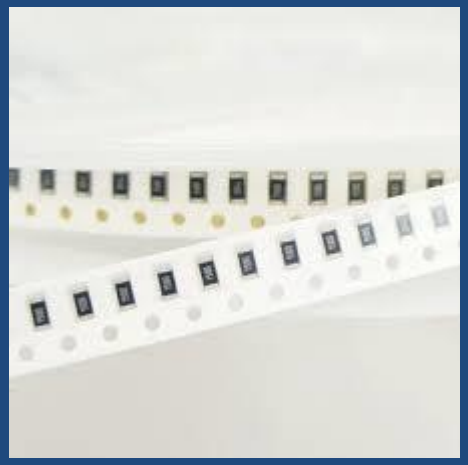


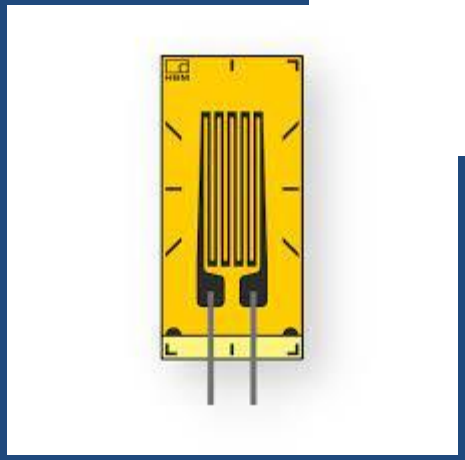
- Symbol:



Resistors

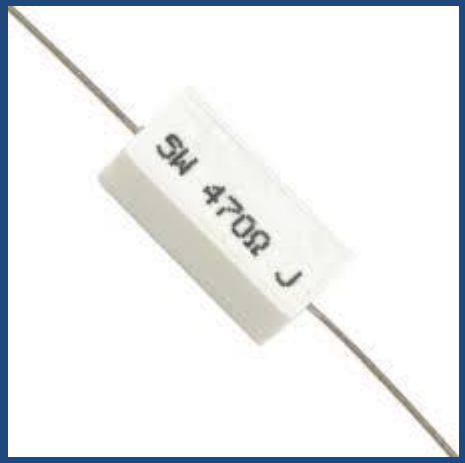


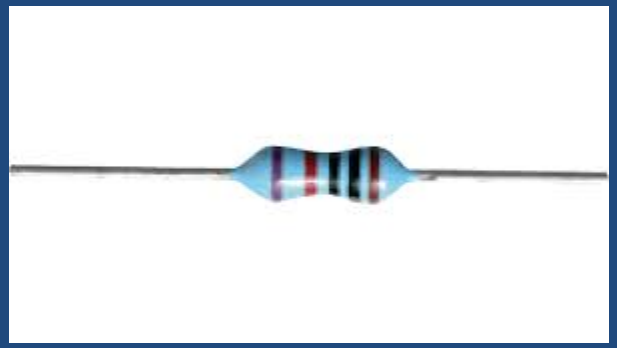




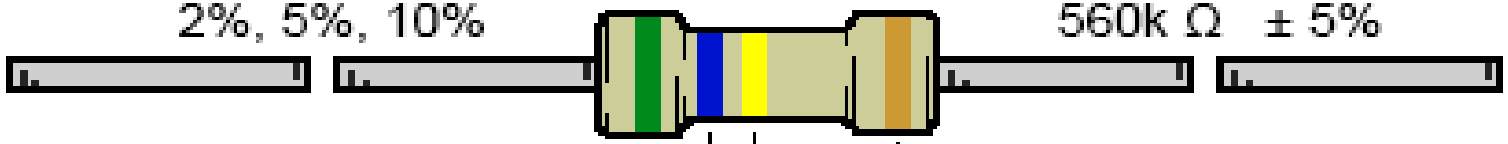
Resistors

Color coding

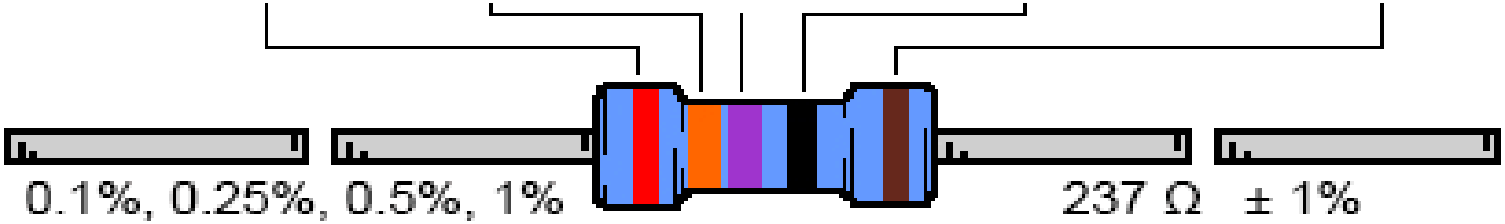




4-Band-Code

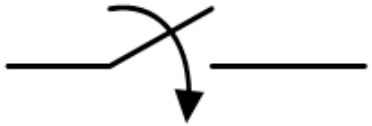


COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8	100MΩ	± 0.05%
White	9	9	9	1GΩ	
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)



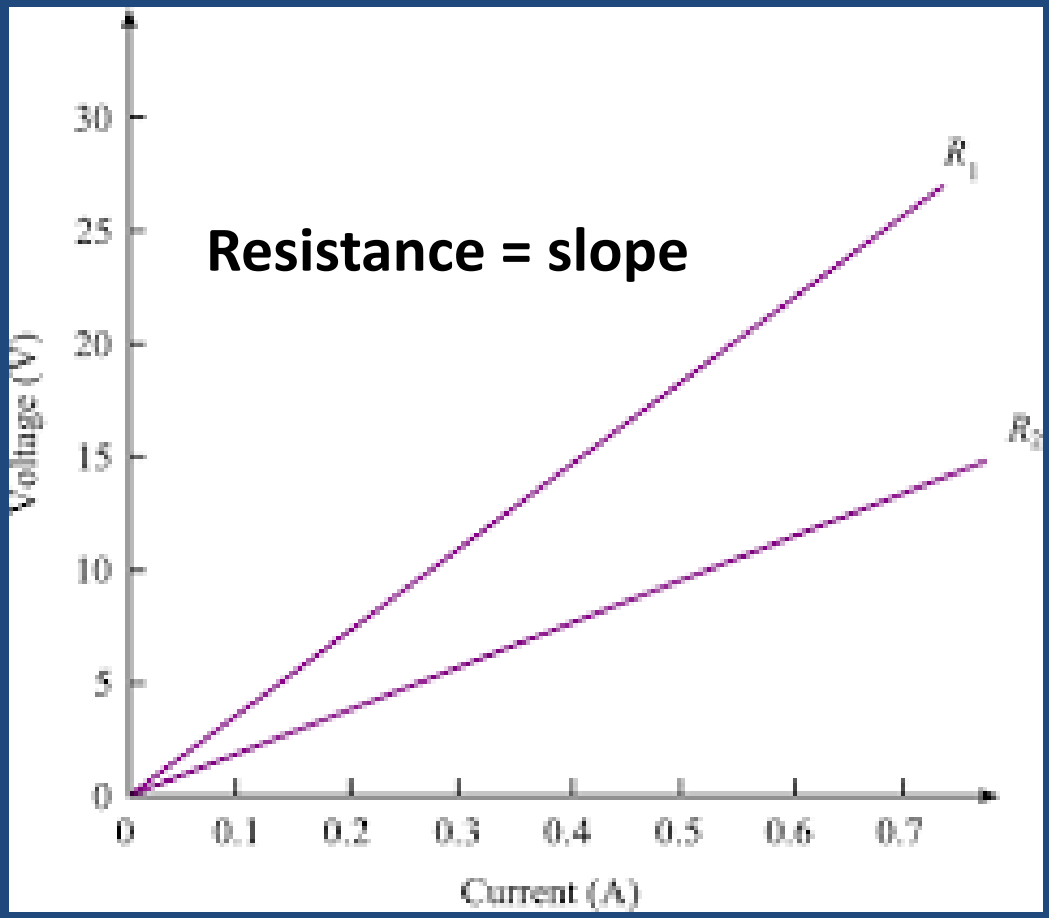
5-Band-Code

Switch and resistance

	
$V = 0$	$V \neq 0$
$I = \max$	$I = 0$
$R = 0$	$R \to \infty$

Ohm's law

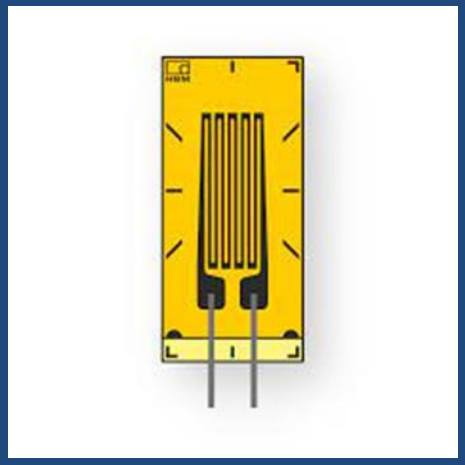
- $V = RI$


Resistance = slope
30
25
20
15
10
5
0
Voltage (V)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Current (A)
R_1
R_2

Other factors influencing the resistance

I. Temperature
II. Intensity of light
III. Pressure, Force,
IV. Humidity, …

=> Use resistor as sensor



Strain gauge

Resistive sensors

Power dissipated

- $P = \frac{W}{t}$
- $V = \frac{W}{Q}$
- $I = \frac{Q}{t}$

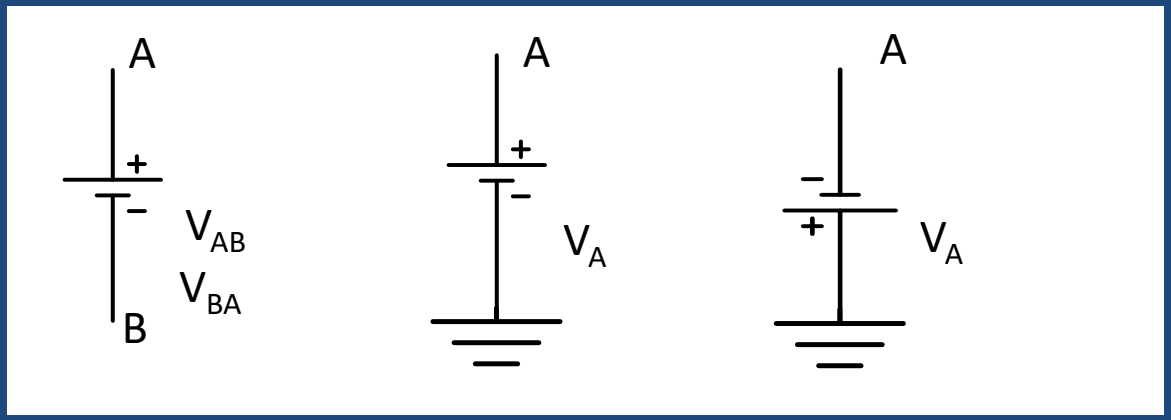
$\Big\}$ $P = VI$

- $V = RI \Rightarrow P = RI^2 = \frac{V^2}{R}$
- Internal Resistance
- Fuse / circuit breaker

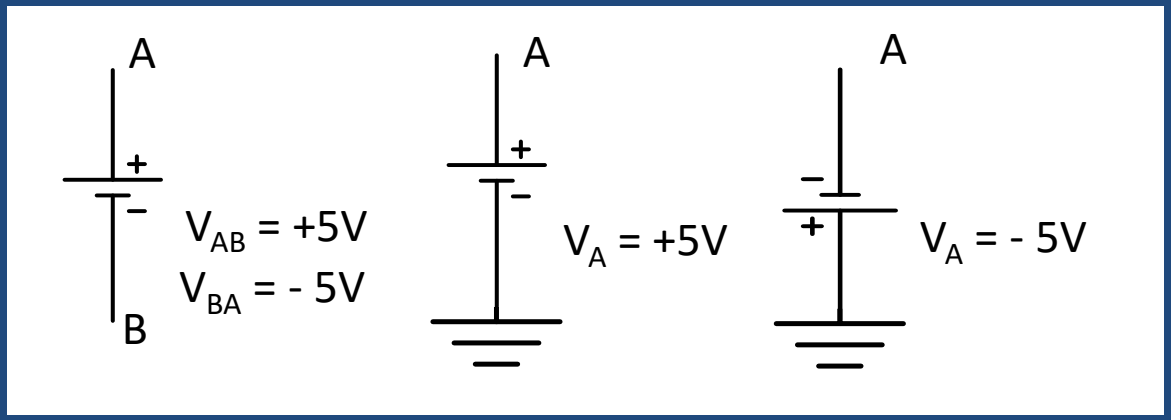
Examples

Example 1

- In the following features the voltage source is 5V. Indicate the values of V_{AB}, V_{BA}, V_A in each case whenever applied.



- Solution



Example 2

A battery is rated at 80Ah, its lifetime is 20h, its voltage is 6V. What are the current, power and total energy stored?

Given:

- Q = 80Ah
- V = 6V
- t = 20 h

Solution:

- I = Q/t = 80/20 = 4A
- P = VI = 6X4 = 24W
- W = Pt = 24X20X3,600 = 1.73×10^{6} J
- W = 24.10^{-3} X 20 = 0.48 KWh

Example 3

A charge of 30 C passes through an element in 6 sec, its voltage is 12 V, power rated is 40W. Find input power and efficiency

Given:

- Q = 30 C
- t = 6 sec
- V = 12 V
- P_{out} = 40 W
- Input power P_{in} and efficiency η

Solution:

- P_{in} = VI
- I = Q/t
- => P_{in} = V Q / t = 12 x 30 / 6 = 60W
- $\eta = P_{out}/P_{in}$ = 40/60 = 0.67 or 67%

Example 4

A radio functions under 220V, drawn a current of 1A and gave a power of 60W. Find Power absorbed: P_{in}, Power lost: P_{lost}, Internal resistance: R_{int}

Given:

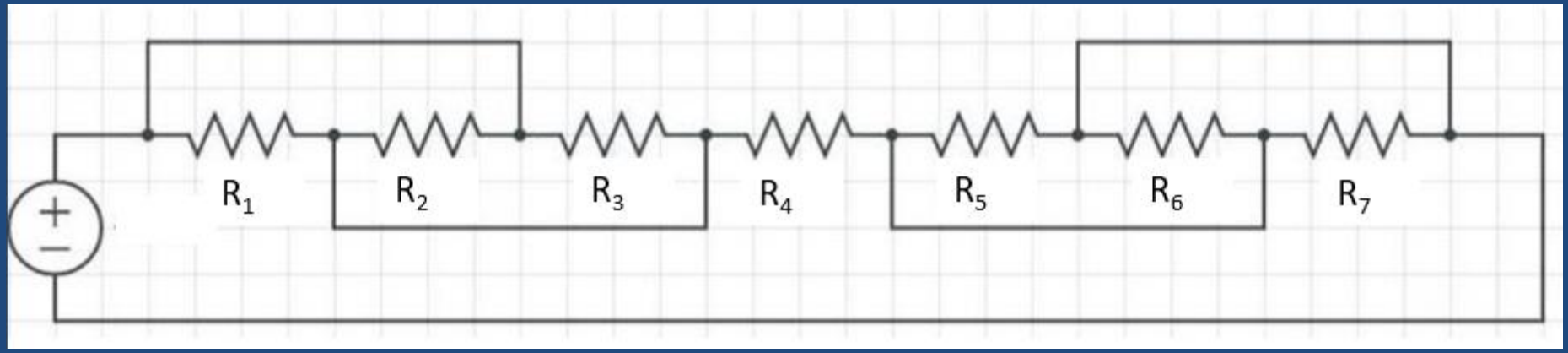
- V = 220V
- I = 1A
- P_{out} = 60W

Solution:

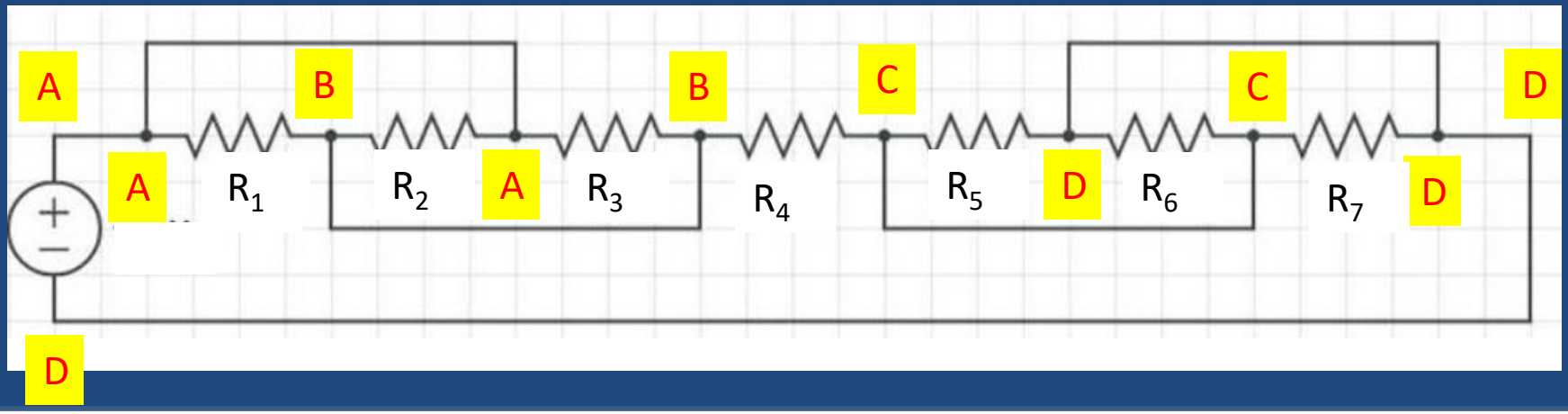
- $P_{in} = VI = 220 \text{ X } 1 = 220W$
- $P_{lost} = P_{in} - P_{out} = 220 - 60 = 160 \text{ W}$
- $P_{lost} = R_{int} I^2 \Rightarrow R_{int} = 160/1 = 160 \Omega$

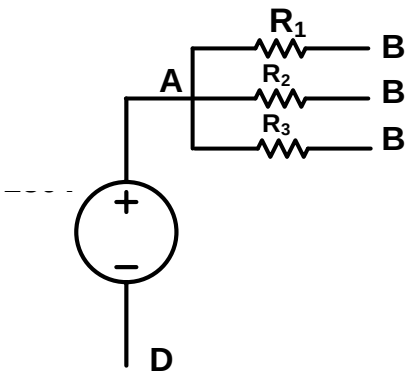
Example 5

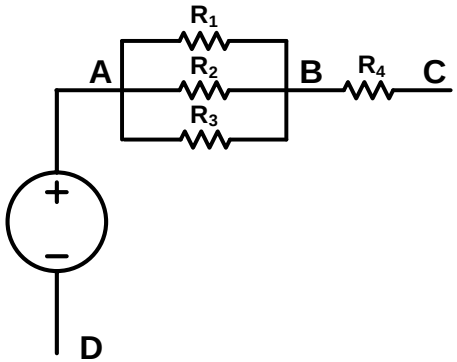
In the following circuit, rearrange the resistors in series and parallel connections

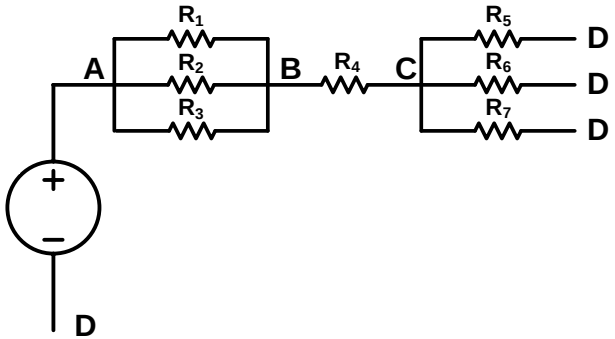


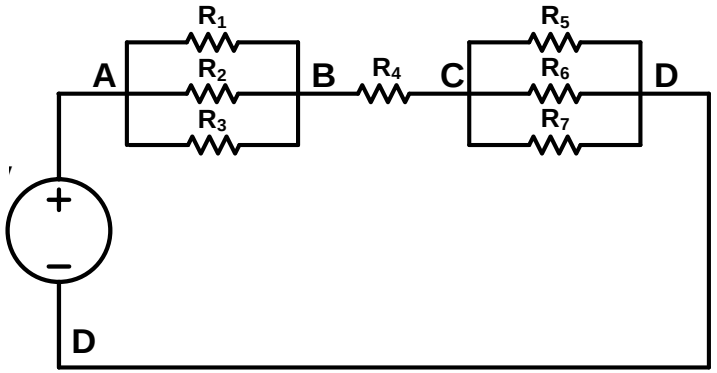
Solution


A
B
B
C
C
D
A
R1
R2
A
R3
R4
R5
D
R6
R7
D
D


R1
A
R2
R3
B
B
B
D


R1
A
R2
R3
B
R4
C
D


R1
A
R2
R3
B
R4
C
R5
R6
R7
D
D
D
D


R1
A
R2
R3
B
R4
C
R5
R6
R7
D
D

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