"It ain't what you don't know that gets you into trouble. It is what you know for sure that just ain't so."

Mark Twain

CHAPTER 1 : INTRODUCTION

Circuit : An interconnection of electrical devices

Theory : A set of axioms, definitions, rules, techniques to understand a subject.

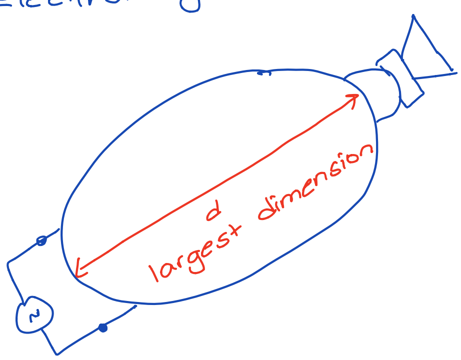
Our Aim : to predict the electical behaviour of electrical systems.

To determine the electrical variables → current, voltage, electrical power, and less importantly charge and flux.

What type of circuits?

Lumped-circuits

Electromagnetic waves travel at the speed of light

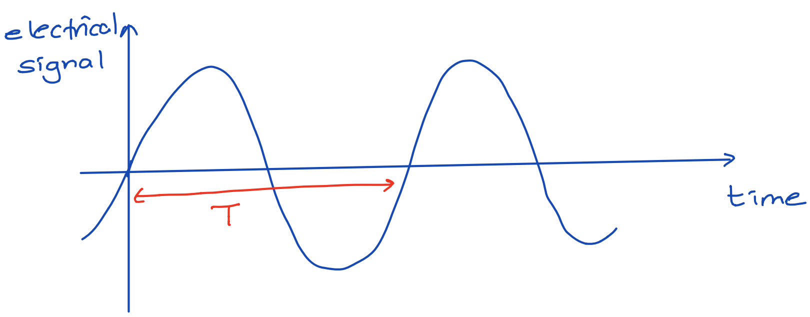


lumped-circuits : propagation delays are not important

$\Rightarrow$ electromagnetic effects occour instantaneously!

Δt : maximum tolerable delay

$$d \ll c \cdot \Delta t$$



$$f = \frac{1}{T}$$

$$\Delta t \ll T$$

$$d \ll cT = \frac{c}{f} = \lambda \text{ (wavelength)}$$

$$\boxed{d \ll \lambda}$$

In case signal contain many frequencies, choose the largest frequency $\Rightarrow$ smallest wavelength :

$$d << \frac{c}{f_{max}} = \lambda_{min}$$

* For audio circuits :

$$f_{max} = 20 \text{ kHz} \quad \Rightarrow \quad \lambda = \frac{c}{f} \simeq 15 \text{ km}$$

* Other cases :

$$f_{max} = 20 \text{ MHz} \quad \Rightarrow \quad \lambda = 15 \text{ m}$$

$$f_{max} = 20 \text{ GHz} \quad \Rightarrow \quad \lambda = 15 \text{ mm}$$

<u>Current</u> : rate of change of the electrical charge passing through a cross-section in a part of circuit.

$$i = \frac{dq}{dt} \quad \text{in Amperes (A)} \quad \Rightarrow \quad A = \frac{\text{Charge}}{\text{Time}} = \frac{C}{\text{sec}}$$

<u>Note</u> : curret can be positive or negative

<u>Voltage</u> : potential difference between two points A and B. This is equivalent to the electrical work done by the electrical field to move a unit charge against the electrical field from B to A.

change in energy per unit charge

$$V = \frac{dw}{dq} \quad \text{in Volts (V)} \quad \Rightarrow \quad V = \frac{\text{Joule}}{\text{Coulomb}} = \frac{J}{C}$$

<u>Note</u> : voltage can be positive or negative

<u>Electrical Power</u> : the rate of change of electrical energy with respect to time

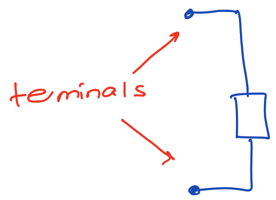
$$P = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = V \cdot i \quad \text{in Watts (W)}$$

$$\Rightarrow \quad W = \text{Volt} \times \text{Amp}$$

<u>Note</u> : power can be positive or negative

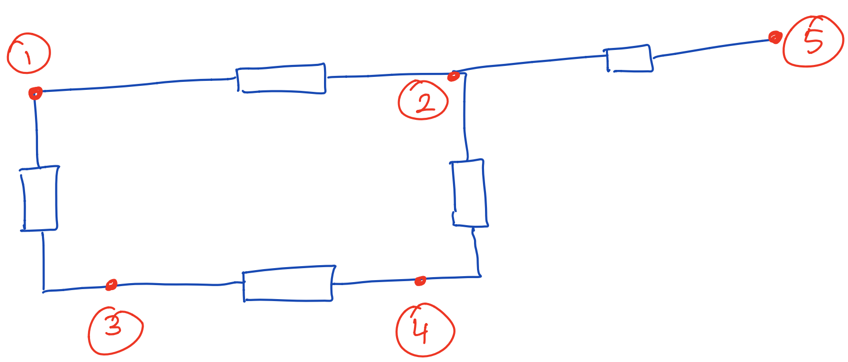
Basic Terminology

Terminals: The joints where devices are accesible from outside. We apply electrical excitations to terminals and measure electrical variables at terminals.



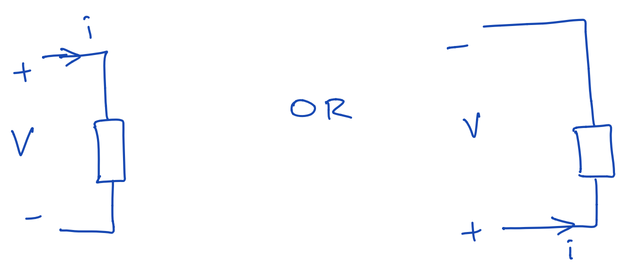
Electrical Circuits: Arbitrary interconnections of electrical devices through their terminals.

Nodes: A junction in the circuit where the terminals are connected together, or any isolated terminal. If two terminals are connected by an electrical wire only, they form a single node.



Connected circuit: Any node can be reached from any other node by traversing a path through circuit elements.

Reference Directions: We will use passive sign convention.
$\Rightarrow$ the current flowing from (+) terminal to the (−) terminal of the device.



* $p = V \cdot i > 0$, means the device is receiving power from the rest of the circuit.

$p = V \cdot i < 0$, means the device is giving power to the rest of the circuit.

Voltage : defined as potential difference between two points. Choose an arbitrary point as the reference point to measure voltages ⟹ called ground point

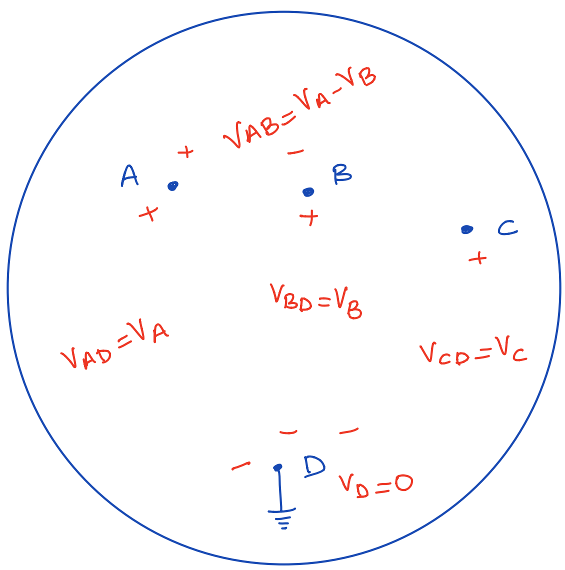
This can be done in any conservative field which has a potential (e.g., gravitation → measure height → reference point → sea level)

We declare the potential of ground point as zero.

Node voltage : the voltage between any node and ground.

Then, we have :

$$V_{AB} = V_{AG} - V_{BG} = V_A - V_B$$

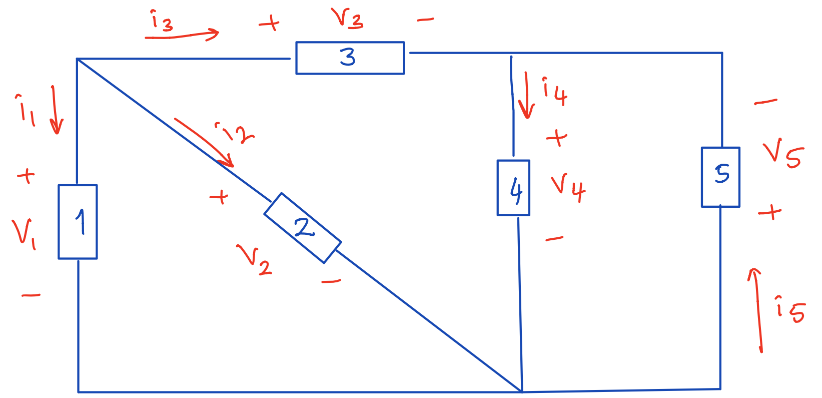


e.g.,

$V_{AB} = 50\ V$ ⟹ point A has 50V more electrical potential than point B

$V_{AB} = -20\ V$ ⟹ point A has 20V less " " than point B

Example :



D_1 : $V_1 = 100\,V$, $P_1 = -1\,W$

D_2 : $i_2 = 5\,mA$, $P_2 = 0.5\,W$

D_3 : $V_3 = 25\,V$, $i_3 = 5\,mA$

D_4 : $V_4 = 75\,V$, $P_4 = 0.75\,W$

D_5 : $V_5 = -75\,V$, $i_5 = 5\,mA$

Are these devices giving or receiving power?

Find the missing variable (i, V, P) for the devices.

* D_1 : $P_1 < 0 \Rightarrow D_1$ is giving power

$$i_1 = \frac{P_1}{V_1} = -10\,mA$$

* D_2 : $P_2 > 0 \Rightarrow D_2$ is receiving power

$$V_2 = \frac{P_2}{i_2} = 100\,V$$

* D_3 : $P_3 = i_3 \cdot V_3 = 0.125\,W > 0 \Rightarrow D_3$ is receiving power

* D_4 : $P_4 > 0 \Rightarrow D_4$ is receiving power

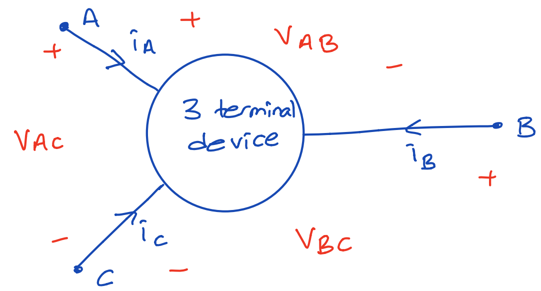
$$i_4 = \frac{P_4}{V_4} = 10\,mA$$

* D_5 : $P_5 = V_5 \cdot i_5 = -375\,mW < 0 \Rightarrow D_5$ is giving power

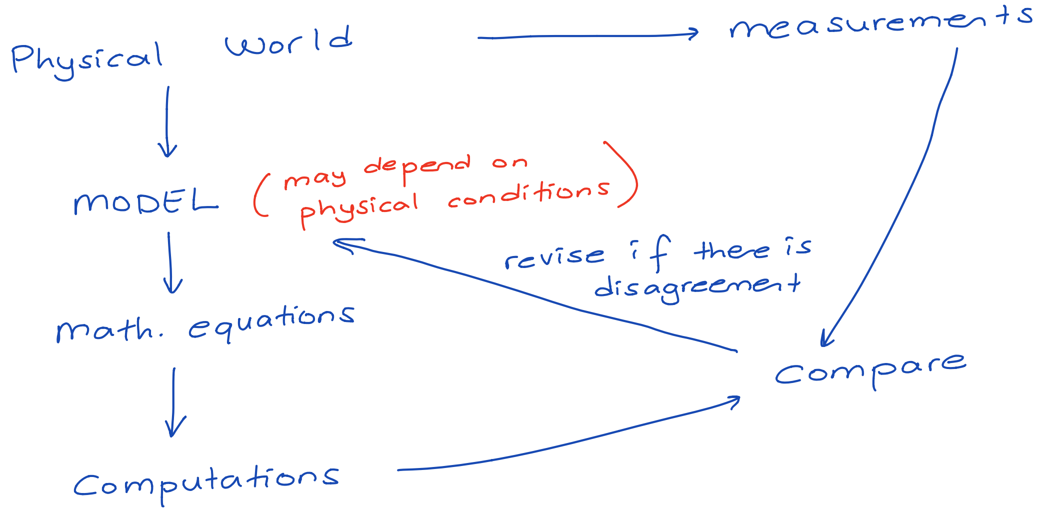
* Note that $P_1 + P_2 + \dots + P_5 = 0 \Rightarrow$ conservation of power

$\Rightarrow$ Tellegen's Theorem

* Note : not all devices have 2 terminals. we have 3 terminal (e.g., transistor), or many terminal (OPAMP, integrated circuits, etc.).



Devices and Models



In Circuit Theory, we are interested in:

- the electrical behaviour of circuits, i.e., voltages, currents, electrical power
- external behaviour of devices (i.e., measured through terminals)
- not the internal behaviour of the device