FUNDAMENTALS OF ELECTRIC CIRCUITS
Part 1: DC CIRCUITS

Chapter 1: Basic concepts

I. Introduction.

II. Systems of units.

III. Charge and current.

IV. Voltage.

V. Power and Energy.

VI. Circuit elements.

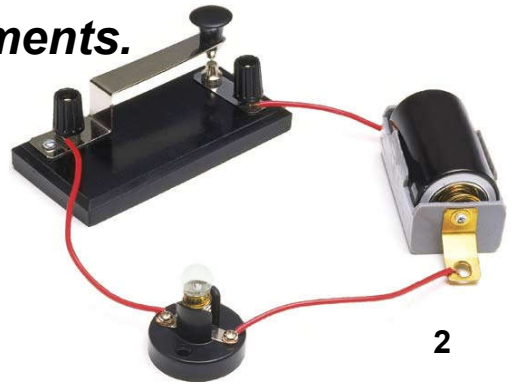
Chapter 1: Basic concepts

I. Introduction.

- ***Electric circuit theory*** and ***electromagnetic theory*** are the two fundamental theories upon which all branches of electrical engineering are built, such as:
  - Power
  - Electric machines
  - Control
  - Electronics
  - Communications
  - Instrumentation
  - etc.
- The basic electric engineering theory course is:
  - The most important course for an electrical engineering student.
  - Excellent starting point for a beginning student in electrical engineering education.
  - Valuable to students specializing in other branches of the physical sciences.
- An ***electric circuit*** is an ***interconnection*** of ***electrical elements.***

Ex1: A simple electric circuit consists of 4 basic components:

- A battery.
- A contact.
- A lamp.
- Connecting wires.



Chapter 1: Basic concepts

I. Introduction.

- ***Electric circuit*** are used in many electrical systems to accomplish different task.
- Objective in this course:
  - Not the study of various uses and applications of circuits.
  - The ***analysis of the circuits***:
    - How does it respond to a give input ?
    - How do the interconnected elements and devices in the circuit interact?
- Study commence by defining some basic concepts:
  - Charge
  - Current
  - Voltage
  - Circuit element.
  - Power
  - Energy

II. Systems of units.

- An international measurement language is the International System of Unit (**SI**), adopt by the General Conference on Weight and Measures in 1960.

- In SI, there are ***six principal units***:
  - From which the units of all other physical quantities can be derived.
  - Use prefixes base on the power of 10 to relate larger and smaller unit to the basic unit.

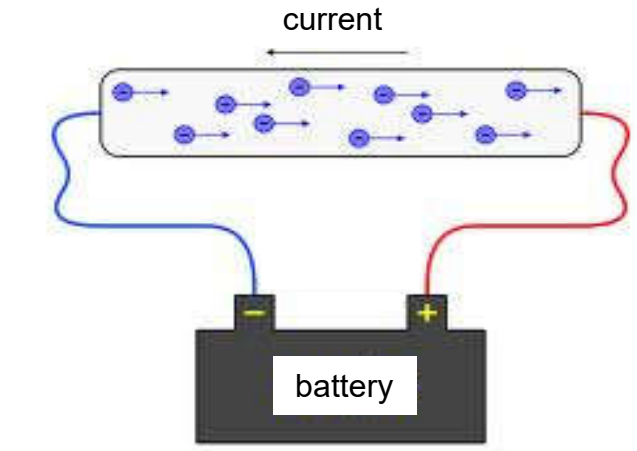
Quantity	Basic unit	Symbol
Length	Meter	m
Mass	Kilogram	Kg
Time	Second	s
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Luminous intensity	Candela	cd

III. Charge and current.

- The concept of electric charge is the underlying principle for explainning all electrical phenomena.
- ***Charge*** is an electrical property of the atomic particles of which matter consists, measured in coulombs (C)
- In atom physic, each atom consists of electrons, protons and neutrons:
  - Electron charge *e*: -1.602×10^{-19} C
  - Proton charge: 1.602×10^{-19} C
- Notes:
  - $1C = 6.24 \times 10^{18}$ electrons → pC, nC, μC
  - Only charges occuring in nature are integral multiples of the electronic charge $e = -1.602 \times 10^{-19}$ C.
  - Law of conservation of charge: Charge can neither be created nor destroyed, only transferred.

III. Charge and current.

- Electric charge is mobile:
  - Can be transferred from one place to another
  - Can be converted to another form of energy.
- When a conducting wire is connected to a battery:
  - Positive charges move in one directions
  - Negative charges move in the opposite direction



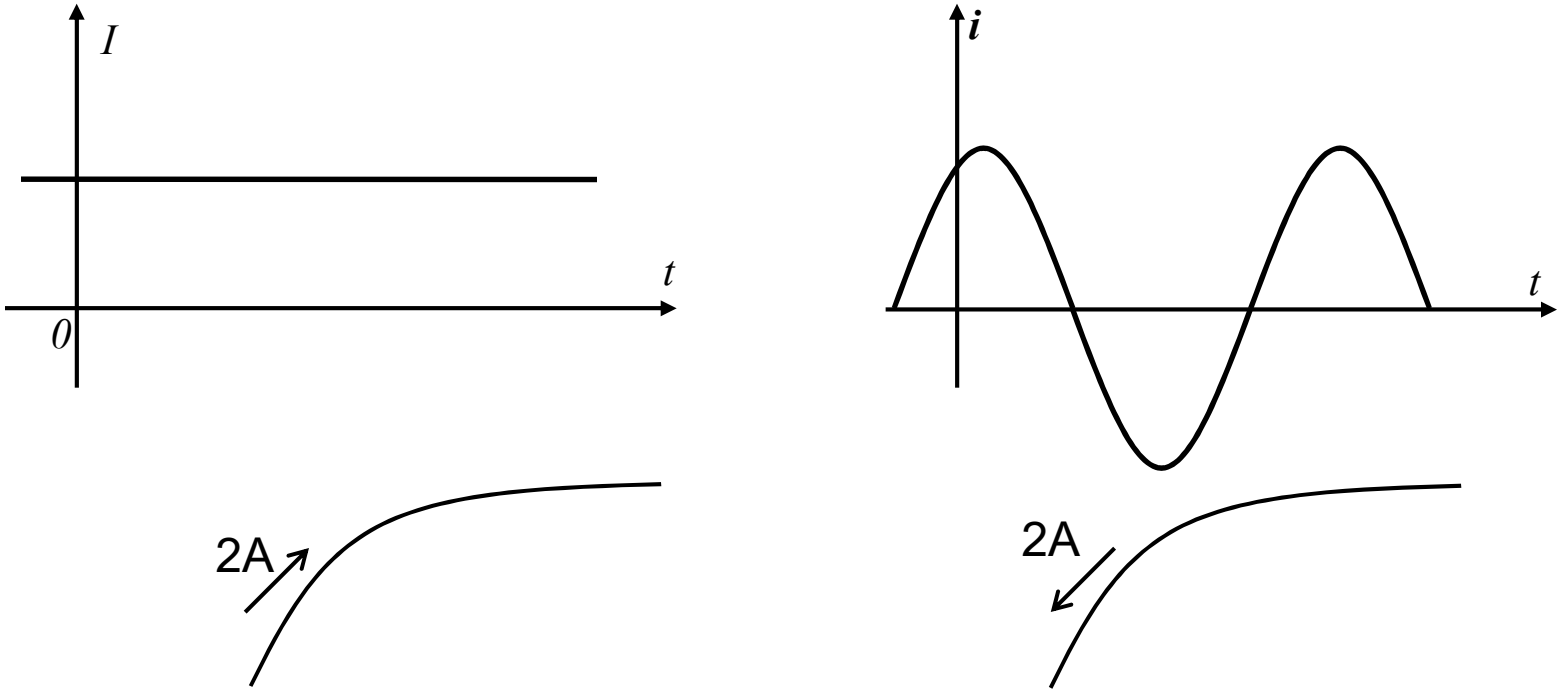
creat an electric current

- It it conventional to take the current flow as the movement of positive charge, opposite to the flow of negative charges (the current in metallic conductors is due to negatively charged electrons).
- ***Electric current*** *is the time rate of change of charge, measured in amperes (A)*

$$i = \frac{dq}{dt} \quad ; \quad [A] = \frac{[C]}{[s]}$$

III. Charge and current.

- There are two common types of current:
  - A ***direct current*** (DC) is a current that remains constant with time (I).
  - An ***alternating current*** (AC) is a current that varies sinusoidally with time (i).

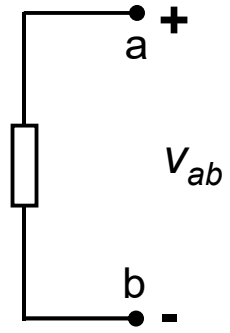


a current of 2A may be represented
positively or ***negatively***

IV. Voltage.

- In order to move the electron in a conductor in a particular direction requires some work or energy transfer (*external electromotive force, emf,* as known as *voltage* or *potential difference*).
- ***Voltage*** (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).

$$v_{ab} = \frac{dw}{dq} \quad ; \quad [V] = \frac{[J]}{[C]} = \frac{[Nm]}{[C]}$$



- The v_{ab} can be interpreted in two ways:
  - Point *a* is at a potential of v_{ab} volts higher than point *b.*
  - The potential at point *a* with respect to point *b* is v_{ab}.

$$\rightarrow V_{ab} = -V_{ba}$$

- There are two common types of voltage:
  - DC voltage: produced by a battery, represented by V
  - AC voltage: produced by an electric generator, represented by V

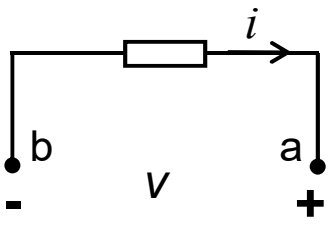
V. Power and energy.

- Although current and voltage are the two basic variables in an electric circuit, they are not sufficient by themselves.
- In fact:
  - Need to know how much ***power*** an electric device can handle ?
  - The EVN's bills are paid for the electric energy consumed over a certain period of time.

    → ***power*** and ***energy*** calculations are important in circuit analysis.
- ***Power*** is the time rate of expending or absorbing energy, measured in watts (W)

$$p = \frac{dw}{dt} = \frac{dw}{dq}.\frac{dq}{dt} = vi$$

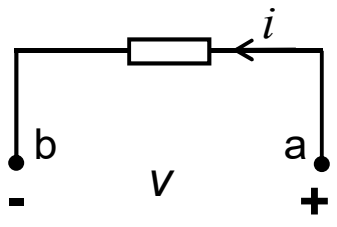
p: the instantaneous power



$p = -vi$

power is being supplied by the element

Passive sign convension is satisfied when the current enters through the positive terminal of an element, and $p = vi$. If the current enters through the negative terminal, $p = -vi$



$p = vi$

power is being delivered to the element

V. Power and energy.

- *Law of conservation of energy:*

$$\sum p = 0$$

- *Energy* is the capacity to do work, measured in Joules (J)

$$\omega = \int_{t_0}^{t} p dt = \int_{t_0}^{t} vi dt$$

- The electric power utility companies measure energy in Watt-hours (Wh)

1 Wh = 3,600 J

VI. Circuit elements.

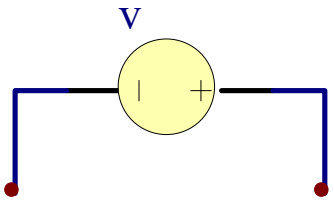
- An element is the basic building block of a circuit.
- An electric circuit is simply an interconnection of the elements.
- Circuit analysis is the process of determining voltages across (or the currents through) the element of the circuit.
- Types of circuit elements:
  - Passive elements: Not be able to generate energy.

    Ex. : Resistors, capacitors, inductors, …
  - Active elements: To be able to generate energy.

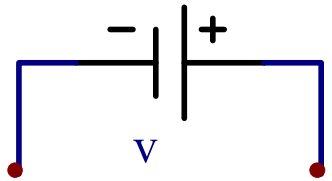
    Ex. : Generators, batteries, operational amplifiers, voltage sources, current sources …
- Two kinds of sources:
  - Independent sources.
  - Dependent sources.

VI. Circuit elements.

- An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit variables.
  - An ideal independent voltage source delivers to the circuit whatever current is necessary to maintain its terminal voltage.

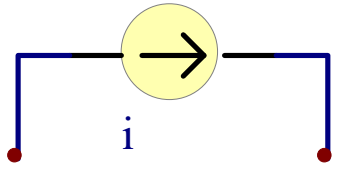


DC or time varying independent voltage source



DC independent voltage source

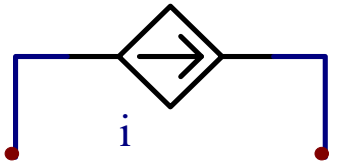
  - An ideal independent current source is an active element that provides a specified current completely independent of the voltage across the source *(the arrow indicates the direction of current i)*



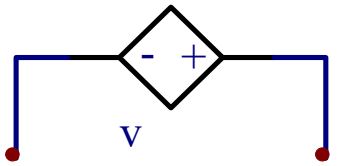
Independent current source

VI. Circuit elements.

- An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.
- There are 4 possible types of dependent sources:
  - A voltage-controlled voltage source (VCVS)
  - A current-controlled voltage source (CCVS)
  - A voltage-controlled current source (VCCS)
  - A current-controlled current source (CCCS)



Dependent current source



Dependent voltage source

- Dependent sources are useful in modeling elements:
  - Transistors.
  - Operational amplifier.
  - Integrated circuits.
  - …