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FACULTY OF TECHNOLOGY

Electrokinetics

Definition

Electrokinetics is the study of electric currents, that is to say the study of charges electrical moving in material media called conductors. In other words, it is the study of electrical circuits and networks.

Electrical conductor

In electricity, a conductor is a material that contains electric charge carriers able to move easily. When this conductor is subjected to an electric field the movement of charge carriers becomes globally ordered, which means that we observe a Electric power.

By extension, a conductor is an electrical or electronic component of low resistance, used to carry current from one point to another.

Among the conductive materials, we can cite metals, electrolytes (or ionic solutions) and plasmas.

Perfect conductors do not exist, so we use ohmic conductors, the best of which are silver, gold and aluminum.

1. Electric current:

2.1 Definition:

Electric current is a collective and organized movement of charge carriers (electrons or ions). This charge flow can occur in a vacuum (electron beam

in cathode ray tubes, etc.), or in conductive matter (electrons in metals, or ions in electrolytes).An electric current appears in a conductor when a difference potential is established between the terminals of the latter.

2.2 Intensity of electric current:

Electric current intensity is a number describing the flow rate of electric charge at through a given surface, in particular the section of an electric wire.

$$I(t)=\frac{dq(t)}{dt}$$

Where: I: is the intensity of the current. q: the electric charge. t: time.

In the international system of units, current intensity is measured in amperes, a base unit whose standard symbol is A. An ampere corresponds to a charge rate of one coulomb per second.

The intensity is measured using an ammeter which must be connected in series in the circuit.

2.3 Current density:

Current density is a vector describing electric current on a local scale. Its direction indicates that of the movement of the charge carriers (but its direction can be opposite for negative carriers) and its norm corresponds to the intensity of the current per unit area. It is connected to electric current by: $I=\iint_S \vec{j}.\overrightarrow{ds}$

where: I is the intensity of the current; S surface, j current density; ds the elementary surface vector.

In the international system of units, current density is measured in amperes per square meter ($A \cdot m^{-2}$).

3. Ohm's law:

The potential difference or voltage U (in volts) across a resistor $\boldsymbol{R}$(in ohms) is proportional to the intensity of the electric current $\boldsymbol{I}$(in amperes) which passes through it (figure 1).

$$U = RI$$

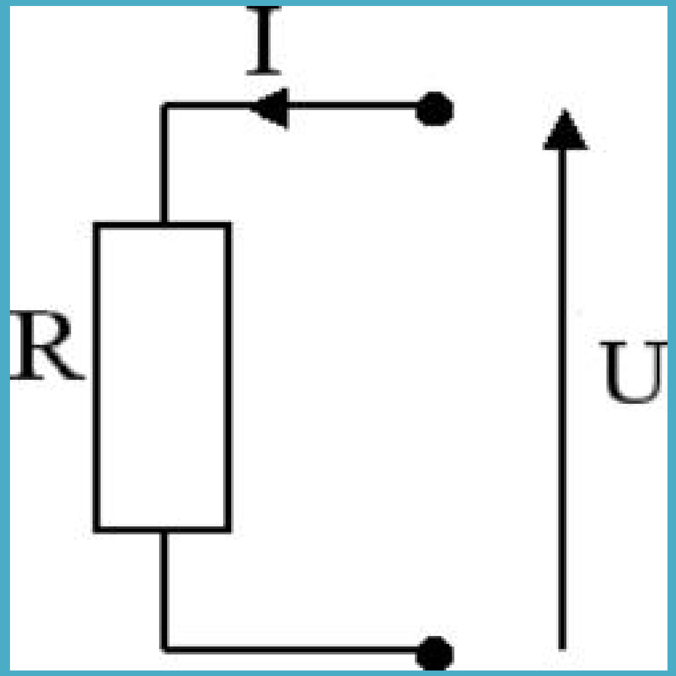


Figure 1 : Resistance crossed by a current I under a voltage U

Resistance is the opposition exerted by a body to the passage of an electric current.

4. Joule effect:

The Joule effect is a heat production effect that occurs when electric current passes through a conductor with resistance. It manifests itself as an increase in the thermal energy of the conductor and its temperature. In fact, this type of conductor transforms electrical energy into calorific energy (energy dissipated in the form of heat). The power dissipated by this conductor is equal to:

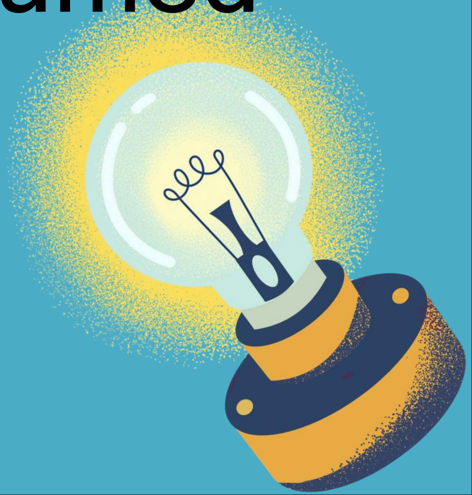
$$P = RI^2$$

The unit of power is the watt (W).

R: the resistance of the conductor.

I: the intensity of the current passing through the conductor.

According to the definition of energy, we deduce that the energy consumed by a resistance during time t is equal to: $E = U.I.t = R.I^2.t = \frac{U^2}{R}t$



The unit of energy is the joule (J).

5. Resistance grouping:

We distinguish two cases for the grouping of resistances:

5-1 Serial grouping:

All R resistors are traversed by the same electric current I, and each of them has only one common end with another resistance (figure 2). The voltage $U_{AB} = U$ is equal to the sum of the resistor voltages.

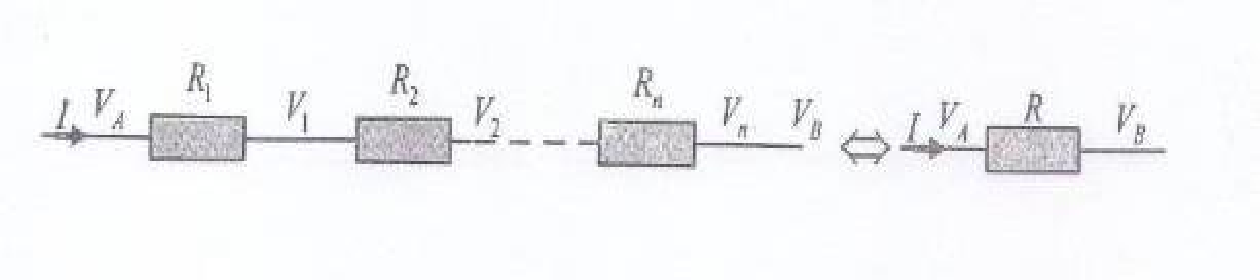


Figure 2 Series grouping of resistors

$$U = U_1 + U_2 + U_3 + \ldots\ldots. + U_n = R.I$$

$$U = R_1.I + R_2.I + R_3.I \ldots\ldots + R_n.I = R.I$$

Thus, we obtain the equivalent resistance of all the resistances grouped in series.

$$R = \sum_{i=1}^{n} R.i$$

5-2 Parallel grouping:

This grouping is characterized by the fact that all the resistors have their common terminals in pairs (figure 3**)**. The voltage is the same between the ends of any resistor R_i.

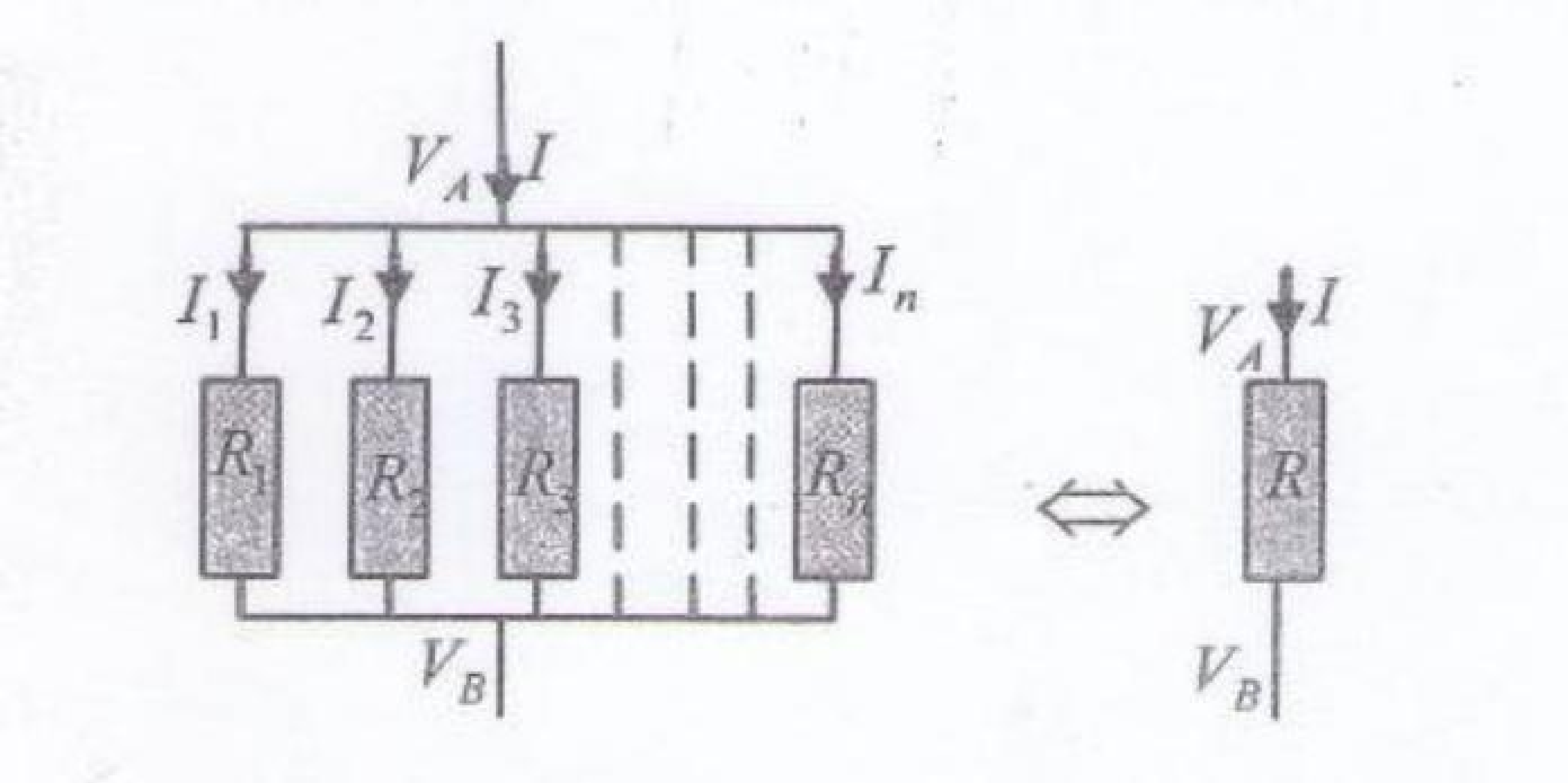


Figure3 Parallel grouping of resistors

The electric current which powers the portion of the circuit is distributed between the resistances, such that:

$$I = I_1 + I_2 + I_3 + \ldots\ldots. + I_n$$

$$I = \frac{U}{R} = \frac{U}{R_1} + \frac{U}{R_2} + \frac{U}{R_3} \ldots\ldots\ldots + \frac{U}{R_n} => \frac{U}{R} = [\ \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots\ldots\ldots + \frac{1}{R_n}\ ].U$$

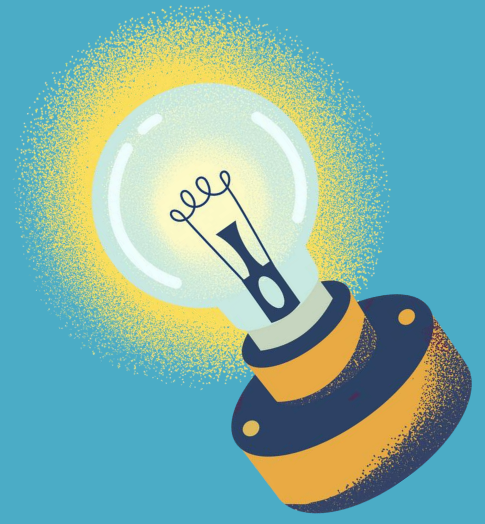
Thus, we obtain the equivalent resistance, in this case, is always smaller than that of the smallest of the resistors connected in by pass.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots\ldots\ldots + \frac{1}{R_n} => \frac{1}{R} = \sum_{i=1}^{n} \frac{1}{R_i}$$

6. Electrical circuits:

An electrical circuit is a set of conductors (wires) and electrical components (sockets, switches, etc.) or electronic components (domestic appliances, etc.) carried by an electric current

The electrokinetic study of an electrical circuit consists of determining, at each location, the intensity of the current and the voltage.



Elements of the electrical circuit:

The electrical circuit is essentially composed of the following elements (figure 4):

1. The node: it is a point where more than two conductors end.
2. The branch: it is a portion of circuit which is inserted between two nodes.
3. The mesh: any closed contour, formed from a series of branches.

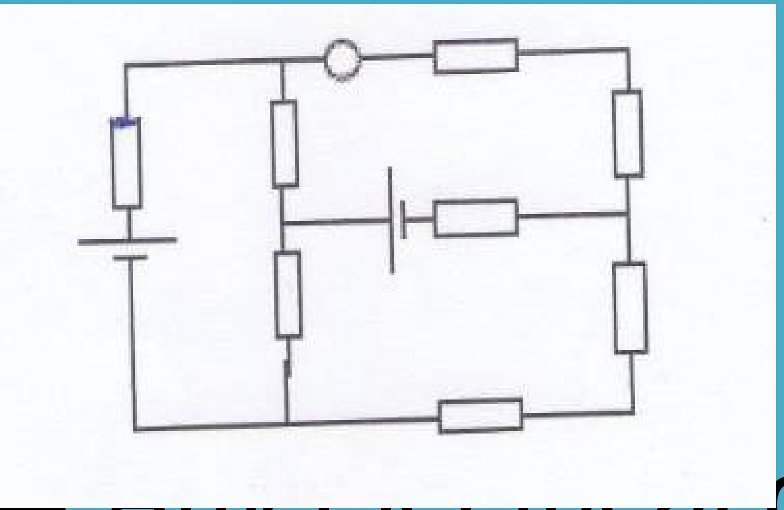


Figure 4 Any electrical circuit

Generators:

To obtain direct electric current in a closed circuit, it is essential to supply the circuit with energy. This is done by devices, which are called generators. We can say that they are sources of electromotive forces to transport charges.

There are 2 types of generators:

Generators or voltage sources:

The voltage source, or voltage generator, is a dipole characterized by a constant voltage between these terminals, whatever the variable intensity it delivers. In what follows, we will focus particularly on DC voltage generators. This type of generator is characterized by an electromotive force e, and a low internal resistance (r) (figure 5).

It is possible to replace a voltage generator, whose characteristics are (e, r) by an ideal source, of electromotive force e, connected in series with the ohmic conductor, of resistance r as indicated in Figure 5.

The electromotive force of a voltage generator is equal to the potential difference between its terminals when it does not deliver any current:

$$I = 0 \rightarrow e = U_{AB}$$

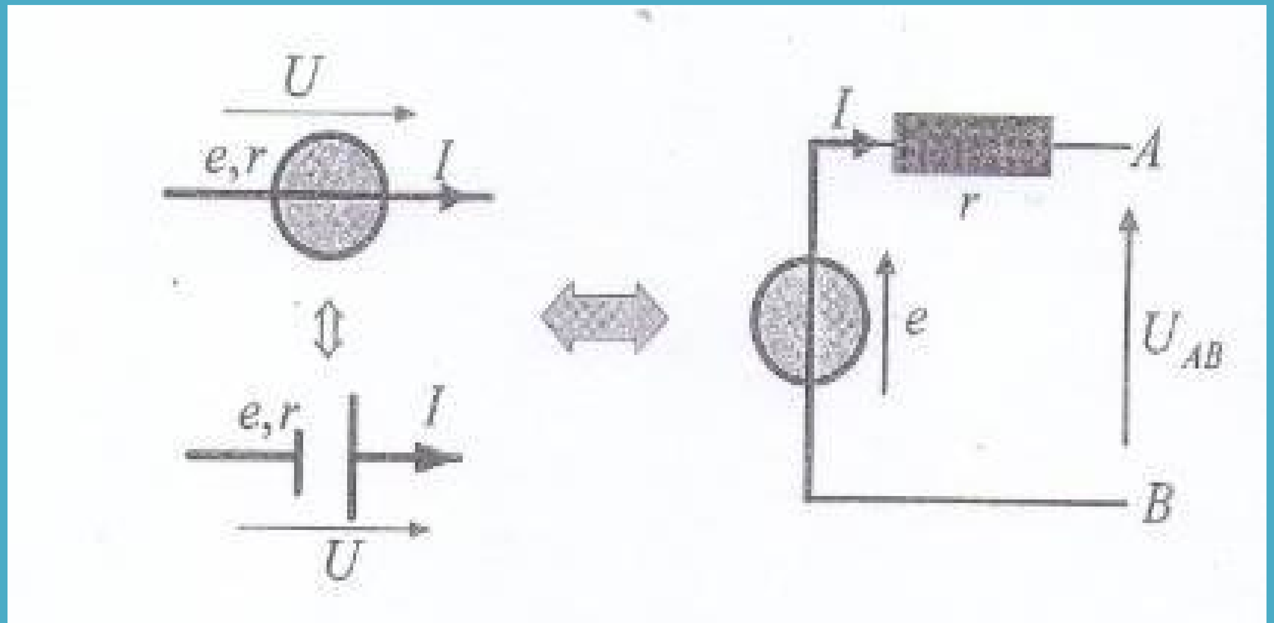


Figure 5: representation of the voltage generator

Generators or power sources:

The current source, or current generator, is a dipole characterized by the flow of a constant current, whatever the variable potential difference between its terminals. In what follows, we will focus mainly on direct current generators. This type of generator is represented by the diagram in Figure 6.

A current generator can be replaced by an ideal current source, which delivers a constant current, and connected in parallel with an ohmic resistance conductor, as shown in Figure 6.

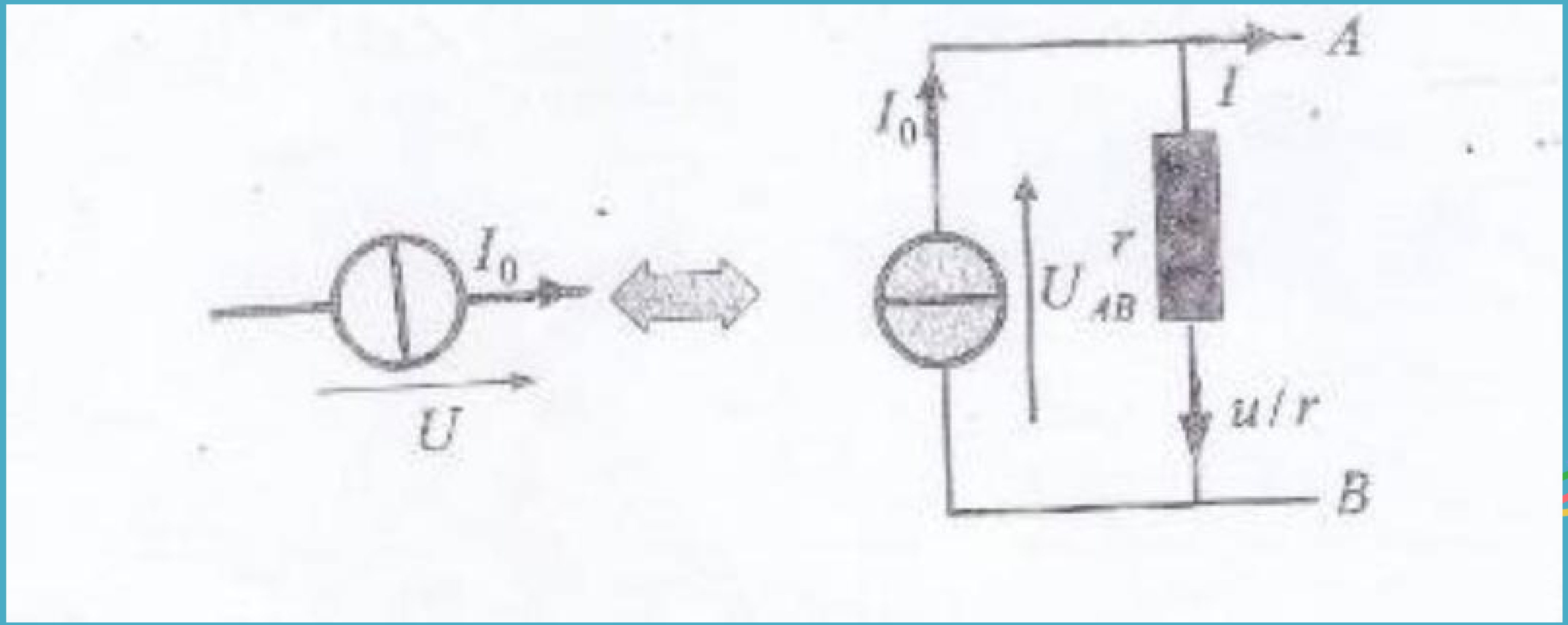


Figure 6: representation of the current generator

7. Kirchhoff's laws:

7-1 First law (law of knots):

At a node of a circuit, the sum of the incoming intensities is equal to the sum of the outgoing intensities:

$\sum I_s = \sum I_E$

This means that the charges do not accumulate, they flow into a node of the network, they obey the rule of energy conservation

7.2 Second law (law of stitches):

In a mesh of an electric circuit, the algebraic sum of the products of resistance by the intensity of the current ($\sum_{k=1}^{n} R_k I_k$) is equal to the algebraic sum of the electromotive forces ($\sum_{k=1}^{n} e_k$).

$$\sum_{k=1}^{n} e_k = \sum_{k=1}^{n} R_k I_k$$

When we apply this law, we must choose a positive direction around the mesh: all electromotive forces and currents which have the same direction will be counted positively, those which have the opposite direction will be counted negatively. We consider the direction of e positive when we enter, according to the chosen positive direction, through the negative pole and exit through the positive pole (which leads to an increase in potential), and the opposite in the opposite case. .

Applications:

Consider for example the following circuit (figure III-5):

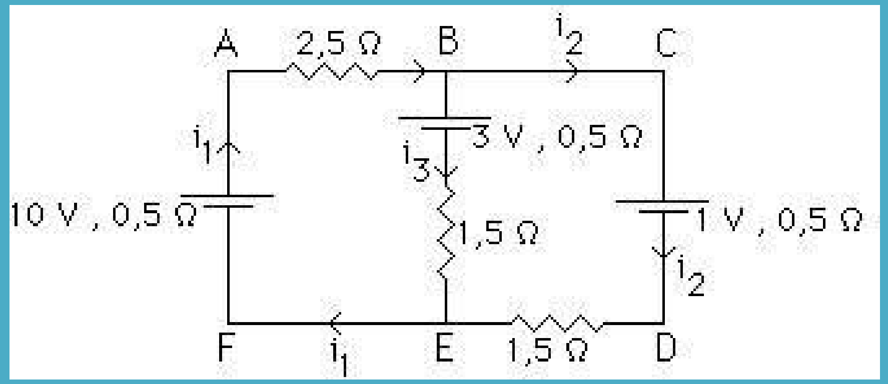


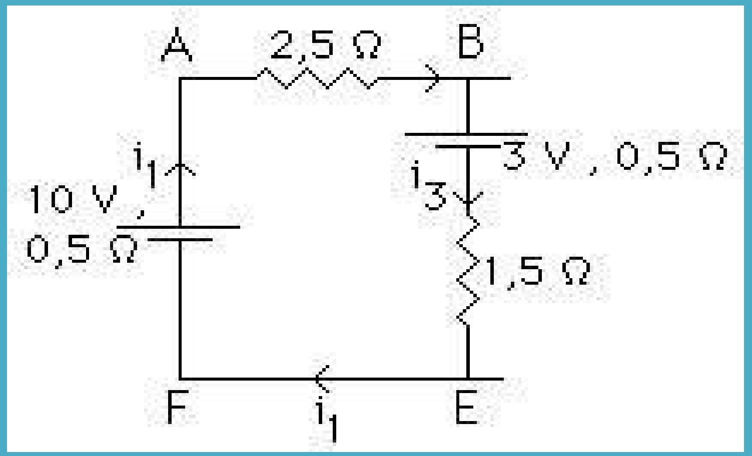
Figure 7 Electrical circuit

We will find the values of the three currents i_1, i_2 and i_3 using Kirchhoff's laws.

Conservation of current (Kirchhoff's first law) implies that $i_1 = i_2 + i_3$

Let us then apply the conservation of the potential on a circuit mesh (Kirchhoff's second law) to the ABEFA then BCDEB meshes.

For the ABEFA mesh:



Starting from point A where there is a potential V_A:

1. from A to B, a resistance of $2.5\ \Omega$ is crossed in the direction of current i_1, which corresponds to a reduction in potential of 2,5. i_1 Volts

2.from B to E,

1. we cross a cell of $E = 3$ Volts from the highest potential to the lowest potential, which results in a reduction in the potential of 3 Volts.

2.The internal resistance of the battery is crossed in the direction of current i_3 , which corresponds to a reduction in potential of 0,5. i_3 Volts.

3.Finally, the 1.5 Ω resistor is also crossed in the direction of current i3, which generates a potential loss of 1,5. i_3 Volts.

3. from E to F, there is no variation in potential,

4. from F to A,

1. the battery of $E = 10\,V$ is crossed from the lowest to the highest potential raising the latter by $10\,Volts$.

2. On the other hand, the crossing of the internal resistance of this battery in the direction of the current i1causes a drop in potential of 0,5. i_1 Volts.

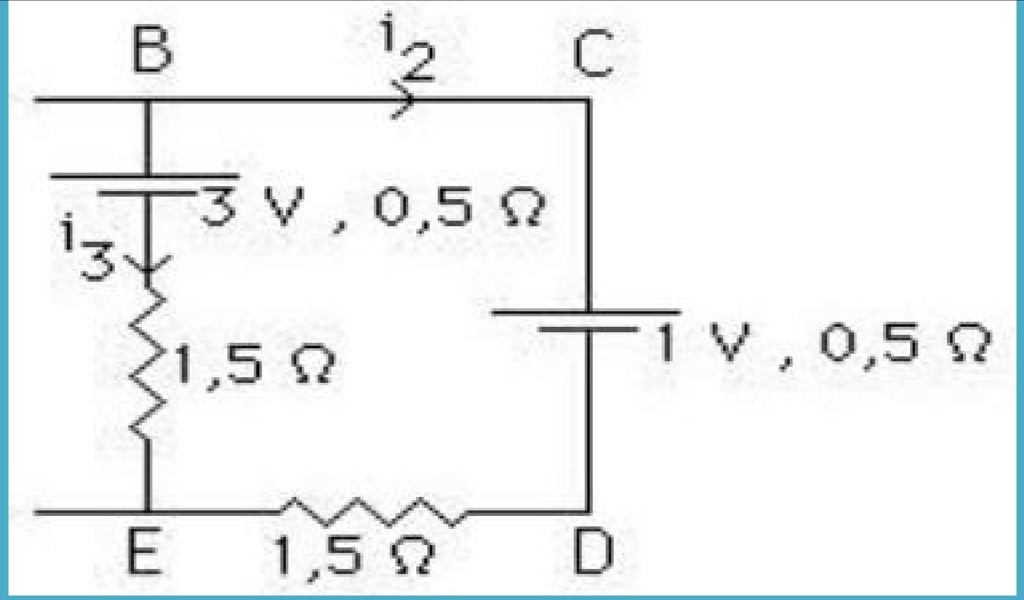
In total, we have after a complete turn:

V_A- 2,5. i_1 - 3 - 0,5. i_3 - 1,5. i_3 + 10 - 0,5. i_1 = V_A

and so

U_{AA} = V_A - V_A = - 2,5. i_1 - 3 - 0,5. i_3 - 1,5. i_3 + 10 - 0,5. i_1 = 0

For the BCDEB mesh:



Starting from point B where there is a potential V_B :

1. from B to D,
    1. there is a loss of 1 Volt through the battery
    2. and loss of $0,5.i_2$ Volt through the internal resistance of this battery.
2. from D to E, there is a loss of $1,5.\ i_2$ Volt.
3. from E to B,
    1. there is a gain of $1,5.i_3$ Volt,
    2. gain of $0,5.i_3$ Volt through the internal resistance of the 3 Volt battery,
    3. and gain of 3 Volts due to the electromotive force of the battery.

In total, we have after a complete turn:

V_B- 1 - 0,5. i_2 - 1,5. i_2 +1,5. i_3 +0,5. i_3 + 3 = V_B

and so

U_{BB} = V_B - V_B = - 1 - 0,5. i_2 - 1,5. i_2 +1,5. i_3 +0,5. i_3 + 3 = 0

We therefore have the following system of equations:

$i_1 = i_2 + i_3$

- 2,5. i_1 - 3 - 0,5. i_3 - 1,5. i_3 + 10 - 0,5. i_1 = 0

- 1 - 0,5. i_2 - 1,5. i_2 +1,5. i_3 +0,5. i_3 + 3 = 0

Or again:

$i_1 = i_2 + i_3$

$-3\,i_1 - 2\,i_3 + 7 = 0$

$-2\,i_2 + 2\,i_3 + 2 = 0$

It is a system of 3 equations with 3 unknowns: i_1, i_2 and i_3.
The resolution of this system gives:

$$i_1 = 2A$$

$$i_2 = 1{,}5A$$

$$i_3 = 0.5A$$

The positive values of these currents indicate that the directions