Unit 5: Electricity

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Textos Marea Verde

Prior knowledge

Activity: Summarize your general knowledge on this topic.

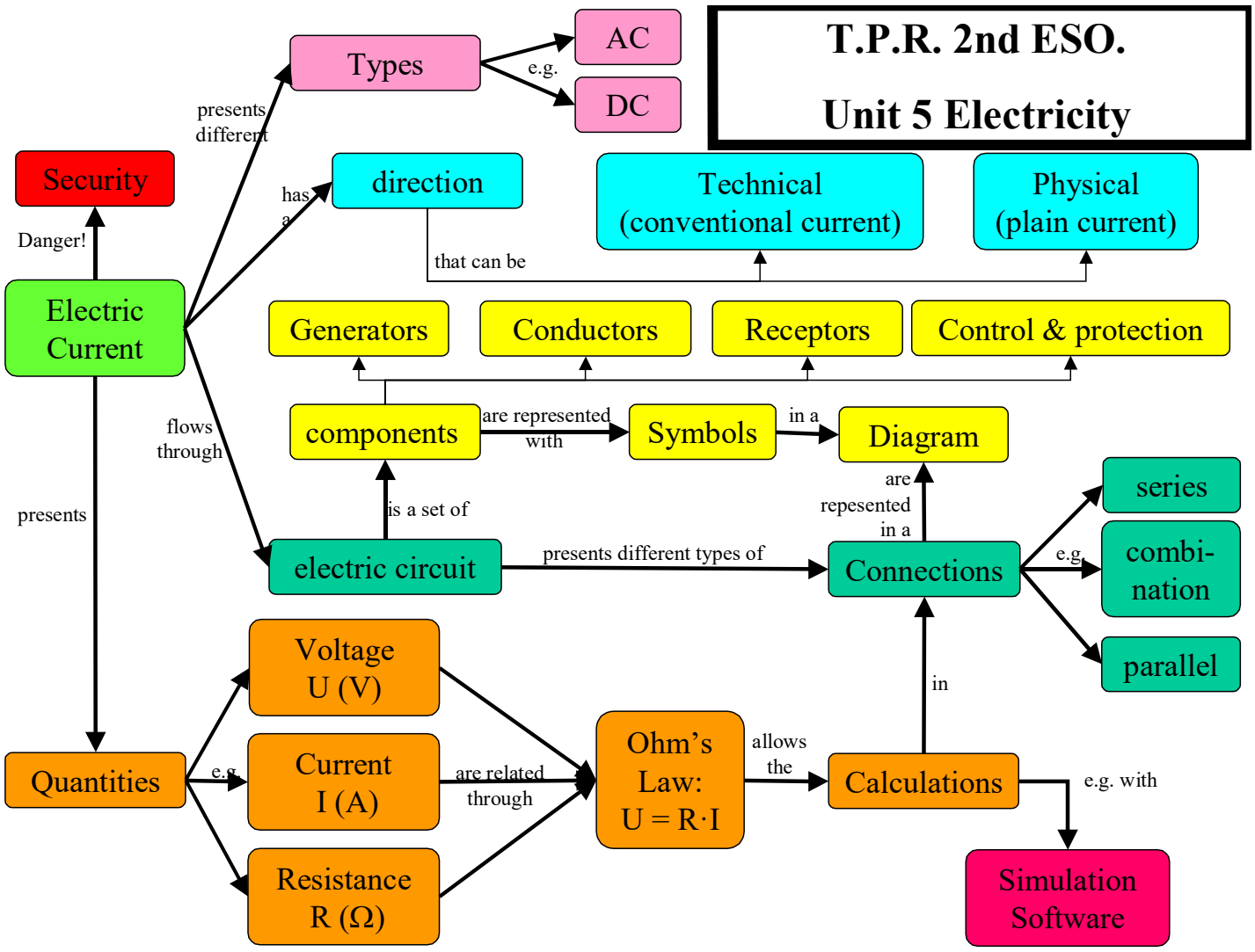
Keywords

Activity: Copy following keywords, understand their meaning and translate them into English.

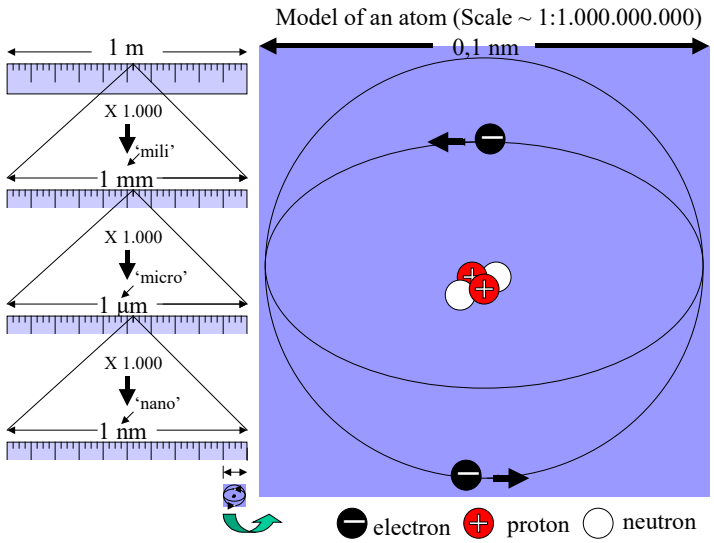
Charge	Resistance (R)	Resistor
Electric current	Circuit	LED
Direct current	Power source	Light bulb
Alternative Current	Battery	Motor
Current (I)	Conductor	Switch
Voltage (U)	Insulator	Potenciometer
Potential difference	Load device	Fuse

Mindmap of the unit

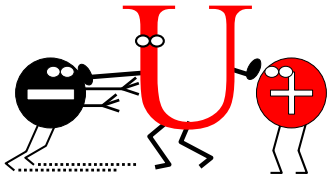
Activity: Analize and try to understand following mindmap



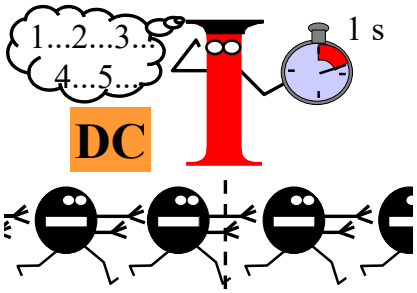
Electricity Basics

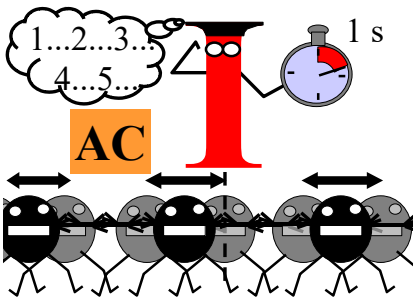


- Electricity is any phenomenon that has to do with **electric charges.**
- Electrical particles: Matter is made up of atoms consisting of a nucleus in the center with protons (**positive electric charges;** +) and an electron cloud in the periphery (**negative electric charges;** -). Negative charges repel each other, as do positive charges, but a positive charge and a negative charge attract one another.

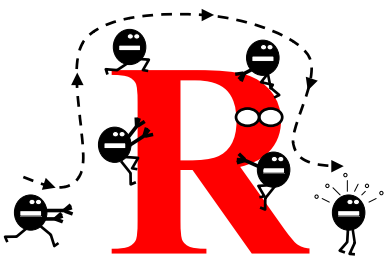


- Electrical conductivity: Some materials (conductors), such as metals, allow electrons to flow through them; others (insulators), such as plastic, wood and ceramics, do not.
- Electric poles (terminals): With energy (either mechanical, chemical or electromagnetic) electrons can be separated farther away from protons, creating an imbalance between two 'points' or **poles**: the **negative pole (cathode)**, the 'point' where electrons has been moved, and the **positive pole (anode)**, the 'point' where the protons remain.
- Electric current: Putting a conductor between a negative pole (-) an a positive pole (+), causes a continuos movement of electrons, from the negative pole to the positive, which is called **electric current**.
- Types of electric current: When the poles remain the same (always positive or negative, as in batteries), electrons in the conductor move in one sense, causing a **direct current (DC)**; when the poles alternate their position (positive-negative-positive-... several times every second, as in the electrical network), electrons change their sense of movement in the conductor, causing **alternating current (AC)**.





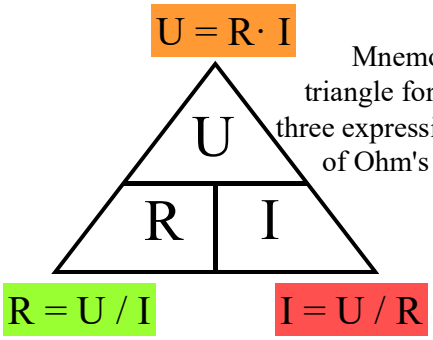
- Electric circuits: An electric circuit is a set of connected components through which an electric current flows to produce an effect such as heat, light, sound and motion.
- Electric variables:
  - The energy needed to separate an electron farther away from positive charges is called voltage (voltaje) or potential difference (diferencia de potencial) and is represented by the letter **U** or **V** and is measured in **volts** (voltios): V.
  - The amount of electrons that pass through a specific point in one second is called current (intensidad de corriente). It is represented by the letter **I** and is measured in **amperes** (amperios)A (1 A = 1 C / 1 s; 1 C ≈ 6,25 · 10^{18} electrons.)
  - The opposition or obstacles that hinder the flow of electrons through a conductor is called resistance (resistencia). It is represented by the letter **R** and is measured in **ohms** (ohmios) Ω; 1 Ω = 1 V / 1 A – see Ohm's law).



- Ohm's law:

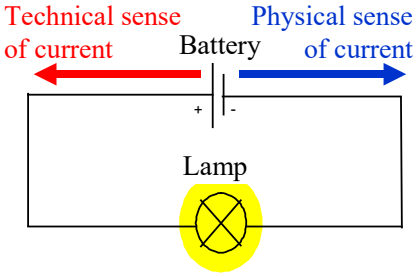
George Ohm concluded in 1822 that there was a proportional relationship between voltage **U**, the current **I** and the resistance **R**, which is expressed mathematically as:

$$U = R \cdot I$$



Mnemonic triangle for the three expressions of Ohm's law

So, if **R** stays the same, doubling **U** means **I** will also double; if **U** stays the same, doubling **R** means **I** will be reduced to the half.



- Sense of the electric current: The **technical (conventional) sense** of the current through the conductors of a circuit is defined from the positive pole to the negative pole. This agreement was met long before electrons were discovered to be the charges flowing through the conductors, namely from the negative pole to the positive pole (**physical sense**).

The flow of electric current in your body gives an electric shock. Electric shock can be highly dangerous (burns, muscular paralysis, loss of conciousness, heart attack). Therefore:

DO NOT work inside an electrical appliances if connected to the electrical grid .
DO NOT touch electrical switches or appliances with wet hands.

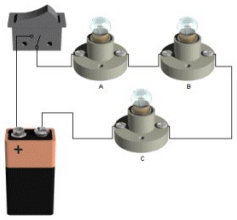
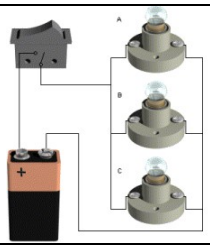
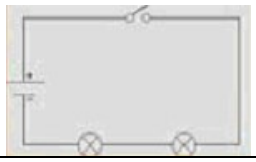
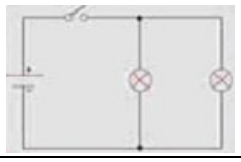
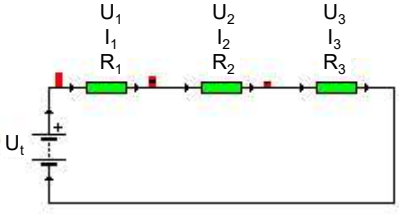
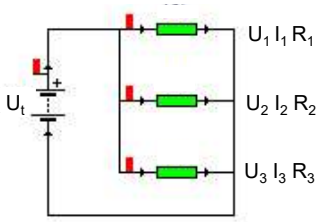
Activities: Copy following exercises and solve them in your notebook

1) What are the particles of atom? Where exactly are they? Which is their charge?
2) What material is used to make the inner and the outer part of electric cables? Why?
3) What is electric current? What are the two types of electric current?
4) Complete : Electric currents are created by the movement of _____. The voltage is measured in _____, the current in_____, the resistance in _____.
5) Express Ohm's Law in three different ways: U = ?, I = ?, R = ?
6) Calculate the voltage if I = 1 A and R = 1 Ω.
7) Calculate the the resistance if I = 0,5 A and U = 4,5 V.
8) Calculate the current if U = 12 V and R = 100 Ω.

5.2. DC-circuits calculations

Load devices (receptors) like lamps, electric motors, electric heaters, etc hinder the electric current (i.e. they show an electrical resistance R) and, therefore, affect the variables voltage U and current I within a circuit. These variables can be calculated, depending on the way the devices are conected in the circuit: series circuits, parallel circuits and series-parallel combination circuits.

5.2.1. Series and parallel

	Series circuits	Parallel circuits
Example (3 bulbs; pictures)		
Example (2 bulbs; symbols)		
Example (3 resistors; symbols)	 $U_t = U_1 + U_2 + U_3$ $R_t = R_1 + R_2 + R_3$ $I_t = I_1 = I_2 = I_3$	 $U_t = U_1 = U_2 = U_3$ $1/R_t = 1/R_1 + 1/R_2 + 1/R_3$ $I_t = I_1 + I_2 + I_3$
Connections	A single wire leads from one load device into the next	Each load device has its own branch
Voltage (**U**)	The voltage is distributed among the different load devices $\mathbf{U_t = U_1 + U_2 + U_3}$	The voltage is the same across every load device $\mathbf{U_t = U_1 = U_2 = U_3}$
Current (**I**)	The same current flows through all the load devices $\mathbf{I_t = I_1 = I_2 = I_3}$	The current is distributed among the different load devices $\mathbf{I_t = I_1 + I_2 + I_3}$ More electric current flows in the branch with the minor resistance.
Resistance (**R**)	The equivalent resistance is equal to the sum of resistances of all load devices. $\mathbf{R_t = R_1 + R_2 + R_3}$ (*)	The equivalent resistance is smaller than the resistances of each one of the load devices. $\mathbf{R_t < R_1, R_2, R_3}$ $\mathbf{1/R_t = 1/R_1 + 1/R_2 + 1/R_3}$ (**)
What happens if a load device fails?	The rest stop working.	The rest continue working.
Bulb's brightness	Bulbs glow dimmer by increased number of bulbs	Bulb's brightness stays the same however bulbs you add

(*) Proof (series circuits):

- $\mathbf{U_t = U_1 + U_2 + U_3 \Leftrightarrow U_t/I_t = U_1/I_t + U_2/I_t + U_3/I_t}$
- $\mathbf{I_t = I_1 = I_2 = I_3}$

$\Rightarrow$ $\mathbf{U_t/I_t = U_1/I_1 + U_2/I_2 + U_3/I_3 \Leftrightarrow R_t = R_1 + R_2 + R_3}$

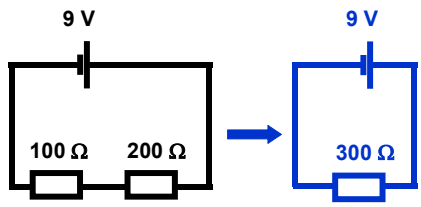
(**) Proof (parallel circuits):

- $\mathbf{I_t = I_1 + I_2 + I_3 \Leftrightarrow I_t/U_t = I_1/U_t + I_2/U_t + I_3/U_t}$
- $\mathbf{U_t = U_1 = U_2 = U_3}$

$\Rightarrow$ $\mathbf{I_t/U_t = I_1/U_1 + I_2/U_2 + I_3/U_3 \Leftrightarrow 1/R_t = 1/R_1 + 1/R_2 + 1/R_3}$

To calculate the variables,
1. first we simplify the circuit to an equivalent one with only one **equivalent resistor**.
2. Then we obtain the variables U_t , R_t and I_t
3. and finally the values for each resistor: U_1 , R_1 and I_1 ; U_2 , R_2 and I_2 ; etc.

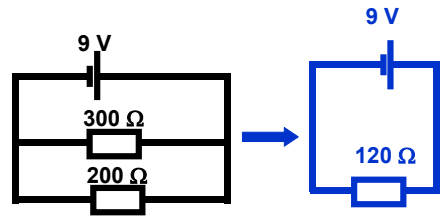
Example of series circuit:



	U (V)	R (Ω)	I (A)
Resistor 1	100 · 0,03= 3	100	0,03
Resistor 2	200 · 0,03= 6	200	0,03
Equivalent resistor	9 (*)	100 + 200 = 300	9/300 = 0,03

(*) Proof: 3+6=9

Example of parallel circuit:



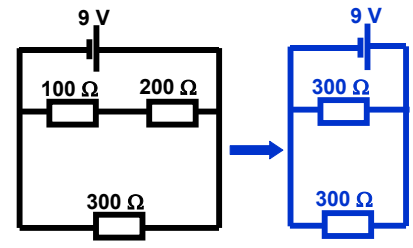
	U (V)	R (Ω)	I (A)
Resistor 1	**9**	**300**	9/300 = **0,03**
Resistor 2	**9**	**200**	9/200 = **0,045**
Equivalent resistor	**9**	$1/R_t = 1/300+1/200 = 5/600$ $R_t = 600/5 = \mathbf{120}$	9/120 = **0,075** (*)

(*) Proof: 0,03+0,045 = 0,075

5.2.2. Series-parallel combination

To solve a series-parallel combination circuit,
1. we have to simplify the circuit to a "only parallel" or "only series" equivalent one.
2. Then we obtain the variables for the equivalent circuit (see 5.2.1)
3. and finally the values for the remaining resistors of the series-parallel combination.

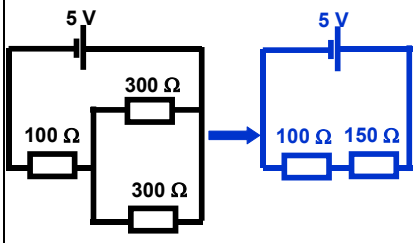
Example of series-parallel combination in which the simplified circuit is a **parallel** one:



	U (V)		R (Ω)		I (A)	
Resistor 1	100·0,03 = **3**	**9**	**100**	100 + 200 =	**0,03**	9/300
Resistor 2	200·0,03= **6**	(*)	**200**	**300**	**0,03**	= **0,03**
Resistor 3	**9**		**300**		9/300 = **0,03**	
Equivalent resistor	**9**		$1/R_t = 1/300+1/300 = 2/300$ $R_t = 300/2 = \mathbf{150}$		9/150 = **0,06** (**)	

(*) Proof: 3 + 6 = 9 ; (**) Proof: 0,03+0,03=0,06

Example of series-parallel combination in which the simplified circuit is a **series** one:

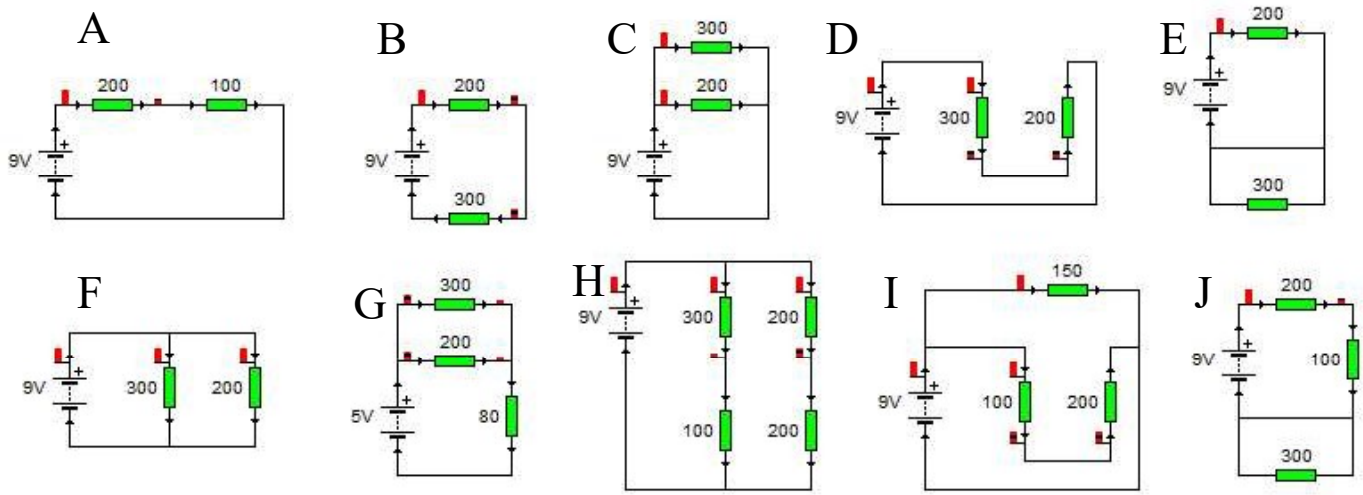


	U (V)		R (Ω)		I (A)	
Resistor 1	100 · 0,02= **2**		**100**		**0,02**	
Resistor 2	**3**	150 · 0,02= **3**	**300**	$1/R_{2,3}$ = 1/300+1/300=2/300 ⇔ $R_{2,3}$ = 300/2 = **150**	3/300 = **0,01**	**0,02** (**)
Resistor 3	**3**		**300**		3/300 = **0,01**	
Equivalent resistor	**5** (*)		100 + 150 = **250**		5/250 = **0,02**	

(*): Proof: 2 + 3 = 5; (**) Proof: 0,01+0,01=0,02

Activities: Copy following exercises and solve them in your notebook

9) Indicate whether the following circuits are series, parallel or series-parallel combination circuits (twocircuits have a trick!).



10) Draw a series-parallel circuit with six resistors in three different ways.

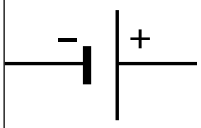
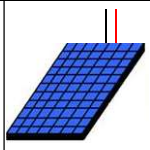
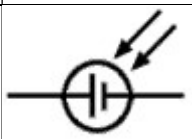
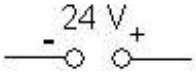
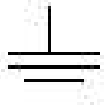
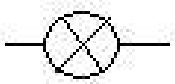
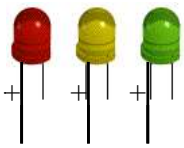
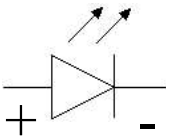
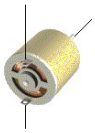
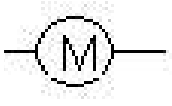
11) We know that a circuit with two identical resistors connected in series to a battery of 9 V has a current of 0,3 mA. Draw the circuit, calculate all the variables (U_t, R_t, I_t, U_1, R_1, I_1, U_2, R_2, I_2) and show the results in a table.

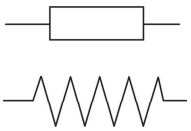
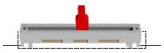
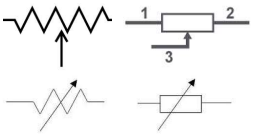
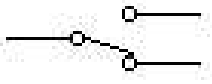
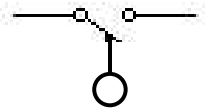
12) We know that a circuit with two identical resistors connected in parallel to a battery of 9 V has a current of 0,3 mA. Draw the circuit, calculate all the variables (U_t, R_t, I_t, U_1, R_1, I_1, U_2, R_2, I_2) and show the results in a table.

13) Calculate all the variables (U_t, R_t, I_t, U_1, R_1, I_1, U_2, R_2, I_2, ..., etc.) of all the circuits of exercise 9 and show the results in tables.

5.3. Components

The components can be classified into generators, conductors, receptors, control and protection components.

Type of component	component	Pictures	Symbol	Use
Generator (generador)	Battery (batería)			Generates electric energy
	Solar cell, photovoltaic cell (célula fotovoltaica, célula solar)			Converts light energy directly into electric energy
	Power supply (fuente de alimentación)			Supplies electric energy
	DC (corriente continua) AC (corriente alterna)			electric poles (+, -): ❑ remain the same ❑ alternate position
	Ground (tierra)			Reference point (0V) for voltage
Receptor or load devices (receptor o carga)	Bulb or lamp (bombilla)			Converts electrical energy into light (and heat)
	LED, light-emitting diode (LED, diodo emisor de luz)			Lights up if connected properly (long leg to + pole); otherwise lets no current to flow through
	Motor (motor)			Converts electrical energy into motion.
	Buzzer (zumbador)			Converts electrical energy into sound

Type of component	component	Pictures	Symbol	Use
Receptor or load devices. (receptor o carga)	Resistor (resistencia)			Limits the flow of current (produces heat)
	Potenciometer (potenciómetro)			Is a resistor with a value set by the user
Control component (componente de control)	Switch (interruptor)			Controls the flow of current
	3-way switch (conmutador)			Alternates the flow of current between two circuits
	Push button (pulsador)			Controls the flow of current
	Limit switch (interruptor fin de carrera)			Is a switch operated by a lever
Protection component (componente de protección)	Fuse (fusible)			Protects the circuit

Activities: Copy following exercises and solve them in your notebook

14) Which control component are used for the light in the classroom and in a door bell?

15) How do you think the lights in the classroom are connected – in series or parallel? Why?

16) A 3-way switch allows you to control a light from two points. Have you got one in your house? Where? Draw the circuit.

17) Which are the effects of the electric current on following devices? Draw the diagrams of their electric circuits.

Device	Effect(s) of electric current	Diagram of electric circuit
Mixer		
Vacuum cleaner		
Sandwich maker		
Hairdryer		

18) Design and simulate different circuits with a simulator (e.g. Yenka; previously Crocodile Technology).