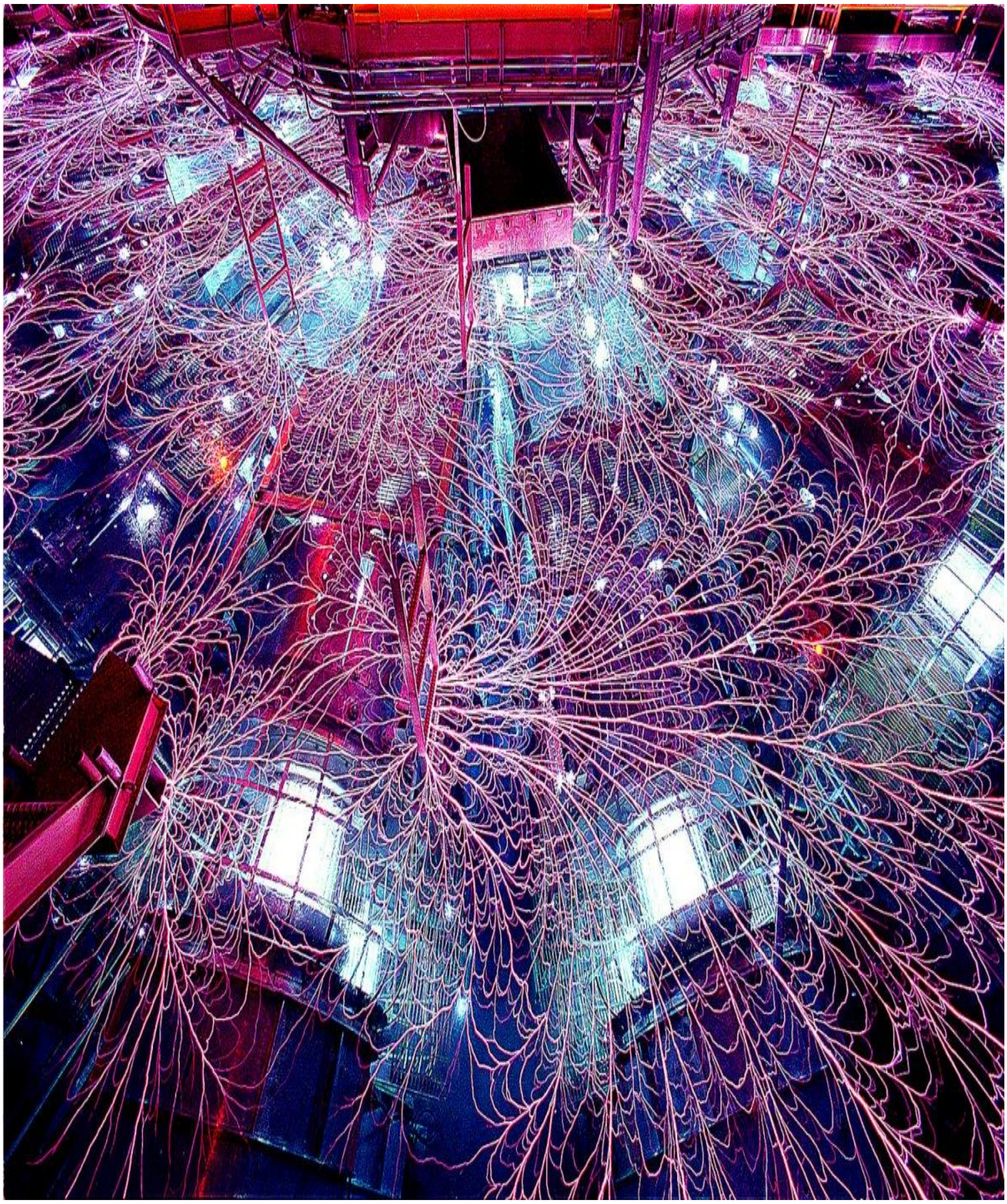
ELECTRICITY



1. ELECTROSTATIC

A.1. Read the text on The History of Electricity in the following link and then answer these questions:

a) What were the two main types of phenomena that show the effects of electricity for the first time?

b) What did Benjamin Franklin's experiments consist of?

c) What did the great scientist Faraday invent?

d) Name five scientists that helped in the production of a Second Industrial Revolution based on electricity.

A.2. Let´s do some experiments about electrification:

a) Electrify a plastic bar with synthetic leather and put it near a cork ball. What happens? Write down carefully the behaviour of the ball before and after touching the electrified bar.

b) A balloon that works as a remote control in the following link.

Most of the phenomena that you have observed are probably familiar to you, but perhaps the repulsion that the cork ball has after touching the electrified bar is not. Why has the ball moved away if it was attracted at first?

One thing is to describe the phenomenon but a different one is to understand it. Science describes reality with the single aim of understanding it. We use some ideas to understand something (a theoretical model to be accurate). Let´s sum up the ideas you will need to understand the previous phenomena:

- Matter has got one property called electric charge that is responsible for the electric attraction and repulsion phenomena that we have observed.
- There are two types of electric charges called positive and negative.
- Non electrified ordinary objects are called neutral and they are so called because they have as many positive charges as negative ones.
- An object is charged when it shows more charges of one kind than of the other one. An object that is considered as a whole will have a positive charge if it has more positive charges than negative ones and vice versa.
- Two objects with the same type of charge are repelled from each other, but if the charges are different they are attracted.
- The total charge is constant so that if an object gives some charge to another, the amount of charge lost by the first one is the same as the amount obtained by the second one.
- An object can give or take electric charge from another by rubbing.
- Two objects that come into contact can share their charges. So a fully charged object can electrify a neutral one by means of contact.

- A fully charged object can attract another neutral one by means of a phenomenon known as charge induction. When the charged object gets nearer the neutral one, the charges are organized and produce a charges separation that can electrify for a moment.

A.3. Use the new concepts and draw simple pictures that represent the objects carrying some positive and negative charges (in fact the number of charges in any object is around a quadrillion):

a) Explain the full behavior observed in the first experiment.

b) How is it possible that the charged balloon attracts a can that is electrically neutral in the second experiment?

A.4. Put an electrified bar near a stream of water. Explain what happens using the previous ideas.

A.5. The following video shows an electrification experiment with a Van de Graaff generator. Can you explain what happens to the hair when it touches it?

The following flash animation will explain how the generator gets electrified carrying electric charges from the bottom of the system to the top.

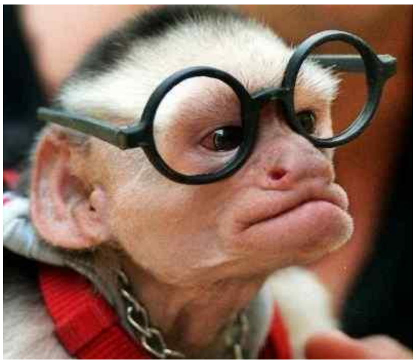
A.6. In the shopping centre “El Ingenio” in Velez-Málaga, the trolleys produced little discharges when people touched them. The solution was to hang a little chain that is in contact with the floor. Can you explain it with the previous ideas? Why do lorries that carry inflammable substances have a small metallic chain which connects them to the ground?

A.7. A very common phenomenon in summer is to get a little electric shock when you put your hand near your car bodywork. Why does it happen more frequently in summer than in winter?

Related to this, if you have ever been to the Faraday room in Principia Science Centre in Málaga, you have probably noticed that the air conditioning is on in some winter days so that the electrification experiments go well. Why do you think it is so?

A.8. Look for the relationship that all the previous learning has to do with the ray phenomenon. Why in the following video does the ray pass through the plane and nothing happens?

Clue: Faraday´s cage.



You can review all you have learnt up to now in the next video

A.9. Relate the studied phenomena to all you know about the structure of matter and how the atoms and the different particles are organized (review the Rutherford atomic model here) answering these questions:

a) Why exactly does a positive charge neutralize a negative charge?

b) Why do the electrons move but the positive charges don´t in the video?

c) Why are the negative charges exchanged when objects make contact?

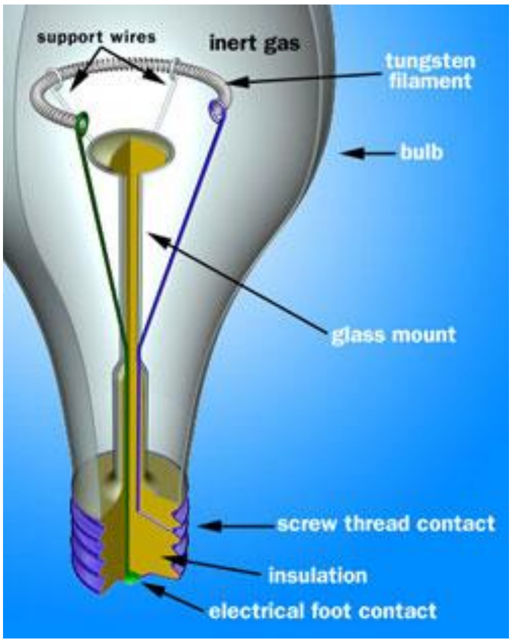
2. ELECTRIC CURRENT

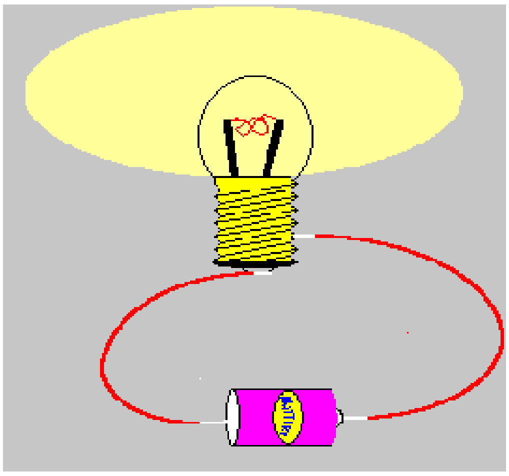
In all the previous phenomena the electrons have been passing from one object to another without control. Could it be possible that the circulation of the electrons could be better controlled and obtain beneficial effects? We are talking about electric current that has changed our lives completely. Use your imagination and ask yourself this question: what would happen in a big city like Malaga if we did not have electricity , for example, for one month?

A.10. What do you think electric current consists of?

A.11. What do you have to do with a battery and a bulb to produce electric current? How many wires do you need?

A.12. Draw the inside of a bulb. What happens when the bulb lights up? What would happen if the bulb did not have its glass protection?



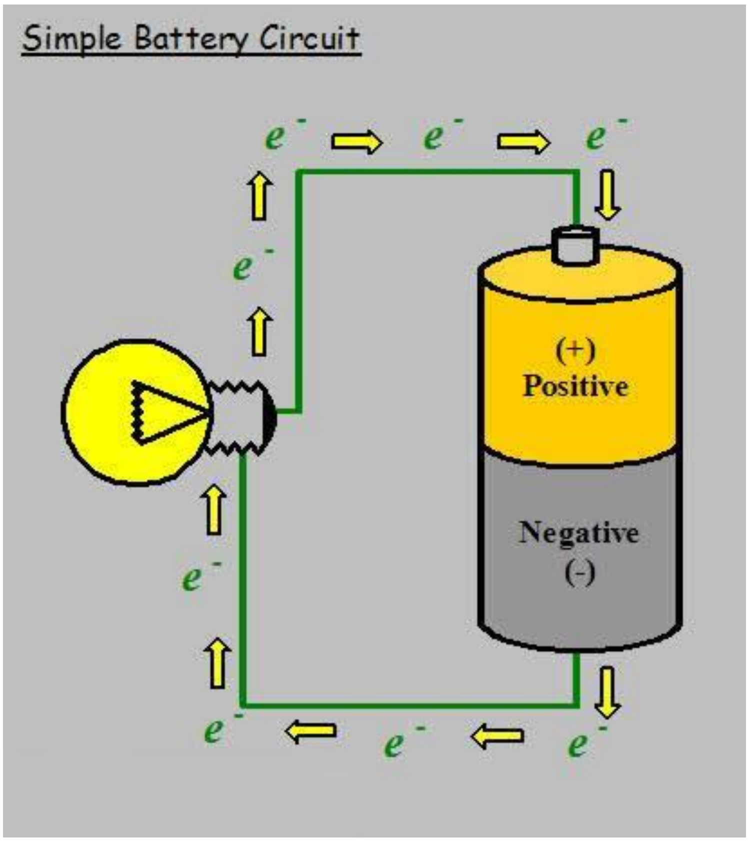


A.13. Look at the picture above:

a) Which side has more electrons in the wire: the right or the left? Explain your answer.

b) Draw lines indicating the way you think the electrons current flows in each branch of the circuit.

Now reconsider the answers in A.13 by looking at the following picture:



A.14. In a simple circuit like the previous one, answer these questions:

a) What do you think is the role of the battery?

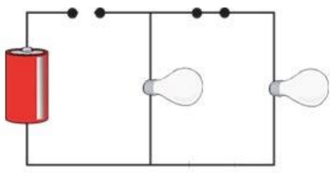
b) And of the bulb?

c) And of the wires?

d) Do not take into account the energy lost through the wires and answer these questions: what relationship do you think exists between the energy that the battery produces and the energy that is lost in the bulb? What kind of energetic transformation happens in the circuit?

[This video] explains electricity as the flow of atomic particles called electrons. Animations demonstrate electron flow. Batteries are described as chemical devices designed to create electron flow and produce energy to ensure their motion.

A.15. In the following picture draw all the possible directions for the different currents when we switch on/off each switch.



The general conclusion is that in order to have an electric current it is necessary to have a generator that keeps the electrons moving and a closed circuit where they can circulate. There will not be a current if the circuit is open.

To properly understand every previous concept, let´s sum up all the ideas that we have been using:

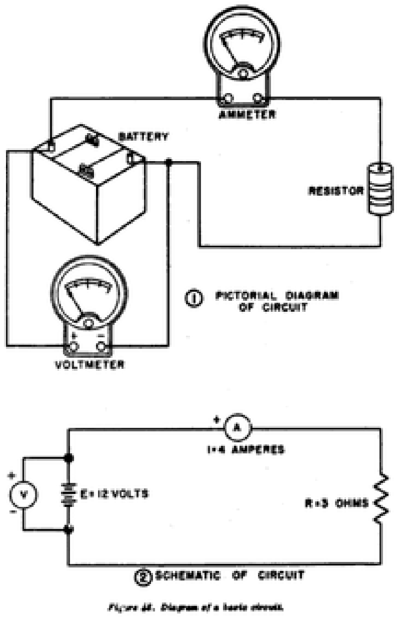
- The battery makes the electrons move: the same number of electrons that come out of the negative pole go into the positive one. The total number of electrons in the battery and in the circuit is constant so the battery does not add electrons.
- The battery gives energy to the electrons by means of a chemical reaction and then we say that the battery moves the electrons thanks to its internal energy.
- The electrons do not decrease in number in the different elements of the circuit, as for example in a bulb, but they do lose energy.
- The energy lost in a bulb turns into internal energy (heat) and irradiation energy (light).
- The wires are the means of transport for the electrons and they are the ones that move. The metal atoms´ nucleuses with a positive charge do not move.
- All the elements have to have a closed circuit so that there is a current.
- The type of electrical current that we have studied is called continuous current because it circulates in the same direction. The current we have at home is called an alternating current because the electrons change their direction many times per second.
- If a material like copper in the wires lets the electrons circulate, we will say that it is a current conducting material. In the opposite case we will say that it is an insulator.

The following flash animation compares a simple continuous current circuit with a water circuit. The energy gain in water is represented by an elevation in the water level (water gains potential energy) and the waste of this energy in water moves a turbine that would represent the role of a bulb, the element that consumes energy in the circuit. The animation lets you observe the effect of an increase in voltage in a battery that would be similar to throwing water from a high place. The following video compares electric current with a flow of marbles; although the main ideas are the same, they are independent of the analogy we use to understand this phenomenon.

The following link presents a complete list of symbols used in circuits. At first you only have to learn the following ones: wires; wires, connected, crossing; wires, not connected, crossing; switch; battery; ground; resistor; fuse; voltmeter and ammeter. The symbol for a light bulb is:

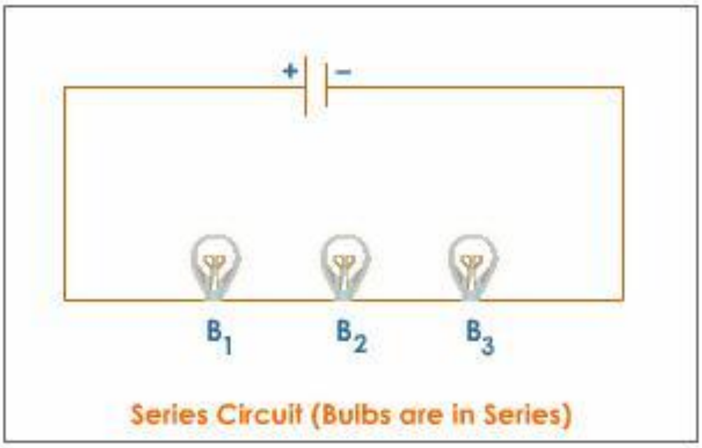
A.16. Complete a table with all the symbols you need to learn.

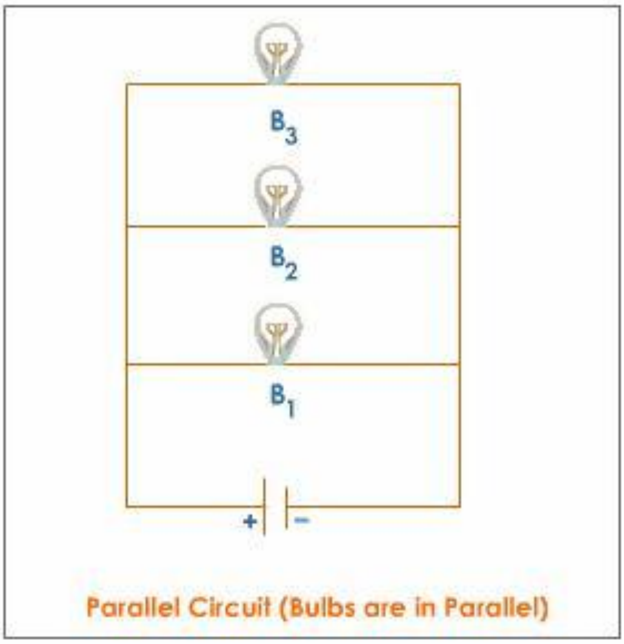
In general terms, it will be easier and more useful to draw the representation with symbols than draw a pictorial representation of a circuit:



3. CONNECTIONS IN SERIES AND IN PARALLEL

We will say that two bulbs are connnected in series if every pole of the battery is connected to a different bulb. Then, the same electron has to pass and give energy to each of them. We will say that they are in parallel if every bulb is connected to both poles of the battery, so the flow of electrons will be delivered to each of them, giving every electron all of its energy to the bulb that it has to pass through.





A.17. Answer these questions after viewing the following video:

a) Why are bulbs in series less bright than a witness bulb connected to a generator?

b) Why do bulbs in series stop shining if one of them is taken away?

c) Why do bulbs in parallel shine the same as a witness bulb?

d) Why can bulbs in parallel be disconnected and not affect the others?

e) How do you think the different electrical elements will be connected in the installation of a house? Why?

4. MAGNITUDES THAT CHARACTERIZE THE ELECTRIC CURRENT

4.1. Voltage

We have just learnt that the battery gives energy that is later transformed in different ways in the different elements of a circuit or in an electric installation: bulbs, heaters, HI-FIs, computers,etc. The electric charge unit in the Units International System is the Coulomb (C), which is equivalent to the electric charge that a huge number of electrons transport: 6. 25 $\cdot 10^{25}$ electrons.

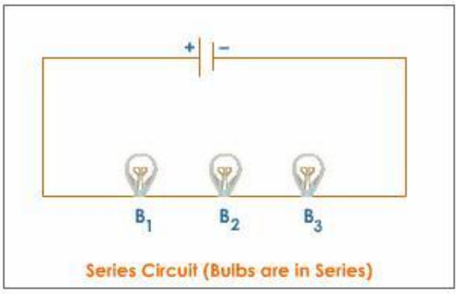
We will say that there is 1 **Volt** between the connections in a battery if this one gives 1 joule of energy to every coulomb of charge that passes by it. We will say that between the connections in a bulb there is 1 volt if in the bulb 1 joule of energy is consumed (in other words, it is transformed into heat and light) for every coulomb of charge that passes through the bulb.

A.18. Look at the battery in the picture:

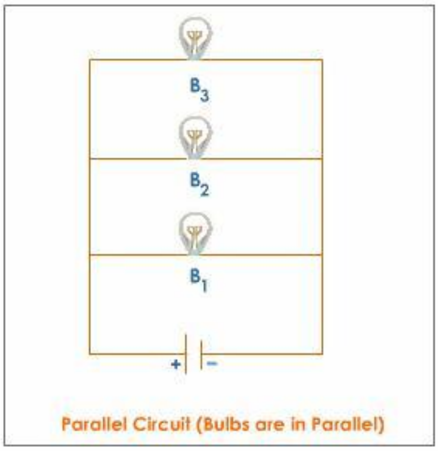
a) What does the voltage 4.5 V mean?

b) How much will the internal energy have decreased in the battery if 12 C of charge passes through it?

c) If the previous battery is connected to a circuit, how much energy will it have transferred if it circulates $1.25 \cdot 10^{26}$ electrons?



A.19.	a) Is it possible in the series circuit above that the battery had a voltage of 9 V and that the voltage in the extremes of every one of the identical bulbs was 4 V? b) If only energy is transferred to the bulbs, and the voltage of the battery is 9 V, and the three bulbs are identical, what will the voltages be in the extremes of the three bulbs?



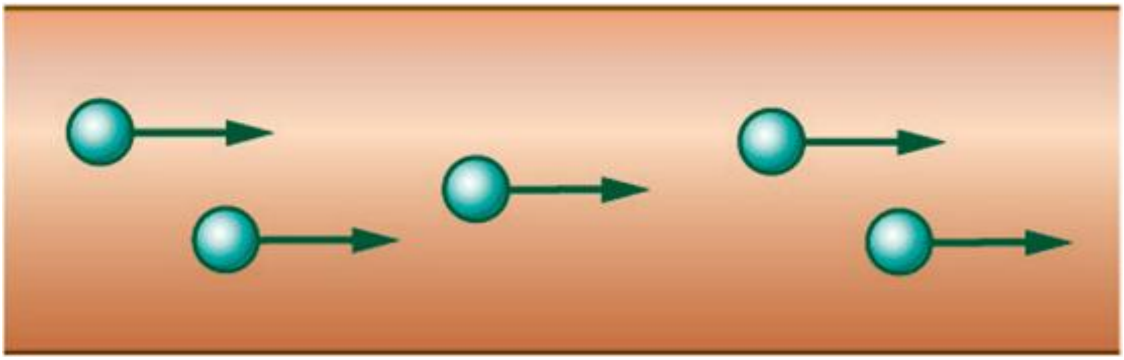
A.20.	a) In the parallel circuit of the picture above, if the battery is 9 V, what will the voltage between the extremes of every bulb be? b) How is it possible that the battery causes the same voltage in the extremes of the three bulbs? c) Draw a picture of the flow of electrons that you think will occur in the different points of the circuit.

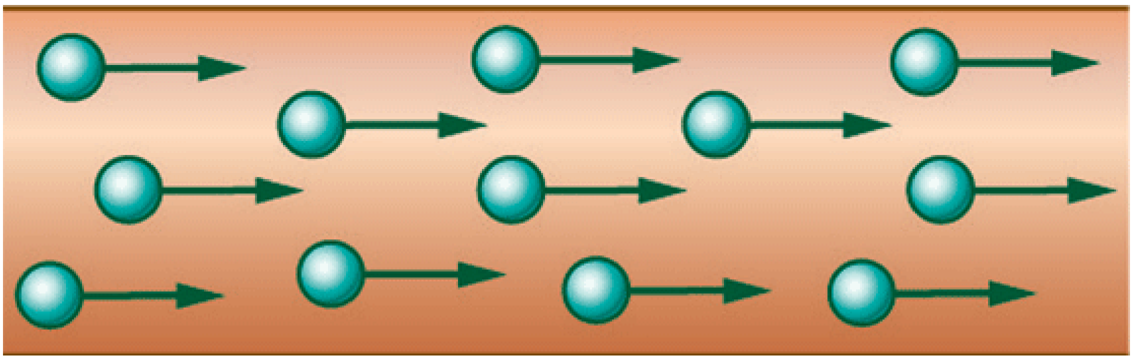
The voltage measures are made with a device called a voltmeter that has to be connected in parallel, touching both extremes of the element that we want to measure. More information about this device in the following link.

4.2. Current intensity

Current intensity is defined as the amount of charge that passes through a specific point of a conductor in the time unit. Have you ever seen wires crossing a road? They measure the number of cars that pass over them per time unit (for example every hour) and this information is used to know the traffic intensity in different places.

Imagine that the cars are electrons, the road is the conductor that electrons pass through and the considered point is the place where the wires have been situated. What does it mean if we say the traffic intensity is high or low? Try to explain it.



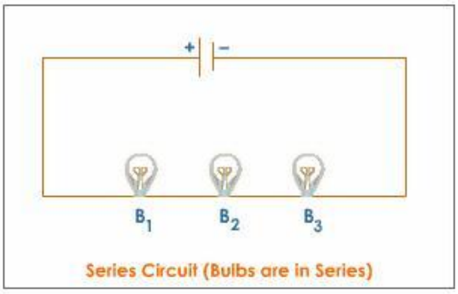


Talking about electrons, current intensity will be calculated dividing the amount of charge (in coulombs) that is passing through a concrete point per time (in seconds). So the current intensity unit in the Unit International System is the **Ampere** (A). 1A means that one coulomb has circulated per second at a specific point.

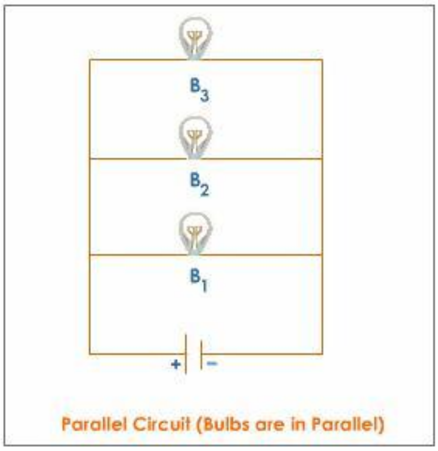
A.21. a) What does it mean if we say that a current intensity of 5 A passes by a point in the circuit?

b) How much charge will pass by that point in 10 seconds?

c) How many electrons will pass by that point in that time?



A.22. In the series circuit of the picture above, what do you think the current intensity that passes by every one of the bulbs will be?



A.23. In the parallel circuit of the picture above, what do you think the current intensity that passes by every bulb will be? Take into account that the bulbs are identical.

The intensity current measures are made by a device called an ammeter that has to be connected in series with the rest of the circuit, so that all the current passes through it. There is more information about this measuring device in the following link.

A.24. The parallel circuit of the previous activity draws an electric sketch putting an ammeter in different positions. If in one of the branches where there is a bulb the ammeter marks 0,1 A ,what will it mark at different points ? Remember to consider that the three bulbs are the same.

4.3. Power

Power measures the quantity of energy that is transferred per time unit and it gives us an idea of the speed energy it is transferred at. The power unit in the Unit International System is the **Watt** (W). Any device has a power of 1 W if it is capable of transferring 1 joule of energy every second.

A.25. a) What does it mean if we say an electric radiator has a power of 1000 W?

b) What will be the difference from one of 2000 W? How can we notice it?

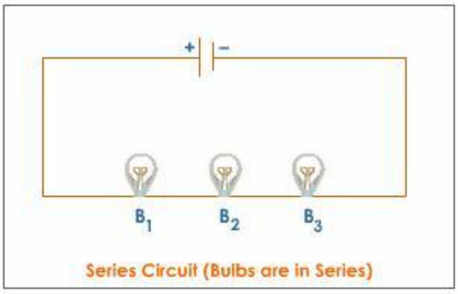
c) What is the difference between a 50 W bulb and a 100 W one? How do you notice the difference?

A.26. Taking into account the units, deduce the mathematical relationship that there must be between voltage, current intensity and electric power. Use it to calculate the electrical power of an ordinary locomotive that works at a 3000 V voltage and a 1900 A current intensity. Repeat the calculation for the AVE locomotive that works at a 25000 V and 350 A. Which one is more powerful? How can we notice this bigger power?

4.4. Electrical resistance

This magnitude gives us an idea of the difficulty that a specific object has when the current passes through it, which is measured in **Ohms** by the Unit System International (Ω). An object with many ohms has a greater resistance when the current passes (insulator). An object with fewer ohms allows the charge to pass without difficulty (conductor).

The following flash animation presents different matters for you to predict and check their insulating or conducting characteristics. Another flash animation presents a classification of the matters into conductors, insulators and semiconductors. The last category would be a kind of intermediate situation. The most important thing is to understand the reasons why matter is a conductor or an insulator. These reasons are related to the force the atoms´ nucleuses attract their electrons: if it is very weak, the electrons can move easily and so the matter is a good conductor; if the electrons are strongly connected to the nucleuses they will not be able to move, so we will have an insulating matter.

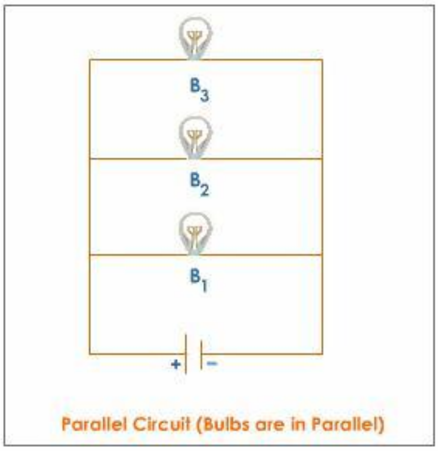


A.27. Let´s now suppose that the electric resistance of the three bulbs in the series of the circuit in the picture increases from B1 to B3 (that is B1< B2< B3):

a) In which bulb will the electrons lose more energy? In which, less?

b) What will happen with that energy?

c) Make a prediction of the brightness that we will expect in each one.



A.28. Let´s now suppose that the electrical resistance of the three bulbs in parallel of the circuit in the picture increases from B1 to B3 (that is B1< B2< B3):

a) Which bulb do you think that the electrons will run more easily by? Which one will be more difficult?

b) Which one will have a bigger current intensity?

c) Make a prediction of the brightness that we will expect in each one.

A.29. Why do you think that the birds do not suffer a shock when resting on power lines?

4.5. Ohm's Law

If your answers to the last activities were right , you have used, without noticing it, at least qualitatively, what is known as the most important equation about electricity, Ohm´s Law.

$$I = \frac{V}{R}$$

The following video will show you how to use it.

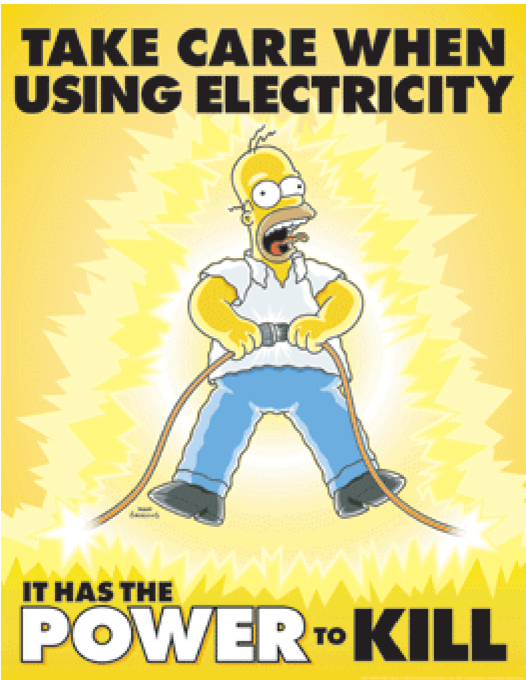
A.30. Connect an electrical heater to a plug that gives a 220 V voltage and with an amperimeter we check that is circulating a 4 A current intensity.

a) Which is the electrical resistance of the heater?

b) If we connect the same heater in the USA with a 125 V voltage, what is the electrical resistance? Which current intensity will circulate now?

c) In which of the two cases will it be more dangerous to suffer an electrical discharge?

5. ELECTRICITY AND SECURITY



A.31. Taking the following web page as a source of information, answer the following questions:

a) What magnitude should you take into account when considering the possible lethal effects of an electrical discharge?

b) What values can be considered lethal?

c) How does an earth wire protect us if we suffer an electrical contact?

d) And a fuse?

e) Why must electricians wear rubber shoes?

A.32. Explain briefly what is the function of a residual-current device (RCD), according to the following link.

A.33. Why is water so dangerous in relation to electricity even though pure water it is not an electrical current conductor? Look for information about this problem.

In the following link you can find an easy game about dangerous behavior at home related to electricity. The following web pages (1, 2) show some pieces of advice to follow in order to avoid problems with electricity.

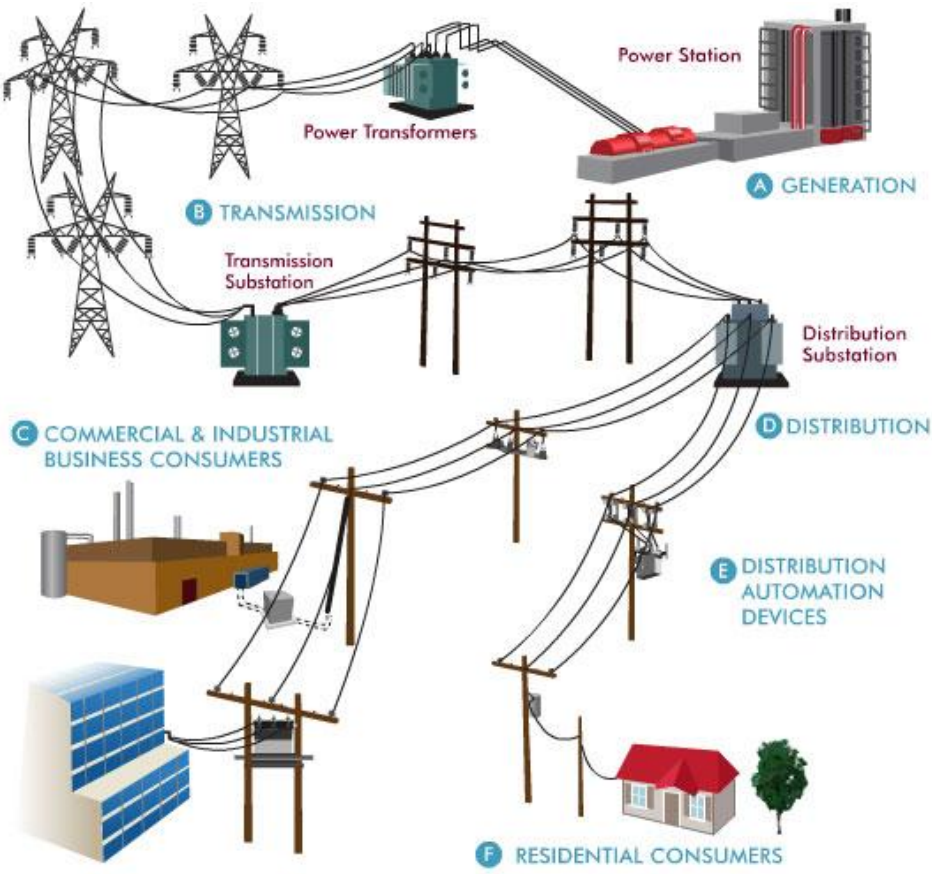
6. ELECTRIC ENERGY GENERATION

Have you ever seen a bike´s dynamo? It is the easiest system of electrical current production that we use in our daily life.

On a greater scale this system is similar but much bigger. It is a turbine that can be moved by water, wind or steam.

(A steam turbine in the picture)

The turbine makes the coil turn in the presence of a magnet (or electromagnet) and then the alternating current occurs (you can see it in the next flash animation). This current arrives at our houses after several transformations and manipulations. You can see a complete sketch of the complete process of the current transformation in the diagram below.



A.34. Looking at the list of countries related to their electricity consumption in the following link, what are your conclusions about the relationships between political and military power, standard of living and electricity consumption? Distinguish between data of the countries' total consumption and the average consumption per capita throughout your analysis. Which of these two types of data do you think gives a more real idea of the standard of living? What about the political and military power? Why?

7. WEBQUESTS

WebQuest 1: WebQuest on Electricity

WebQuest 2: Electricity The shocking truth!

WebQuest 3: Electricity WebQuest

WebQuest 4: It's Electric!

WebQuest 5: Electric Energy

8. QUIZZES

Quiz 1: Electricity Knowledge Quiz

Quiz 2: Electricity Quiz

Quiz 3: Shock yourself with this electricity quiz!

Quiz 4: Electricity Quiz

Quiz 5: Who Wants To Be Millionaire?

Quiz 6: Electricity Jeopardy

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http://www.youtube.com/watch?v=-mHLvtGjum4
http://www.youtube.com/watch?v=apHkG4T6QHM
http://www.youtube.com/watch?v=bSEOOMs5VNU
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http://www.youtube.com/watch?v=pJ36EtABLAk
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http://www.youtube.com/watch?v=WS9ISUXBsa8&feature=related
http://www.youtube.com/watch?v=ymRwIUNlEL4
http://www.zephyrus.co.uk/electricityquiz.html

APPENDIX 1: GENERAL VOCABULARY OF THE UNIT

APPENDIX 2: SPECIFIC VOCABULARY OF THE UNIT