Physics and Chemistry 2º ESO

2023-2024

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Unit 1. Matter

Unit 2. Motion and forces

Unit 3. Energy

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Curso 2019-2020

Unit 1. The matter

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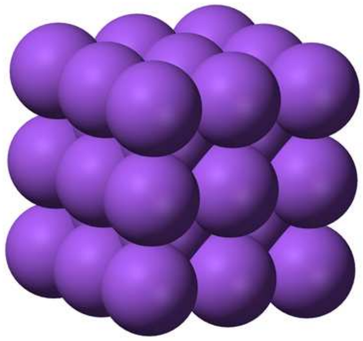
Unit 1. The matter

Since you get up from bed in the morning, you don´t stop seeing objects of every kind: chairs, glasses, furniture, bottles full of water, coins… All objects are made of matter: matter is everything that has **mass** and takes up **space**.

A **substance** is an specific type of matter that is different from any other (water, paper, wood, iron ...) and that forms **materials** which can be used to make objects.

But, how can you know from what substance these objects are made in each case? How can you **differentiate** between substances and **identify** them?



Later you will see the experimental determination of some of the **characteristic properties** of the **substances**, which will be very useful to **identify** them, and you will consider their structure, that is, what you would see if you observed a substance, such as copper sulfate for example, with a powerful microscope. Would you see something similar to a block made up of small balls set in order?

In this unit you will learn to recognize the **model** used to **interpret the properties of matter** and you will relate their characteristics in macroscopic scale (experimental) with the ones in microscopic scale (of particles)

1. The properties of substances

There is a number of **qualitative properties** that are characteristic of each substance and can be useful to identify them: odor (although there are a lot of odorless substances), color (but there are a lot of them which have the same color!), or flavor (but you´d better not taste same of them, as it can be very dangerous!)

The problem that all of these properties have is the fact that they **can´t be measured**: the ability of perception is different for each person. For example, girls have more ability to differentiate colors than boys, the sense of taste and smell is different in each person, etc. So that, these properties only allow us to get an initial idea of the kind of substance we are analysing.

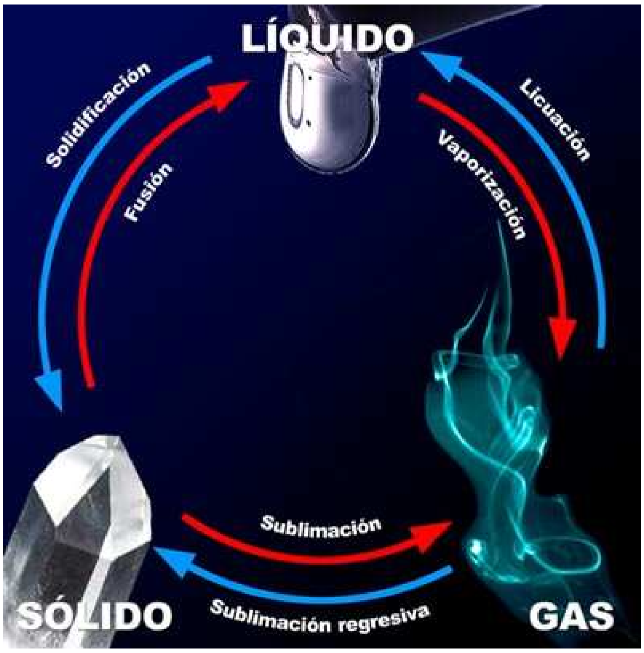
Think of the substance “water”. Its mass and its volume depend on the amount of water you have, but you can have the same mass of water as of any other liquid, or the same volume of two different liquids.

On the other hand, its temperature doesn´t depend on the amount of water. It is the same whether the amount of water is small or big. Besides, you can have different substances at the same temperature.

In summary: none of these three properties are useful to differentiate substances.

1.1 Characteristic properties

Are those which **can be measured**, have a **concrete value** for each substance and **don´t depend on the amount** of matter that we have.



You are going to work with two characteristic properties: **change of state points** and **density.**

In the picture you can see the three **states of matter** and the name of their changes, which you will already know, for sure.

Density measures the relationship between the mass of a substance and its volume. Dense substances have a lot of mass in a determined volume, while low dense substances have little mass in the same volume (**d=m/V**).

The boiling and melting points and the density, are characteristic of a substance. They have a fixed numerical value and don´t change whatever the amount of substance.

As you know, water is a colourless, odorless and tasteless substance, with a melting point of 0ºC and a boiling point of 100ºC. Its density is 1 g/cm^3

In the table you have the values of these three magnitudes in a group of common substances, ordered alphabetically. If you use it, it will be easy to identify a substance. If the values of the melting and boiling points and the density in the table are the same as in our unknown substance, it will be that substance without doubts.

The meaning of the density of substances

It indicates the mass that the specific volume of a substance has. It is usually expressed in grams per cubic centimeter (g/cm^3), per milliliter (g/mL, equivalent quantity when talking about a liquid), or per liter (g/L, also for liquids).

IS (International System) unit is kg/m^{3}but it is used less often because its numerical value is 1000 times bigger: it is easier to say that the density of aluminum is 2,7 g/cm^3 than 2700 kg/m^3.

2. The measuring process

Properties that can be measured are called **magnitudes**. You are going to work with some of them, which you will determine in an easy way: mass, length, volume, temperature, time and density.

Some of these magnitudes are determined from other ones and are called derived units: volume is calculated as “length to the third” (the volume of a cube is calculated as its side elevated to the third!), and density is the relationship between mass and volume.

2.1 The International System of Units

We use **the International System of Units (IS)**, which has a unit for each magnitude, used as a universal reference, so it can be understood in every country.

Magnitud	Símbolo	Unidad SI	Símbolo
Longitud	l	metro	m
Masa	m	kilogramo	kg
Temperatura	T	kelvin	K
Tiempo	t	segundo	s
Volumen	V	metro cúbico	m^3

Observe that temperature is measured in Kelvin in the IS. It is a centigrade scale like Celsius (ºC) although this one is more common in our daily life. The equivalence between these two magnitudes is 0 ºC are 273 K, in order to change one to the other, you can use the relationship: **T(K) = T(ºC) + 273**.

Writing units

It is necessary that **you always write the units** of the magnitudes, because a number without units has no practical meaning.

2.2 Scientific notation

It is often used when we work with very big o very small numbers. It is used in calculators and spreadsheets, and you need to know how to work with it. For the moment, you will only use it with **numbers 1000 times bigger or smaller.**

In scientific notation, 1500 is written as $1{,}5\ 10^3$, and 0,0025 is written as $2{,}5\ 10^{-3}$: there is only one number before the decimal coma, and the base ten to a power that is the number of digits after the coma in the original number if it is bigger tan 1, or before the coma if it is smaller tan 1.

Decimal dot or decimal coma?

To indicate decimals, you can use both decimal dot (calculators) or decimal coma (spreadsheets), but written downsides, not upsides. Don´t use the dot to separate thousands. It is right to write 1,25 or 1.25, but it is wrong to write 1´25 or one million as 1.000.000 (1 000 000 is allowed)

2.3 Multiples and submultiples

A lot of times we use units that are multiples or submultiples of the original number in order to make it easier to work with them. You need to know how to work with numbers from 1000 times bigger than the original to numbers 1000 times smaller, as you can see in the table, where you can find other examples that you may already know.

Número	10^n	Prefijo	Abreviatura	Ejemplo
1000000000	10^9	giga	G	gigabyte (GB)
1000000	10^6	mega	M	megavatio (MW)
1000	10^3	kilo	k	kilogramo (kg)
100	10^2	hecto	h	hectopascal (hPa)
10	10^1	deca	da	decámetro (dam)
0,1	10^{-1}	deci	d	decímetro (dm)
0,01	10^{-2}	centi	c	centímetro (cm)
0,001	10^{-3}	mili	m	miligramo (mg)
0,000001	10^{-6}	micro	µ	microgramo (µg)
0,000000001	10^{-9}	nano	n	nanosegundo (ns)

2.4 Conversion factors

To express a measure in a different unit, you have to multiply the initial measure by the conversion factor that relates the two units.

How do you transform 11,5 kilometers in meters? You need to know the equivalence between the two units, very easy in this case: 1 km = 1000 m. As the two quantities are the same, their quotient is the unit, and you can write the relationship in two ways:

$$\frac{1\ km}{1000\ m} = 1 \quad \frac{1000\ m}{1\ km} = 1$$

Now you just have to multiply the initial quantity by the conversion factor to eliminate the initial unit and obtain the final one.

$$11{,}5\ km \frac{1000\ m}{1\ km} = 11500\ m$$

You have to notice that the unit km appears in the numerator and the denominator, so it is eliminated and you obtain the unit m, which is the unit you want to get in the end. Notice also that **multiplying by a conversion factor is multiplying by the unit!**

Changing units with conversion factors

To express a quantity in a different unit, you have to multiply the initial quantity by the conversion factor that relates the two units, so you can eliminate the initial unit and obtain the unit you want.

2.5 Significant numbers

When you do a measure, you can express it with more or less significant numbers depending on the instrument used: if a scale appreciates until tenths of a gram and indicates 14,6 g, the value has three significant numbers. If you solve a problem with this value, the result will have a maximum of three significant numbers, and two if you use a value with two significant numbers.

How many significant numbers do we have to write?

a) When you measure something, as many as the instrument provides us.
b) When you do calculations with more than one magnitude, you must give the result with the lower quantity of significant numbers of all the magnitudes you have used.

Besides, you have to consider the sensitivity of the instrument. For example, if you measure masses with 3 significant numbers (10,2 g, 28,5 g, etc) in a scale that appreciates tenths of a gram, the result can´t have two decimal numbers, as the scale only appreciates one: 3,45 g or 0,27 g won´t be valid results.

3. Identifying solids

To determine the density, you need to determine the mass and the volume of the solid. The result is expressed in g/cm^3 o kg/m^3 ($1\ g/cm^3 = 1000\ kg/m^3$). With this value and the data table you can identify the substance the solid is made of.

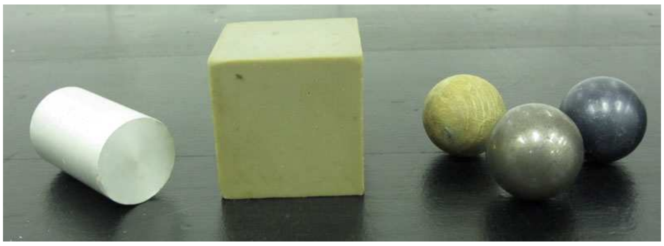
The scale

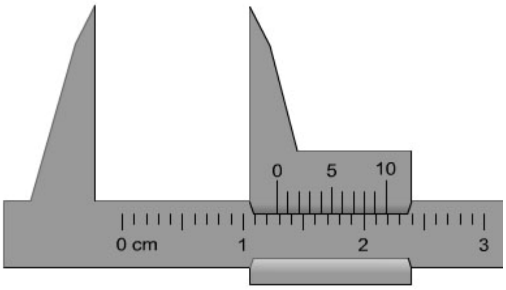
The maximum mass that can be measured by a scale is its capacity. The minimum mass that it is able to detect is its sensitivity. Scholar laboratories normally have scales with a capacity of 500 g and a sensitivity of 0,1 g.

3.1 Measuring the density of regular solids

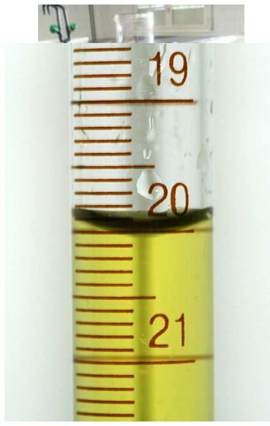
Measurement of the mass: press the tare button, set the solid and read the mass.

Measurement of volume: measure with a caliper or a flexometer its side, edge, diameter, etc., depending on the geometric shape of the object. Use the appropriate formula (V = hπr2 in a cylinder, $V=a^3$ in a cube, $V=4/3\ \pi r^3$ in a sphere).





Look at the picture of the caliper. It marks 1,28 cm. To know it, you have to look at the 0 in the mobile scale (the superior one) which is between 1,2 and 1,3, but closer to 1,3. Now, look for the marks in both scales, superior and inferior, that are in the same position. In this case, is the eighth mark in the superior scale, so the value is 1,28 cm.



3.2 And what if the solid is irregular?

The volume is determined by immersion in water: we add water to the measuring cylinder, we read the volume and then we introduce the object. Its volume will be the difference between the two values taken.

Naturally, this method is only useful for small objects that fit inside the measuring cylinders.

To measure the mass, we weight the measuring cylinder with the liquid and then with the solid. The mass of the solid will be the difference between the two measures.

Measuring the volume of liquids with measuring cylinders and burettes

When we add water to a narrow tube, we observe that the surface of the liquid forms a curve called "meniscus". To read the value properly, you have to put the measuring cylinder or burette at eye-level and write down the value in the lower part of the meniscus.

In the picture, the value is 20,0 mL. Notice that the burette appreciates until 0,1 mL

3.3 What liquid is it?

You have to put a measuring cylinder in the scale, tare, add the liquid until a given volume and measure the mass of the liquid. As you already know the mass and the volume, you can calculate the density and identify the liquid using the data table.

3.4 Boling points

As there are liquids with similar densities, sometimes we need to measure also the boiling point to be able to differentiate them. Notice that while the substance is changing its state, the temperature stays constant.

3.5 Temperature and physical states

It is very important that you learn to deduce the physical state of a substance by knowing its boiling and melting points, which are in the data table.

Think of the case of water. It melts at 0ºC and boils at 100ºC. What is its physical state at -34ºC? The temperature is lower than the melting point, so it is in solid state. And if the water is in liquid state, the temperature will be between 0ºC and 100ºC. At a temperature of 145ºC, which is higher than the boiling point, its state is gaseous.

In what state is it?

- If the temperature is lower tan the meltingpoint, the substance is in **solid state**.
- If the temperature is higher tan the melting point but lower tan the boiling point, the substance is in **liquid state**.
- If the temperature is higher tan the boiling point, it is in **gaseous state**.

4. A model for the matter

To explain why the substances have characteristic properties (density, points of change of state, tendency to evaporate, solubility in water) we start studying experimentally the different properties of gases.

Propiedad	Sólidos	Líquidos	Gases
Volumen	Fijo	Fijo	Ocupan totalmente el recipiente
Forma	Fijo	Se adaptan al recipiente	Se adaptan al recipiente
Compresibilidad	Nula	Nula	Grande
Densidad	Grande	Grande, menor en general que los sólidos	Muy pequeña

4.1 The pressure of gases

Gaseous state is the easiest to study because in order to explain the situation of a gas inside a closed recipient you only need four magnitudes. You already know three of them: the **quantity** of gas (**n**), the **volume** of the recipient (**V**) and the **temperature** (**T**).

You also need to know he pressure produced by the gas (**P**). What is the meaning of this magnitude?

If you want to cut a piece of plasticine and you have a knife, ¿what should you do? It is sure that you will use the edge of the knife and not the flat part of the blade. If it is sharp, it will be easier to cut, and also if the force you do is bigger.

The pressure is the magnitude that measures the deforming effect of a force, and it is calculated as the relation between the force applied and the surface where it is applied. Using the IS, it is measured in Pascals (Pa) but in the laboratories it is very common to use atmospheres (atm) or mercury millimeters (mm or mm Hg)

The bigger the force applied and the smaller the surface, the bigger the pressure will be.

Using this simple idea it is easy to explain why we leave traces in wooden floors when we walk with needle heels but not if the heel is wider. The weigh is the same, so we apply the same force on the floor, but the support surface is different, so the effect produced is bigger when there is little surface, in the stiletto (high-heel shoes).

TABLA DE DENSIDADES Y TEMPERATURAS DE CAMBIO DE ESTADO DE ALGUNAS SUSTANCIAS

Sustancia	Densidad (g/cm^3)	T de fusión (ºC)	T de ebullición(ºC)
Acetona	0,80	-95	56
Ácido clorhídrico	1,26	-115	85
Ácido nítrico	1,50	-42	83
Ácido sulfúrico	1,83	10	317
Agua	1,00	0	100
Aluminio	2,70	659	1997
Amoniaco	0,00077	-78	-33
Benceno	0,89	6	80
Butano	0,0026	-136	-1
Calcio	1,55	838	1440
Carbono (grafito)	2,25	3527	4200
Cloro	0,003	-102	-34
Cloruro de sodio	2,16	801	1413
Cobre	8,94	1083	2582
Dióxido de azufre	0,0029	-75	-10
Dióxido de carbono	0,002	-156	-79
Estaño	7,31	232	2270
Etanol	0,79	-117	79
Glicerina	1,26	20	290
Hidrógeno	0,00009	-259	-253
Hierro	7,89	1539	3000
Mercurio	13,60	-39	356
Níquel	8,96	1083	2595
Nitrógeno	0,0013	-210	-196
Octano	0,70	-57	126
Oro	19,3	1063	2965
Óxido de calcio	3,30	2580	2850
Oxígeno	0,0014	-218	-188
Plata	10,50	961	2210
Platino	21,40	1769	4530
Plomo	11,34	328	1750
Sodio	0,70	98	892

What does pressure measure?

Pressure measures the force by unit of surface. It is calculated by dividing the force applied by the surface where it is applied: **P=F/S**

Compressing the air of a syringe

When you compress an hermetic syringe which contains air and whose tip has been sealed using a drop of glue, you observe that the volume occupied by the gas decreases while you push the plunger of the syringe, and that each time you need to apply more force on the same surface, which means more pressure. When you stop pushing, the gas expands until it comes back to the original situation. In summary, when the pressure increases, the volume decreases.

Heating a beach ball

If you leave a deflated ball in the sun, you will observe that it inflates. When the temperature increases, the volume occupied by the gas increases too.

Heating a bottle

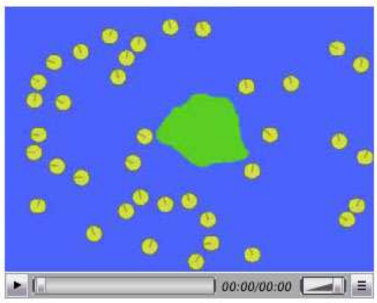
But if the recipient has a fixed volume, when you heat it, the pressure increases and the bottle can explode if it can´t resist the pressure reached. So, when the temperature increases, the pressure increases too.

Injecting air

If you blow air inside a balloon, it inflates, but if it is a bottle with fixed volume, the pressure increases.

In summary, the four magnitudes are related: **the pressure produced by a gas is higher when the amount of gas and the temperature are higher, and when the volume of the recipient is lower**.

4. 2 The model of particles



The accepted explanation nowadays is that matter is made of particles so small that they can´t be seen directly by human eye. With the picture on the right you will understand the process: The big particle is the one we can see, and the small ones are the ones we can´t see, but the small ones move in a disordered way and, when they hit the big particle, they make it move. In this way, the air particles are the ones that cause the smaller particles (that seem to be suspended in the air) to move. This disordered movement of particles is called **Brownian motion**

Principles of the model of particles

1. Matter is made of very small and invisible particles.

2. All the particles of a substance are equal to each other, but different from those of other substances. For example, they differ in the mass they have.

3. The particles are in constant motion due to the thermal agitation, so when the temperature increases, they move faster.

4. There are forces of attraction between particles, which decrease quickly with distance.

4.3 Properties of substances

As the proposed model says, particles move faster when the temperature of the substance is higher. The effect can be seen especially in the case of gases. Speed is a property of particles, while temperature is a property of the substance made of these particles

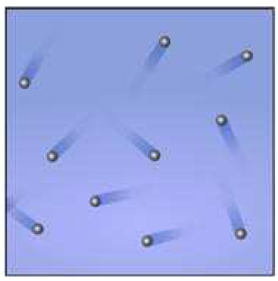
In solids, particles are ordered regularly, forming macroscopic structures called crystals. In liquids, particles are more disordered, and in gases the disorder is total.

Partículas y estados físicos

Sólido	Líquido	Gas
Ordenadas	Desordenadas	Desordenadas
Cercanas entre sí	Cercanas entre sí	Muy lejanas entre ellas
Velocidad casi nula	Velocidad pequeña	Velocidad muy grande
Se atraen entre ellas	Atracción media	No se atraen

4.4 Pure substances and mixtures

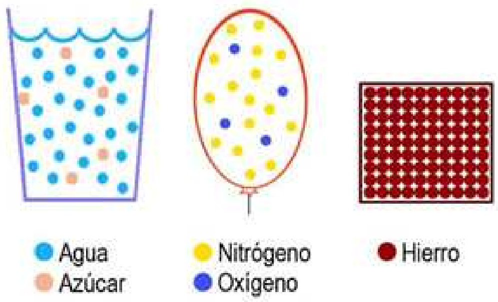
It is easy to represent the substances in a recipient through a particle diagram.A spray bottle filledwith gas may be represented as a square box with circles representing the particles of gas.



A substance is **pure** if is made by only one substance and one kind of particles. If there is more than a substance and so, more than one kind of particles, it is a **mixture**.

If the substances in a mixture are equally distributed through the mixture, it is **homogeneous**, while if the different kind of particles can be seen just looking at them, it is **heterogeneous**.

The diagram on the left represents a glass of water with sugar. Most of the particles are water. As there are two kinds of particles equally distributed, it is an homogeneous mixture.



In the middle there is a diagram representing a balloon filled with air, which is made mainly by two gases: oxygen and nitrogen (there are very small quantities of water, CO_2 and other gases). It is also an homogeneous mixture.

On the right there is a piece of iron, which is of course a pure substance, as it is made only by one kind of particles.

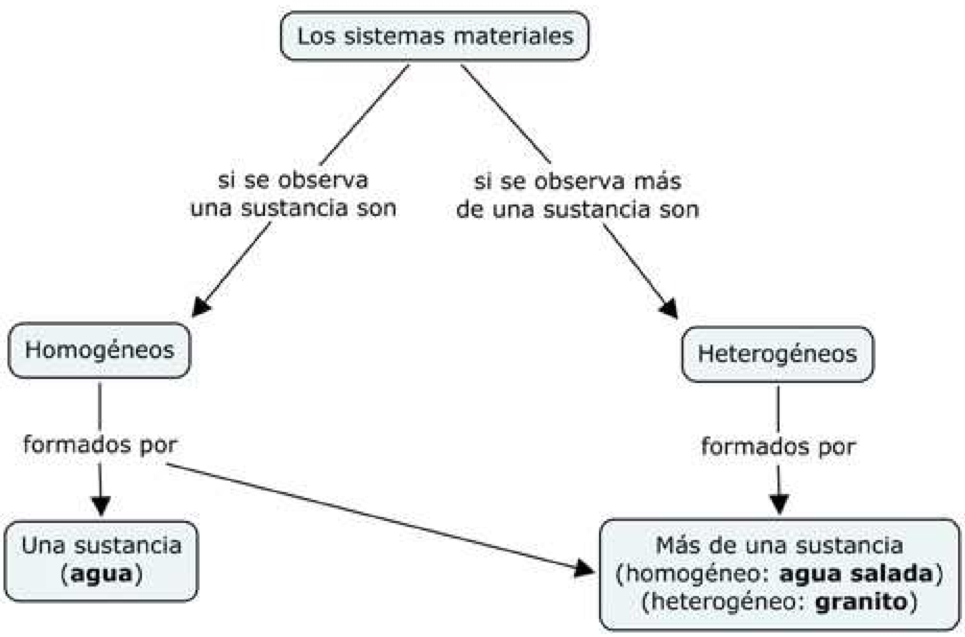
Pure substances and mixtures

The conceptual diagram gives us an experimental vision of homogeneous and heterogeneous systems, depending on if we observe one substance (water, but also salty water), or more than one (granite). Nevertheless, salty water is a mixture of two substances (salt and water), although we can´t differentiate them just looking at it.

A substance is **pure** if is made by only one substance and one kind of particles. If there is more than a substance and so, more than one kind of particles, it is a **mixture**.

If the substances in a mixture are equally distributed through the mixture, it is **homogeneous**, while if they can be seen different just looking at them, it is **heterogeneous**.

Homogeneous mixtures are often called **dissolutions**, where the component in higher proportion is the **solvent**, and the component in lower proportion is the **solute** (in a dissolution of sugar in water, water is the solvent and sugar is the solute).



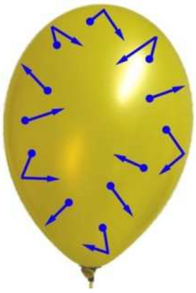
4.5 Diagrams of particles

The diagrams of particles must reflect the physical state of the represented substance.

Solids

Observe different crystalline solids. In every case there is a geometric structure on a macroscopic scale of cubic, prismatic or other shapes.

It seem logical to suppose that this happens because the particles that form each substance are ordered at microscopic scale, and when there is a number of them big enough, we can see the crystal, which reproduces that geometric ordering.



Gases

In the case of the gas inside the balloon, there is no regular structure because the particles move quickly and in a disordered way, hitting the wall of the balloon to keep it inflated.

Liquids

In liquids, the diagrams of particles are different if the substance dissolves, like sugar, or if it doesn´t, like marble. Look at the picture where there is a representation of an homogeneous and an heterogeneous mixture, where the piece of marble not dissolved can be seen easily.

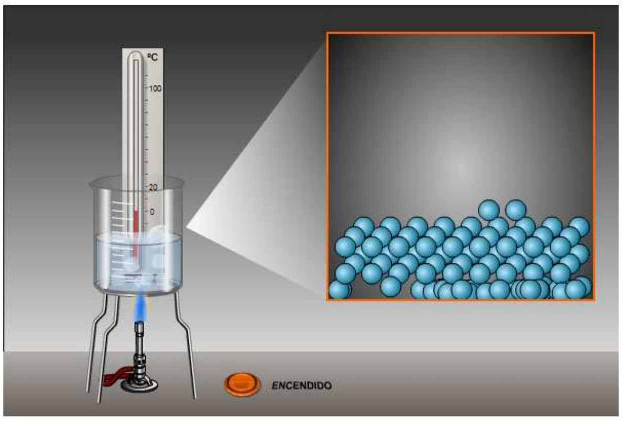
You can represent similar diagrams in other cases that you know: oxygen is dissolved in water (so that fish can breathe), whose diagram would be similar to the diagram for sugar dissolved in water, as it is an homogeneous mixture. Another similar diagram could be the one for alcoholic drinks, where alcohol mixes with water.

4.6 Physical states and changes of state

You have applied the model for solids, liquids and gases. Now it is the time to use it also to interpret the changes of state. In the picture you have ice, liquid water and water vapor. Ice melts at 0ºC and water boils at 100ºC. It is also possible to study the condensation of vapor and solidification of water.

Use the simulation to observe how these changes of state are produced from an experimental point of view, paying special attention to the variations of temperature during the process.

Notice that the energy in the form of heat supplied by the Bunsen burner is used to heat the substance, so the particles start to move faster and are more separated each time.



To explain the melting of ice, the particles separate a little, so they can move like you can see in the simulation. In order to do that, the need to overcome the attraction between particles in solid state.

Once the melting point is reached, the distance between particles gets bigger as they move faster, so little by little the substance changes from solid state to liquid state, and all the energy is used for this process, that´s why the temperature doesn´t get hotter. Once all the ice is melted, the water starts to heat again and starts to evaporate at low temperature, although it doesn´t finish until the boiling point is reached.

4.7 Explanation of experimental facts

The two main applications of every model are:

- **Explaining the observed facts**

-**Predicting facts that are going to happen**.

There is a balloon adjusted to the mouth so that the closure is hermetic. If you heat the flask with the flame of a bunsen burner or on a heating plate, you can see that the balloon swells, and that when you leave it to cool to room temperature, it returns to the initial situation.

This situation and a lot more can be explained using the model of matter that you have studied, and you will also be able to predict what will happen when you act on a system (what will happen to the balloon if you put it inside the freezer?)

5. Working at thelaboratory

The laboratory is a common working place for scientific subjects. It is necessary that you now the working rules, especially everything related to safety, and the materials you are going to use.

Working at the laboratory

The laboratory is a working place where you are going to use instruments and tools that may be dangerous, so you have to follow some rules to assure your own safety and your companions safety.

1. When you arrive to the laboratory, set yourself in a table with your colleagues (one or two) and leave your belongings in the shelf under the table.

2. Check that you have all the materials you need in the tray on the table.

3. Stay in your working place to facilitate mobility within the laboratory.

4. You should use gloves and glasses when you work with chemical products.

5. You mustn´t touch, smell or taste chemical products. It can be very dangerous if you don´t know their properties.

6. Make sure that you use the right substance or material in each case and that you do it correctly.

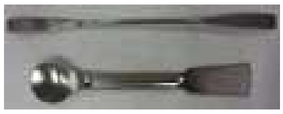
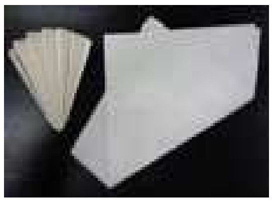
7. Don´t mix products if you are not sure that you have to do it, because you can produce dangerous reactions.

8. Follow the teacher´s instructions to eliminate the residues when you finish your work.

9. Wash your hands before you leave the laboratory.

10. When you finish, leave the material tidy, as you found it.

AND IF YOU HAVE ANY PROBLEM ...
TELL IT IMMEDIATLY TO YOUR TEACHER

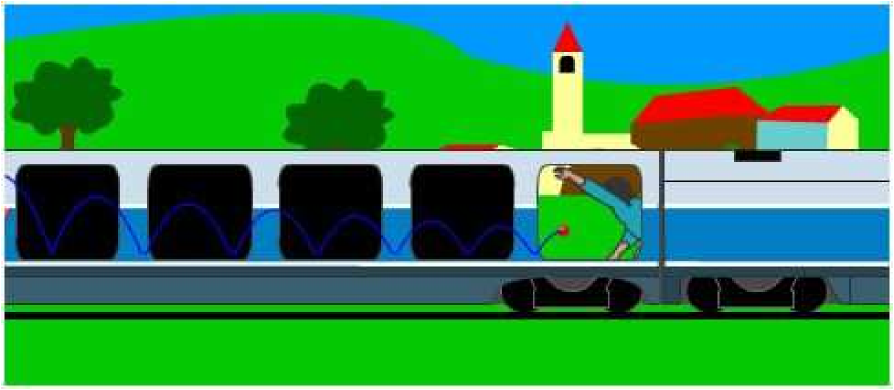
			
Balanza digital	Flexómetro	Calibre	Espátulas
			
Probeta	Matraz aforado	Soporte, pinza de bureta y nuez	Bureta en soporte
			
Vaso de precipitados	Erlenmeyer	Embudo	Embudo de decantación
			
Cápsula de porcelana	Cristalizador	Gafas	Vidrio de reloj
			
Gradilla y tubos de ensayo	Frasco lavador	Mechero Bunsen	Papel de filtro

Unit 2. Motion and forces

In this unit you are going to observe and explain experimental facts related to the motion of objects and the changes caused by the action of forces of different kinds (elastic, gravitational, electric, magnetic...).

1. The speed of mobiles

In the next simulator you can see a child with a ball in his hand. He lets it fall, in a way that you can observe the trajectory of the ball from two points of view: from an observer who is seated inside the train and from the point of view of another observer who is seated outside



Notice that what each of them perceive is different, depending on their situation. The motion is relative.

Units of speed

Although the speed of cars is measured in km/h, its unit in the IS is m/s (distance travelled by the mobile in one second). Its equivalence can be calculated in a very easy way:

$$1\frac{km}{h}=1\frac{1000\,m}{3600\,s}=\frac{1}{3{,}6}\frac{m}{s};\quad 3{,}6\frac{km}{h}=1\frac{m}{s}$$

What is speed?

"The speed of a mobile is x m/s" means that if its speed does not vary it will travel x meters in every second of its movement.

Is a magnitude that measures the speed with which a mobile moves, that is to say, the space travelled by the mobile in a unit of time.

The higher the speed, the more distance the mobile travels in less time.

In IS it is measured in meters per second (m/s) although in daily life is more common to measure it in kilometers per hour (km/h).

It is measured in km/h for the motion of cars and in m/s in I.S. (1 m/s = 3,6 km/h).

1.1 Speed changes

Average speed

In a journey where the speed is not constant, we can calculate the average speed, which is the constant speed the car needs to have in order to travel the same space in the same time.

What is the acceleration?

When the speed of a mobile changes we say that there is acceleration. It measures how quickly the speed changes. If it is big, it means that the speed changes very quickly, increasing or decreasing. If there is no acceleration, the speed is constant.

Instant speed

The average speed relates the space travelled by a mobile in a determined time big enough: if this time is short, as it can be 0,1s, in an interval of time so small the speed can be considered constant and it is called instant speed. Is the one we can see in the speedometers of cars

Acceleration and kinds of motion

If the speed is constant, the motion is uniform.

If the speed increases or decreases, the motion is accelerated, with positive or negative acceleration respectively.

The acceleration measures how quickly the speed changes. It indicates how it changes by unit of time.

If the acceleration is constant, the motion is uniformly accelerated.

What does it happen when a car goes around a curve?

Although its speedometer marks always the same, actually the speed is not constant as there is something that changes in its movement: the direction it takes, as it only doesn´t change in rectilinear movement.

A mobile has acceleration (its speed changes) if we modify the quickness (the distance travelled per unit of time) or the direction of its movement.

1.2 Freefall

What does it happen when we leave an object to fall close to the Earth? What kind of motion does it have? And when we throw it vertically upsides? These kinds of movements are very frequent and know you are going to describe them. Later you will learn why they move this way.

The acceleration of gravity

When a body of small size and aerodynamic shape experiments freefall close to the surface of the Earth, its speed increases in 9,81 meters per second every second. In order to do calculations you can consider that the increase is 10 meters per second every second (10 m/s^2). As when we let it fall its speed is zero, one second later it will be 10 m/s, another second later it will 20 m/s and after three second the speed will be 30 m/s.

This is an experimental value. When you study gravitational forces you will learn that it is not constant: depending on where the free fall happens, it will be different (it is not the same in the Equator than in the Poles, although the difference is small, and it is not the same in the Earth or in the Moon, which is an example where the difference is much bigger).

1.3 Objects that rotate

Objects not only change their position when they move from one place to another: they can also rotate, as it is the case of multimedia discs, centrifuges, drills, satellites or mixers. They normally rotate with constant speed. Now you are going to see how its rotational speed is defined.

Vinyl records were used before music CDs, which occupied their space as they had more capacity and allowed us to choose which song we wanted to hear without the necessity of using mechanical pieces like the arm or the needle of the record-player. They had two different sizes and turned at different speeds: singles and LPs. Nowadays they have become popular again and we can buy them at record stores.

There are two magnitudes related to rotational movements and to every other periodical movement (those where the positions are repeated from time to time, as it happens to pendulums): the period (time that it takes to do a full turn), and frequency (number of turns per second).

Uniform circular motion

The characteristic properties of uniform circular motion (circular trajectory with constant speed) are:

Turning speed (revolutions per minute, rpm).

Period (the time it takes to repeat a complete circle, seconds, s).

Frequency (number of times the movement is repeated per second per second, rps or hertzs, Hz).

2. Forces in your surroundings

There is no body, object or person in the Universe that doesn´t experience a force.Forces act everywhere. Every time you make a movement is because there are forces acting on you, and even when you are quiet you experience different forces. The particles forming your body are also connected thanks to different forces acting amongst all of them, so if forces didn´t exist, living beings wouldn´t exist!

But, **what is a force**? Although is very difficult to define, you are going to see that some of them are very intuitive and others can be understood through the effects they produce.

The effects of forces

In the case of the "soga-tira" or in the car, the people involved are applying a force to the rope or the car, originating a change of the speed of these objects. The bigger the force, the bigger the change they produce.

Forces not only originate changes of the speed of a body as you have just studied, but also a body deforms or changes its direction due to a force.

If you look at the picture, both the sponge and the spring deform due to the action of a force exerted by a person.

In the case of the baseball ball, it changes its direction because of the force exerted by the bat. Depending on how the force is, the ball will move in different ways.

Whatis a force?

A force is **the measure of the interaction between two bodies**, that can cause changes in:

- Their speed.
- Their shape.
- Their direction.

The force is the result of the interaction between the two bodies, but is not something that gets accumulated inside them: a strong person is someone capable of making a great force but people don´t contain the force inside them.

In an easy way, we can say that it is a push or a pull.

2.1 Characteristics of forces

Direction and sense of forces

When we work with forces there are two important concepts, direction and sense, that are different although in daily life we use both with the same meaning.

Direction and sense

It is very important to difference correctly the concepts of direction and sense.

Direction: way followed by a body in its motion.

Sense: each one of the two opposite orientations of a direction.

The intensity of forces

As you have just seen, besides direction and sense, we can define the intensity of a force, that tells us if the force is strong or weak, but saying that a force is strong or very intense doesn't give us a lot of information, so that we define a unit that allows us to assign a numerical value. The intensity of a force is measured in Newton (N) in IS.

Very often in Science, units of measurement have their origin in the name of great scientists that deserve this honor for their achievements. The intensity of a force is measured in Newtons as a tribute to the great Isaac Newton.

In these cases, the name almost always starts with capital letter.

The application point of forces

The application point is the exact place where the force is applied. It is very important to determine the effects of a force on a body. For example, it is not the same to close a door from the extreme than when we are close to the axis.

Characterizing a force

Besides the **direction** and **sense**, in order to know how a force is and the effect that it can produce on a body, we need to know the **application point** and the **intensity**, which informs us about how big it is.

The arrows that represent forces have a different length depending on the intensity of the force, its numerical value in N.

Who was Isaac Newton?

Isaac Newton was one of the greatest minds that humanity has had. He was born in England in 1642, and during his student time he developed a branch of Mathematics, calculus, becoming the best mathematician of his time, although his best known contributions were in the field of Physics.

He performed his first investigations in Optics, proving that white light is made of a composition of the lights of the rainbow colors, and developing a theory that explained the nature of light. He also invented the reflector telescope, which is the base for most of the present telescopes.But, if for same reason he went down in history, it was for discovering the three laws of the movement of the bodies, and for defining the concept of gravity in his famous Universal Gravitation law, establishing the basis of modern science.

It is said that inspiration came to Newton when he saw an apple fall. At that moment he thought that the same force that made objects fall it was the one that kept the Moon in orbit around our planet. Some years later he published his mechanical treatment concluding that they were the same laws that govern the plant movement and the movements in the surface of the Earth.

2.2 Measuring forces

In order to measure forces we use instruments called **dynamometers**.

The dynamometers that we are going to use are very simple. As you will see, it is just a spring that shows the value of the force needed to produce a stretching. You will observe too that the higher the force, the longest the stretching.

If you observe different dynamometers you will see that if the spring is not very consistent, it stretches a lot when little force is applied, but if a spring made ofthick thread, it needs a much bigger force to stretch. It is important to know how long it stretches when we apply a determined force.

Resultant of several forces

When several forces are acting, we can express the action of all of them with a single force that will produce the same effect acting alone. This is call net force or resultant force.

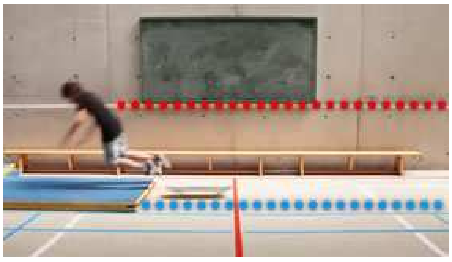
2.3 First law of Newton

Inertia

An idea that persistedfor centuries was that an object moves because a continuous force is being applied to it during all its motion. Today we know that objects tend to stay in the state they are (moving or quiet) unless a force is applied to them.

In the video you can observe how a boy skateboarding follows the first law of Newton in two different situations.

In the first one, the force is applied to the skate making it start moving, but the boy tends to stay quiet, as he was before, because the force is not being applied to him.



In the second situation, the boy is riding the skate, that stops when it hits the pad. The boy keeps moving because the pad hasn´t applied any forces to him. The red dots show his movement, which is the same that he had when he was moving before crashing into the pad (notice that this is very similar to what you have done with the skate).

Firs law of Newton or inertia law

If there are no forces applied to a body, it maintains the same motion than it had initially (it will keep moving straight orit will remain quiet).

Mass and inertia

Mass is a measure of the inertia, the resistance of a body to be set in movement, be stopped or have its motion state changed.

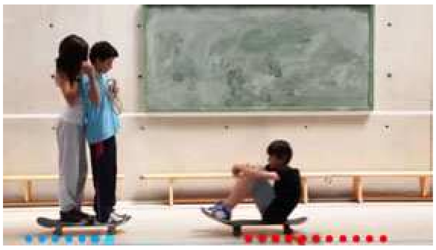
2.4 Second law of Newton

The second law of Newton relates the change of speed (acceleration) that a body experiments when a force is applied to it.

The second law of Newton

It says that the change of speed (acceleration) of a body when a force is applied to it is directly proportional to the intensity of the force and inversely proportional to its mass.

$$F=ma$$



When we **apply the same force to objects with different mass, the object with less mass (less inertia) will increase its speed quicker**.

You can watch the next video to see the relationship between the force applied and the change of speed for the boys and girls we have met before. You can also see the same effect in the international space station.

In this case, the skate with two boys has more mass than with just one boy. The skate with more mass moves less distance because its speed increases slower (the result is even more obvious when we add a third person!).

2.5 Third law of Newton

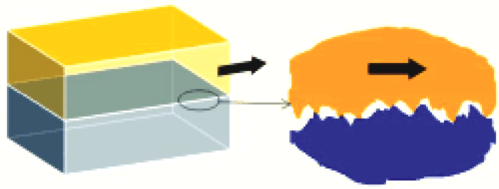
The third law of Newton, or **action-reaction law**, says that forces are not presented alone, they go in couples. When a body 1 applies a force to another body 2, the second one also interacts with the first one applying a force to him. Both forces have the same intensity and direction but opposite senses. The application point will be in a different body for each case.

For example, if you punch a table, it is going to hurt you, because when you hit it you apply a forceto the table but also the table applies a force to you with the same intensity: the harder you hit, the stronger the force you will receive in your hand, and the more it will hurt.

Third law of Newton

When a body applies a force on another body, this one applies a force on the first one with the same intensity and direction and opposite sense.

3. Frictional forces



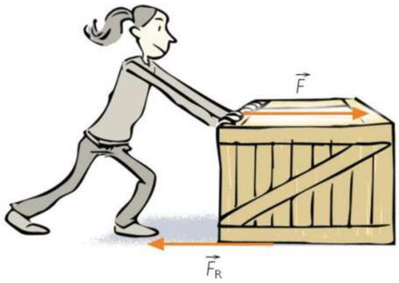
Friction is a force that appears when there are two bodies in contact, avoiding that one slides over the other one. Is the force that allows us to walk and depends, among others, on the nature of the surfaces in contact: if they are very rugged, they stuck when they try to slide one over the other, as you can see in the picture.

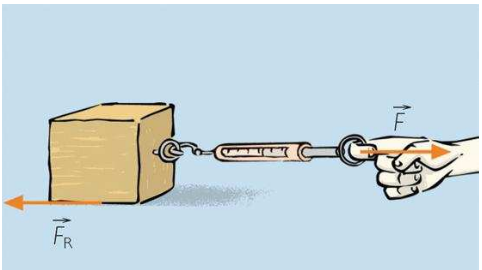
You know that it is not the same to walk on asphalt than on ice. When you try to walk on ice friction is much lower so it is much more difficult to move.

Diagrams of forces

When we push or pull and object to move it, there is a force called frictional force.

If you look at the pictures you can see that when the girl pushes the box or pulls the block she is applying a force. Because of this, another force that goes against the first one appears: it is called **frictional force**.





As you have already seen, it is different todrag the wooden block by the different surfaces: frictional force depends on the nature of the surfaces in contact. The rougher they are, the greater the friction force and the more polished, the smaller. This is why walking on ice is more difficult than on asphalt, as frictional force is much lower.

Frictional forces

Frictional force is the force that appears when a body tries to slide over another one. Its sense is opposite to the sliding of both of them. Its value depends on the nature of the surfaces of the bodies involved.

Freefall

As you have already observed in the Pisa tower experiment, the fact that some bodies fall faster than others depends on the presence of air and the frictional force that it creates. In the next video you will observe two different experiments that prove this: the first one in an empty chamber where all the air has been extracted and the second one in the Moon, that has no atmosphere.

Notice that both objects fall at the same speed when there is no air.

Frictional forces

All bodies would fall at the same time if frictional force didn´t exist between them and the atmosphere. Frictional force is different depending on their shape or size, but not depending on their mass.

4. Gravitational forces

Remote forces

The forces you have seen before are the result of the interaction of bodies that are in contact. Now you are going to study more mysterious forces, as they are the result of the interaction of bodies that are separated by a certain distance, so they are caused by some of their properties.

The first force that we are going to see is gravitational force, which is the force that every body that has a mass experiment. Is the responsible for what we call weight, but also for the fact that our planet is spinning around the Sun.

Back to Earth

In the surface of our planet we observe that every object is attracted by the Earth with a force that we call weight. **Weight is caused by the mutual attraction between a body and the Earth because they both have mass**: the bigger the mass, the bigger the attraction between them (the force applied by the Earth on us becomes bigger, but also the force applied by us to the Earth!).

The weight of an object is proportional to its mass, but both concepts are very different although we use them daily with the same meaning.

Mass and weight

Weight is a force resultant of the interaction between two bodies with mass. It is measured with a dynamometer and its unit is the Newton.

Mass doesn´t change depending on where the object is but weight can vary depending on its location.

How do we calculate the weight of a body?

You know that it is measured with a dynamometer but, what if the body is too big? In order to measure it we use a balance, that indicates the mass of the body, using the relationship P=mg, where m represents the mass of the body and g is a constant of the surface of our plant that has a value of 9,81 N/kg.

The unit for the weight is the Newton (N), because the weight is a force.

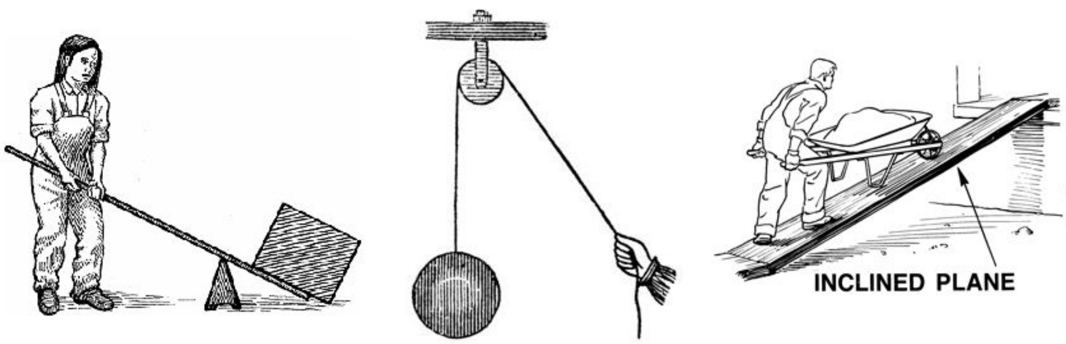
The meaning of g

On the Earth it has a value of around 9,8N/kg: the Earth attracts each kilogram of mass with a force of 9,8N.

5. Machines

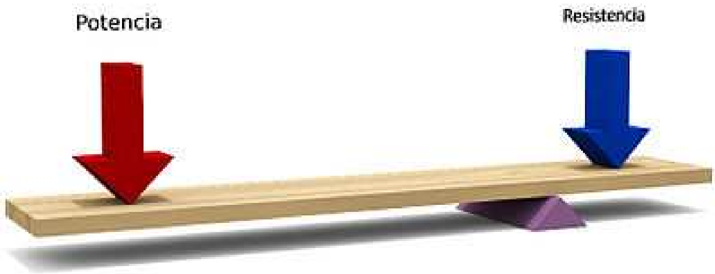
We spend a lot of time applying forces in our daily life: brushing our teeth, opening a door, walking on the street… They are activities that require the action of a force, and the list is never-ending!

Since the antiquity, the human beings have tried to make the different processes that require the action of big forces easier.Because of that they invented processes or mechanisms that allowed them to do different tasks in a simpler way, reducing the force required.



Some of the simplest machinesare the lever, the pulley and the inclined plane.

The lever



A lever is machine composed of a rigid bar that oscillates on a support point due to the action of two forces, power and resistance. The resistance is the force that needs to be overcame and the power is the force we need to apply.

Levers are used because they allow us to overcome big resistances applying smaller powers, or to get longer displacements.

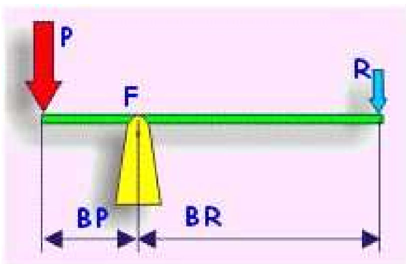
There are different kinds of levers in three big groups: first grade, second grade or third grade, depending on where the support point is located in relation with the application points of the forces. Here you can see some examples:

Some levers allow us to reduce the force we need to apply to do a task, as in the case of the nutcracker. This instrument is used to break the shell of a nut, something that would be much more difficult if we tried to do it only with our hands. The scissors and the pin are similar examples.

Law of the lever

The product of the resistance multiplied by the distance to the support point (BR) is equal to the product of the power multiplied by the distance to that point(BP).

P·BP=R·BR



6. Electric forces

A bit of History

In the ancient Greece, 26 centuries ago, Thales of Mileto got to attract light objects, like straw or feathers, rubbing amber with a cat skin.

Much later, in 1600, an English researcher, William Gilbert, found several materials (glass, sulfur,salt, resin, …), that presented similar properties to amber when they were rubbed and they called them electric. The reason for this name is that amber was called **elektron** in Greek.

In the XVIII century, the French Charles du Fray observed that identical materials rubbed in the same way repelled themselves, so he reached the conclusion that there were two different kinds of electric phenomena: attractive and repulsive.

In the middle of that century, the American scientist Benjamin Franklin established the theory of electric fluid, which said that electric phenomena were caused by the motion of this fluid from one body to another. He made the kite experiment and invented the lighting rod.

In 1785, Charles A. **Coulomb** formulated**the laws of electrostatic**. “The electric forces between two charged particles are directly proportional to its charges and inversely proportional to the square of the distance between them”.

Electrostatic phenomena in your surroundings

In your daily life you have observed and experimented phenomena that are examples of the electrostatic nature of matter:

- All of us have felt that when we comb our hair it is attracted by the comb. The same attraction phenomenon is observed when we unwrap an article covered with cellophane paper.
- When children play with balloons they feel how their hair is attracted too, and they know that when they rub a pen with their clothes it has the ability to attract little pieces of paper.
- When you put on or take off a sweater you feel little sparks.
- After walking barefoot on a carpet, you feel a prick when you touch a metallic object.
- After driving our car we can feel a little cramp when we get out and touch the door.
- In a storm, lightings and thunderbolts are generated.

You can try the balloon experiment at home, but it is more spectacular to charge the body to repel the hair as you can see in the video!

Pay attention to the simulation. John Travolta is an American actor, singer and dancer, known for his acts in films like Saturday Night Fever or Grease. He rubs his right foot with the carpet like if he was performing one of his famous dances. Observe that there is a spark when his hand is close to the metallic door handle...

6.1 Experimental methods

Electrification ad electric charge

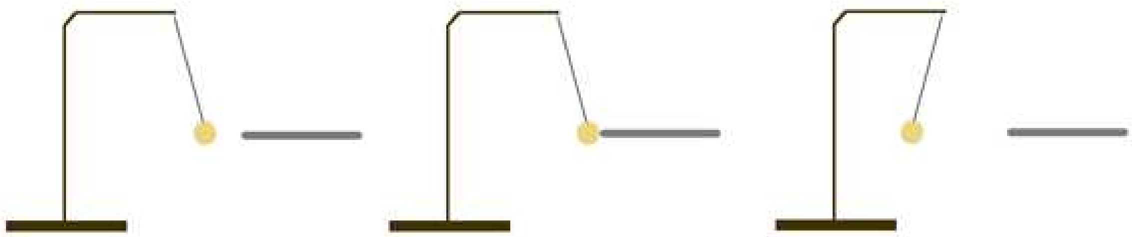
When you rub the plastic ruler or the pen, they acquire the property of attracting light bodies like confetti, or deflecting the waterjet.

In order to explain this phenomenon, we admit that the ruler has acquired a property that we call **electric charge** and we say that it has electrified.

Electrification is the phenomenon by which certain materials are charged electrically by rubbing them strongly with others.

Electrification by contact

- When you approach the rubbed plastic bar to the pendulum ball, it gets closer.
- Once the bar and the ball are in contact, there is repulsion between them: the ball has electrified.



- When touching simultaneously the balls of two pendulums, they get electrified and repel.
- When touching each ball with a rod of different materials, they attract.

Electrification by induction

- Electrification of a body can happen without contact with the electrified body.
- There are two kinds of electric charge. The glass acquires **positive charge** when it is rubbed, and the plastic acquires **negative charge**. They are assigned this way by agreement.
- Bodies with charge with the same sign repel themselves, and bodies with opposite charges feel attraction.

6.2 Electrification and charges

In the previous experiments you have observed that bodies can be electrified by three different ways: friction, contact and induction.

At the end of the XIX century, some particles with negative charge were discovered. They were called **electrons**. This discovery made scientists think that atoms are not indivisible. They had to have a positively charged part, because they are neutral on the whole.

Several experiences allowed them to discover that this positive part is a dense nucleus around which the electrons rotate. This nucleus consists of two types of tightly bound particles, **protons** and **neutrons**. Protons have a positive charge and neutrons have no charge.

The charges of electron (negative) and proton (positive) are equal but with opposite sign. The presence of electrons allows us to explain the three ways of electrification that you have seen.

Electrification by friction

When we rub two bodies, there is a motion of electrons from the surface of one body to the surface of the other one. The body that looses electrons looses negative charge and becomes positively charged. The body that gets electron is negatively charged.

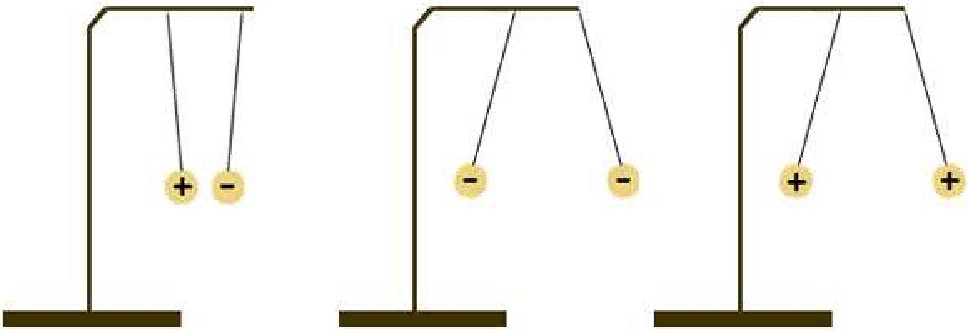
Electrification by friction is the result of the transference of electrons between two bodies.

- A positively charged body has lack of electrons.
- A negatively charged body has excess of electrons.

Electrification by contact

When you putin contact a discharged body (the ball of the pendulum) and a charged body (the rubbed rod), the electrons move from one body to the other one:

- If the bar is negatively charged (plastic), some electrons move from the bar to the ball, that rest negatively charged.
- If the bar is positively charged (glass) some electrons move from the ball to the bar and the pendulum becomes positively charged.



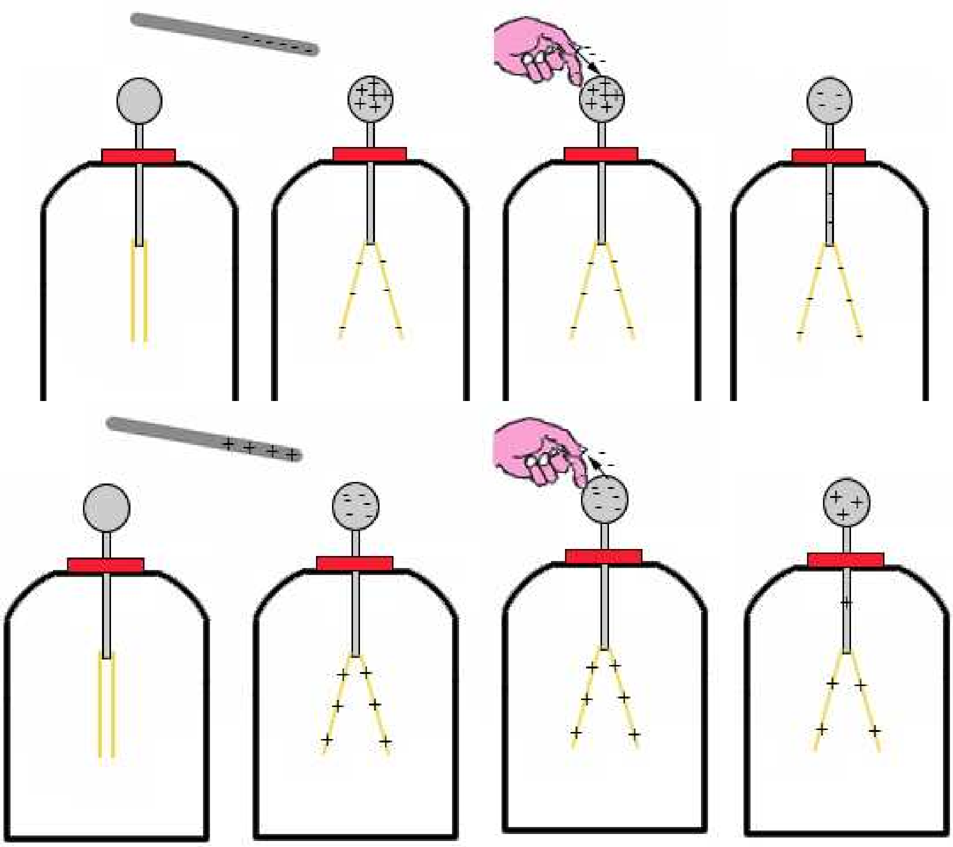
Electrification by contact

Is the result of the redistribution of electrons between two bodies, that move from the body with negative charge to the body with positive charge.

Electrification by induction

When we approach a rubbed rod (charged) to the electroscope, the electrons get close or far from the area where the rod approaches depending on its charge, if it is positive or negative. The electrons are attracted by the positive rod and repelled by the negative one.

The electroscope keeps being neutral, but the closest area to the positive rod has an excess of electrons and the area which is further has a lack of electrons. The closest area to the negative rod has a lack electrons and the furthest areahas an excess. You can charge the electroscope as it is shown in the pictures.



Electrification by induction

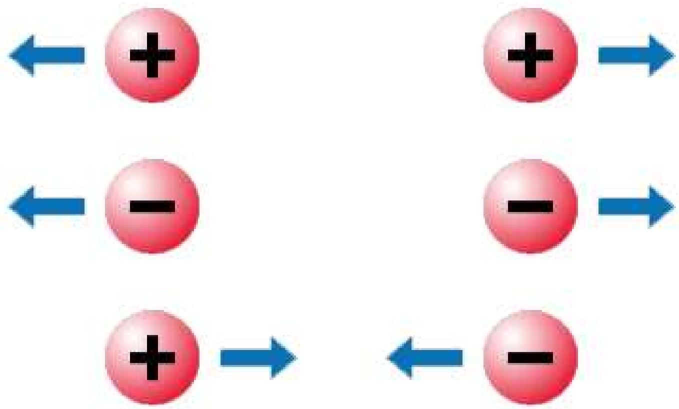
A body is electrically neutral when it has the same number of positive charges than negative charges.

Electrification by induction is the result of the motion of electrons of the neutral body, attracted or repelled depending on thecharge (positive or negative) of the body that gets close to it.

In electrification processes, the total electric charge keeps constant (electric charge remains the same). Electrons move from one body to the other, but the total charge is the same.

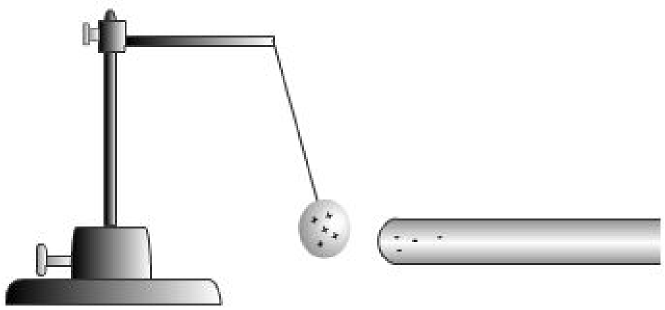
6.3 Forces between charges

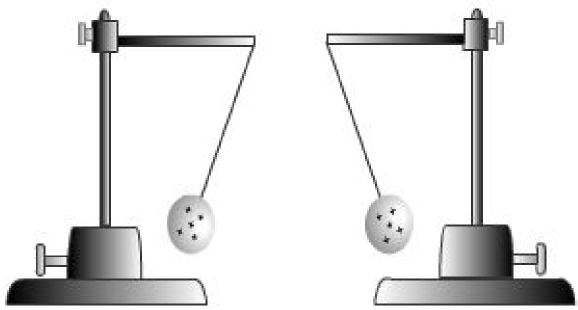
Kinds of charges



You have seen that electric phenomena can be repulsive of attractive. To explain them, we use a property of matter called electric charge. There are two kinds of electric charges: positive and negative. Charges of the same sign repel, and charges with opposite sign attract themselves.

In the next simulations you can observe how two bodies, one positively charged and the other one negatively charged, attract (on the left), and how two positively charged electrostatic poles repel (on the right). The closer they get, the more they repel themselves.





Electric charge

Is a physic magnitude whose unit in the I.S. is the **Coulomb** (C).

The charge of the electron is the elemental unit of electric charge. Its value is -1,6 10^{-19} C in I.S. units.

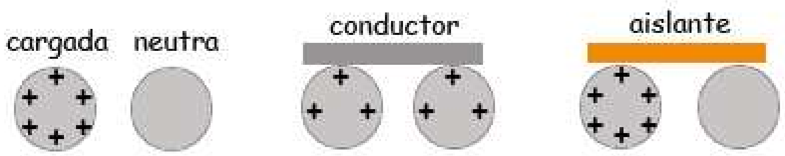
The charge of a body is always a multiple of the charge of the electron.

Conductors and isolators

In the electrification experiences we have used a bar of glass or plastic. What would have happened if we had used a metal bar?

A metallic rod doesn´t charge if we rub it holding it with our hand, but it does if we rub it while we hold it with a plastic or glass handler and we don´t touch with our hand.

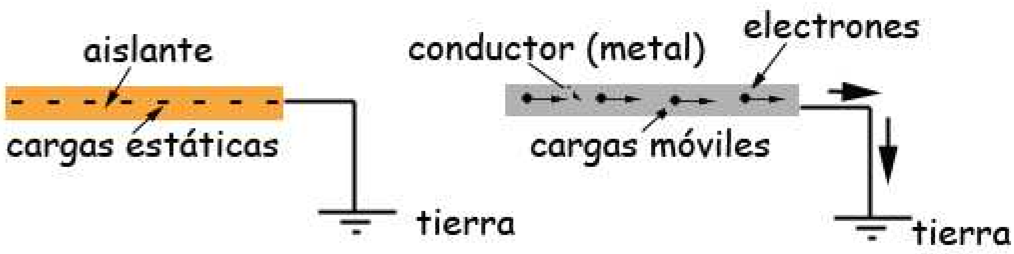
This is because in a neutral body charges are distributed in a situation of balance. When the body is electrified, two things can happen: the first one is that the charges (the electrons) distribute through the body and the second one is that they remain were they were putted. Materials of first kind are called conductors and materials of the second one are called isolators.



Bodies where charges move freely are called **conductors**.

Bodies that don´t allow the motion of charges are called **isolators**.

A body acts as a conductor or an isolator depending on its nature. Conductor materials have electrons that can move easily through the material, while isolators have electrons strongly joined.



Examples of isolator materials are wood, plastics, glass and rubber.Metals are conductors and some dissolutions too (for example, salt dissolved in water).

The distinction between conductors and isolators is not absolute. There are a lot of very interesting intermediate situations, as it is the case of **semiconductor** materials (silicon, for example), due to its importance in the manufacturing of electric devices.

7. Electric current

Observe around you. Wherever you look, you will see some electricdevices: illumination, the computer or even your mobile phone.

The discovery and later development of electricity and electric devices caused a huge change in society, in a way that we can say that our life won´t be the same without technology.

The motion of electric charges through a conductor is essential to make most of the machines on our surroundings work, from our stopwatch to the machinery of our company.

As you have already seen, the force between charges has different nature depending on their sign. When we put in contact two charged bodies, one negatively (with excess of electrons) and the other positively (with lack of electrons), the electrons of the first one will experiment a force that will make them move to the positively charged body.

What is electric current?

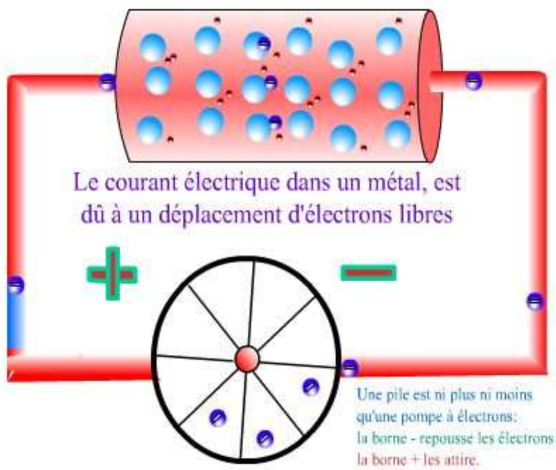
Electric current is the continuous flow of electric charges between two points.

Electrons and electric current

Electric current is produced through a medium that allows its passage, called a conductor. If this route is carried out in a way that the charges can return to the starting point, we say that it is an electric circuit.

When electric current was discovered for the first time, electrons were not known, and it was considered that it was made of positively charged particles. They were mistaken. The sense of the current was defined as directed from the positive pole to the negative pole because the positive charge of the positive pole repelled the positive charges of the electric current.

Nowadays we know that, as we associate the electric current with the motion of electrons, the real sense ofthe current is from the negative pole to the positive pole, as the electrons come out from the negative pole and move due to electric attraction towards the positive pole. The sense of the current is the opposite to the motion of the electrons.



In the next animation you can observe the motion of electrons that creates electric current. First, you have to close the switch, clicking on the opened section of the circuit marked as "Fermez l'interrupteur".

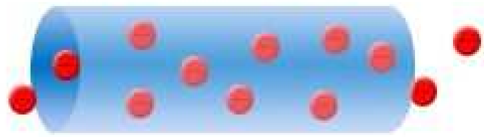
Magnitudes in circuits

The three characteristic magnitudes of an electric circuit are:

- Intensity (I).
- Potential difference(V).
- Resistance (R).

7.1 Intensidad (I), voltage (V) y resistencia (R)

Intensity of electric current



If you want to indicate the amount of water in a river you use the word "flow". The more water per unit of time, the greater the flow.

There is an analogous magnitude in electricity, called current intensity. It measures the amount of charges (electrons normally) flowing through a section of the conductor per second. The more number of charges, the greater the intensity.

Intensity (I)

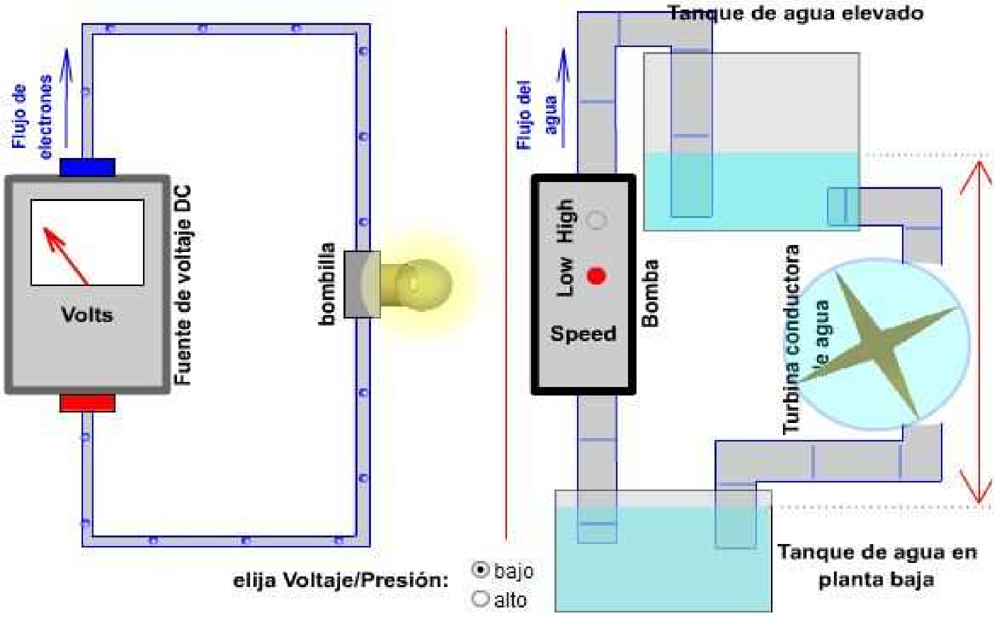
Intensity of the electric current (**I**) is the number of electrons moving through a section of a conductor per second.The unit in IS units is the **Amper** (**A**), which is a charge of 1 Coulomb going through a section of a conductor per second (1 A = 1 C/ 1 s).

Potential difference or voltage

You have already studied that electric current is the motion of electrons through a conductor when they are attracted by positive charges or repelled by negative charges.

If we don´t want the current to stop flowing, we need a power supply (a battery or a plug).In order to understand it, look at the next animation that compares the behavior of electricity with the flow of water in a pipe system (it is called hydraulic simile).

Look first at the hydraulic circuit. When we impulse the water with more pressure, the flow of water increases and the wheel rotates faster. You can change the pressure with the High/Low switch.



Now look at the electric circuit. It is easy to identify the equivalent to the flow: it is the intensity of the current that you have just studied. Exactly like water, that needs a pump that impulses it to continue its flow, charges need a booster that allows it to continue flowing. This device is called generator.

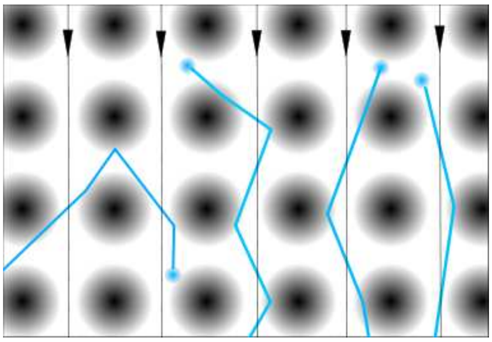
Objects fall because of their mass, moving from higher to lower points. The same thing happens to charges: they move because of the potential difference between two points of the circuit. The higher it is, the faster the electrons move, and the higher the intensity of the current.

Voltage (V)

Potential difference, also called **voltage** (**V**) between two points of an electric circuit, is the energy acquired or lost by the unit of charge when it moves from one point to another.

The unit in International System is the **volt** (**V**).

Resistance



In the models that you have seen until now, charges move freely, but this doesn´t happen in real life. When an electric current goes through a section of an electric circuit, the electrons crash into the particles of the conductor, loosing speed and energy.

The amount of energy lost depends on **the kind of conductor**: if it is a good conductor it will loose little energy but if it is an isolator it will loose a lot of energy or even all of it.In order to understand this behavior, the hydraulic simile is again very useful. The increase of resistance corresponds to a narrowpipe, that makes the flow of water more difficult.

Resistance (R)

Resistance (**R**) of an element of the circuit is the opposition to the flow of the charges. The I.S. unit is the **ohm**(**Ω**).

7.2 Electric circuits

Ohm´s law

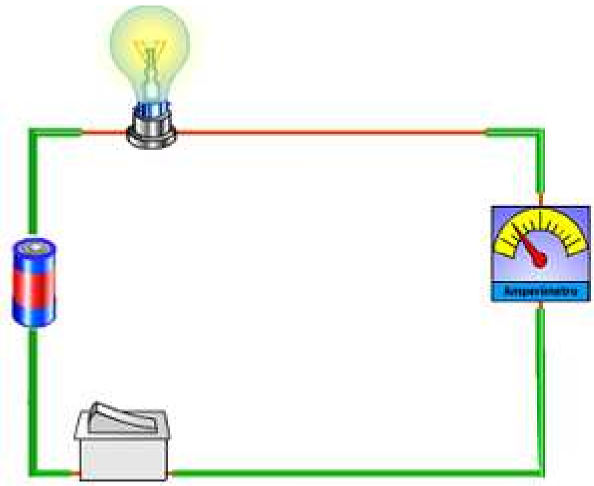
It establishes the relationship between the three magnitudes in an electric circuit: intensity, voltage and resistance. It is very important in order to do calculations in circuits, as you will do in Technology.

The intensity is higher when the electrons have more tendency to flow (V) and lower when there is more opposition to the flow (the resistance R).

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

Electric circuits

In order to have electric current that allows our electric devices to work, we need to plug them to the distribution net of our house or to use batteries if the consume is low.



In Technology you will work with electric circuits with an electricity source and elements that consume it (engines, lightbulbs, switches…). Besides constructing them, you will represent them graphically and you will do calculations applying Ohm´s law. In the picture you can see a circuit with some of these elements.

8. Magnetic forces

Magnets

Besides gravitational and electric forces, there is a third kind of remote interaction: magnetic forces, produced by magnets that act on objects made of iron and some more other materials (cobalt, nickel and their alloys).

Forces of electric nature are produced by positive or negative charges, so there are objects that have net charge of one sign or the other, and they produce different effects. However, magnets have both properties at the same time: a north pole in one side and a south pole in the other. Also, if you break a magnet into two pieces you obtain two magnets.

Magnetic forces of action and reaction

Magnets attract objects, but by reaction these objects attract the magnets too. There are two forces, an action-reaction pair, in a way that a force is applied to the magnet and the other on the object.

Depending on the mass of the magnet and the object, we observe that one of the objects move more clearly (the one with less mass experiments a higher acceleration and is the one that displaces more in the mutual attraction).

Kinds of magnets

There are two kinds of magnets: permanent and electromagnets (that only have magnetic properties when electric current flows through them).

There are natural and artificial magnets. The most powerful magnets used nowadays are made of an element called neodymium(Nd).

When you work with this kind of magnets, you have to be very careful because they produce forces so strong that they can hurt you if they give you a pinch.

Polarity of magnets

Magnets have to poles orientated in a way that north and south poles attract themselves but north-north and south-south repel.

Magnets deflect the trajectory of objects made of iron because they apply a force to them that makes them change the direction of their motion.

The Earth has magnetic properties, observed in a compass (where we can see the magnetic interaction in the geographical north and south poles) and that is used precisely to orientate us as it shows the direction of the North Pole.

8.1 Electromagnetism

Magnets and electric current

Electricity and magnetism have a relationship so narrow that we often talk about electromagnetism. Electric current produces magnetic effects while using magnets electric current is generated: we just have to move a magnet close to a coil (set of turns).

Unit 3. Energy

The word energy sounds familiar to us because of its use in daily life. Continually we hear about electric energy, a battery with a lot of energy or even a person with more or less energy. Even more, we suffer energetic crisis when we run out of battery in our mobile phone or the gasoline in our motorbike is about to run low. **Energy is involved into every fact and change happening in our surroundings.**

Although the word energy is very commonly used in our daily language, it is difficult to give a precise definition. One of the difficulties is that it appears between us in many different ways: as electric energy, thermal energy, luminous energy … The objective of this unit is **to understand better the meaning of the energy**.

Energy has been known with different names since a lot of a time ago, but science adopted this name at the starting of 19th Century, when machines were studied and Freyman, one of the most famous physicist nowadays, says that it is one of the most difficult concepts to understand and that science still hasn´t given an answer to it. Through this unit you will **study the concept of energy and its properties**: energy is presented in many different ways, it remains and degrades. You will also study **the different sources of energy**: some of them renewable and others, the most common in our lives, not renewables.

After that, you will see **how energy is transferred from some bodies to others**: through **work** and heat.

Next you will study how heat is a way of transference of energy from the hottest bodies to the bodies with lower temperature. Because of this, you will have to use a magnitude that you already know: temperature. It is high when you have fever, when you heat your meal and also in the month of august in Zaragoza when the thermometer in Pilar Square shows 40ºC or more.

You will investigate what the temperature of a body depends on when you supply heat to it and the effects of heat on solid, liquid and gaseous bodies. You will also see the ways of transferring heat and their relevance on the thermal isolation in clothes or in the design of more efficient houses. Finally, you will study other two essential kinds of energy: **light** and **sound**.

The energy necessary for life

When you run or jump you are doing activities that you can do only if you have energy. But, where do you get it?

We all know that in order to be active we need to feed ourselves in the same way that cars need petrol to work.

Energy is essential for life and for being able to do al our daily activities, from getting up to going to the high school, studying, doing sport… In the same way, the energy that cars take from petrol is used for moving, home appliances work thanks to the energy taken from electricity and windmills work thanks to the energy provided by the air.

Your life and all your vital activities depend on a good supply of energy.

1. Properties of energy

Properties of energy

1. It is presented in **many different ways**.
2. It is **transferred.**
3. It is **conserved**.
4. It is **degraded**.

Energy appears in many different ways

The first property of energy that we can see in the previous pictures is that it **can appear in different ways, being possible the conversion from ones to the others**.

Kinds of energy

In all of these examples that we have seen, energy is presented in different ways. In some cases, like the bike rider or the 100 m runners, the train, the light of the lantern, the heat of a flame or the sound of a speaker, they are clearly manifested and they are easy to identify: we speak about **kinetic energy**, **luminous energy**, **heat energy** or **sound energy**.

But **there are forms of energy that don´t show up because they are stored**. In the pictures you have already seen some of them: the water stored in a dam, the energy of a house or the energy of a rock in the top of a mountain, the energy stored in our body, or in a tense rope or spring, the energy in carbon, petrol, natural gas, uranium or plutonium… **These are called potential energies.** They are stored and we can use them when we need.

The energy of the water in the dam, in the house or in the rock in the top of the mountain are called **potential due to the height or gravitational potential.** We **can get it back by letting the objects fall**. The energy in a spring or a rubber is called elastic.

The energy stored in our body, in food, in carbon, petrol or natural gas is called **chemical energy and we can get it back by setting our body in action or burning the fossil fuel.**

The energy obtained from uranium or plutonium is called nuclear energy. It is released as heat in a controlled way in the nuclear reactors of a nuclear plant, or in a chained reaction in atomic bombs.

Forms of energy

Energies that are directly manifested**: kinetic, luminous, heat and sound**.

Potential energies (that are stored): **gravitational, elastic, chemical and nuclear**.

1.1 Energy is transferred

Energy is the cause of the changes that objects experiment. Energy can make and object start moving, change it shape, increase its temperature or height or emit light or sound. These **changes happen when the energy is transferred from some bodies to others**.

Potential energies

The fact that energy is necessary for a process or a change doesn´t mean that we have to associate the existence of energy to the presence of activity.

In many cases, like the water of a reservoir, **the energy is stored** in a useful way, so it can be used lately. There are many different ways of storing energy: compressing a spring, through a battery, the water of a reservoir …

1.2 Energy is preserved

Having energy is like having money. Money is only useful when we can change it for a service or for objects. In the same way, energy is only useful when it is transferred.

When energy is transferred we can ask ourselves where it has gone. A scientist interested in energy is like an energy accountant. He makes a balance of the financial status before and after each deal or trade: the scientist makes a balance of the initial and final energy for each transference. If he counts all the energy, he will reach the conclusion that **the amount of energy is the same after the transformation than before it**.

Conservation of mechanical energy

Since it starts to fall from the higher point until it starts to stop, the potential energy of a rollercoaster is converted in kinetic, and after that in potential. The sum of both kinds of energy is the same through all the process, so the energy is conserved. When the trolley goes to the top, the total energy increases because there is an external source (electric engine) and when it stops it does it because of the action of an exterior braking force.

Mechanical energy is conserved unless there are external forces that make it increase (the engine) or decrease (the brakes).

1.3 Energy is degraded

Availability of energy

In the last years we have heard a lot about energetic crisis. Since 1974, the cost of petrol has varied brutally, increasing more than 10 times, decreasing after that more than a 50% and increasing again. This fact has performed an important role in Spanish economy, because it is not a producer country and it depends on external supplies.

Continually we are told to use the energy properly, or that we have to be careful with energetic savings. However, we have just said that the third property of energy is that it is always conserved. Where is the point in conserving the energy if the total energy of the Universe doesn´t varies?

This third law of energy is a little tricky because there **are some forms of energy that are more useful than others**. It is easier to obtain energy from then and transform itinto the kind of energy that we need-. Although the energy of a process is equal to the sum of all the energies when it has finished, it is possible that the final forms of energy are less useful.

The possibility or impossibility of using the energy that has been produced after a process constitutes what is known as **energy degradation**.

If you look at a car that is on the road, the energy from petrol transforms into energy for the motion of the car, energy for the light of the headlights, energy for the sound of the claxon. These energies are useful for us as they allow as to doing what we need with the car: move, and move safely.

Some energy is “lost” because of the friction between the tires and the road, or between the air and the car: the tires heat up and also the road. This heat energy is not useful for us as we can´t take advantage of it. This is what we consider as the fourth property of energy: its degradation.

The degradation of energy

In every process, the energy conserves, but **some forms are less useful** than the original ones: the energy has degraded.

Energetic efficiency

Is a way to express the relationship between the useful energy obtained in a process, so a process is efficient when the energetic loses are small. Its value varies between 0 and 100 %.

1.4 Diagrams of energy

A way to represent the different forms of energy and the transformations in a process is using **diagrams of energy**.

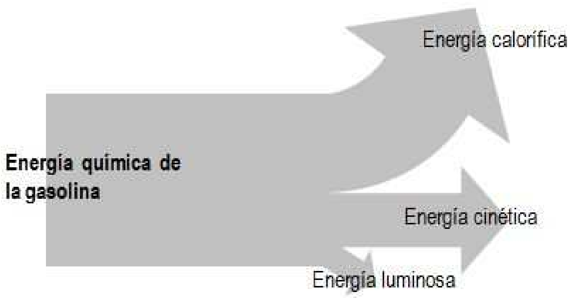
They represent the four magnitudes of energy. They give information about:

a) The **different forms of energy** in a process.

b) The **process of transference**. In the bottom of the arrow we indicate the energies supplied and in the top we write down the energies originated.

c) The **preservation of energy**: the width of the entry arrow must be the sum of the widths of the exit arrows.

d) **Degradation**. In exit arrows, we have to represent also the part of the energy which is not useful for of purposes.



Look at the example of the diagram of a car going through the motorway: the potential chemical energy of the fuel transforms into energy for the motion of the car or kinetic energy, luminous energy for the headlights and heat energy generated by the friction between the pieces of the engine and between the tires and the road.

Diagrams of energy and properties of energy

- The **energies of the process** are: chemical energy of the fuel, kinetic energy, luminous energy and heat energy.

- The transformations are: energy from the fuel **transforms** into kinetic, luminous and heat energy.

- The total amount of energy provided by the fuel is transformed into kinetic, luminous and heat: **energy preserves**.

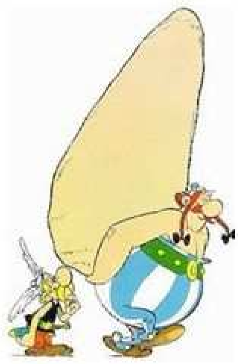
- Kinetic and luminous energy are useful but the heat energy caused by friction is not useful for the process: **energy degrades**.

1.5 Work and energy

Work, work, work….so tiring!

The word "work" is normally used when we talk about something that requires an effort, like studying, moving an object, pushing a wall or cutting a tree.

In scientific language, this magnitude has a more precise meaning: **work is produced when a force causes a motion**. In the picture we see Obelix hitting a rock with a hammer. Even if he does a big effort, the rock doesn´t move, so Obelix is not doing work. In the picture on the right Obelix moves a rock that was on the floor. The force applied on the rock causes a motion, so he is doing work.



When a force moves an object the **amount of work done depends on two factors: the value of the force and the distance travelled by the object.**

Work in Physics

Work is a way of transference of energy from some bodies to others. It requires the application of a force and that the force causes a motion.

Work= force x displacement

Work is the energy transferred from one body to another through a force that causes a displacement.

2. Temperature

Every day your hear about temperature: it is very cold, temperature will increase tomorrow, there is a heat wave…

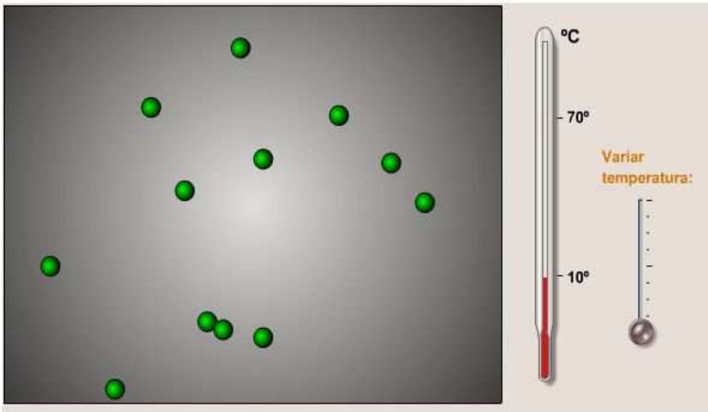
This year you have already studied that change of state temperatures are characteristic of a substance and allow us to identify it and that they are measured with thermometers.

But, what is temperature? It is a property of bodies that we perceive through the sense of touch. According to this perception, things are more or less "hot" or "cold".

Temperature and thermal energy

In order to have a clear idea of what the temperature of a body is, we have to think that the objects that are around us are made of particles, which are in continuous motion in solids, liquids and gases.

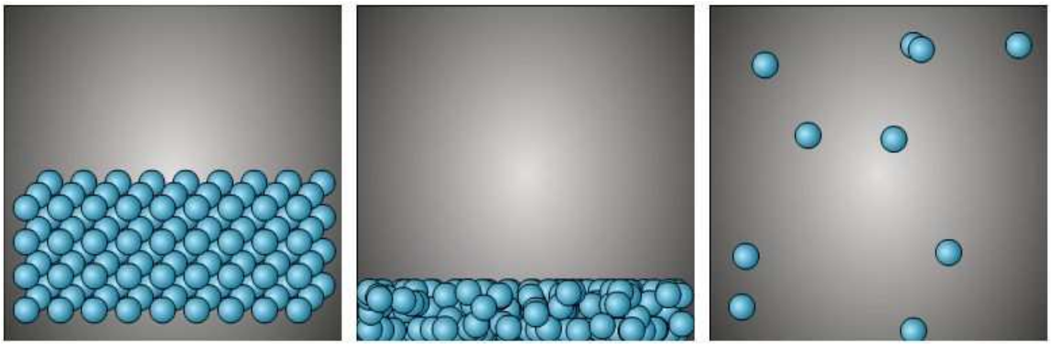
The temperature of a body indicates the grade of agitation of the particles. The higher the temperature of a body, the higher the speed of its particles, and the higher its kinetic energy.



We can say that **the temperature in the thermometer is a measure of the thermal energy, directly related to the grade of motion of its particles and to its kinetic energy**.

In solids, the motion of particles is small and it is reduced to just a little vibration (particles are strongly joined). In liquids, particles vibrate and form groups that move. In gases, particles are much more separated and move freely.

Temperature, thermal energy and motion of particles



Temperature is a magnitude measured with the thermometer and it is a measure of the thermal energy of a body. It is caused by the grade of agitation of the particles that constitute matter.

2.1 Thermometers

In order to measure temperature we use thermometers. They are made of a tube of glass closed in the top and joined to a little deposit in the bottom, where there is a liquid (mercury or dyed alcohol).

This **liquid expands when the temperature increases** and goes up in the tube. The length of the liquid column gives us the measure of the temperature in an indirect way. In order to measure the temperature of an object, the tube must have a **graduated scale**.

To graduate the scale of a thermometer we need to have two reference temperatures that we will use to compare with any other temperature. The most used **scale is Celsius**, commonly know as centigrade scale, because it is divided in 100 grades.

In Celsius scale, the reference temperatures are the melting temperature of ice, which is assigned to the 0 grades value (0ºC), and the boiling point of water when atmospheric pressure is 1 atmosphere, assigned to the value of 100 grades (100 ºC).

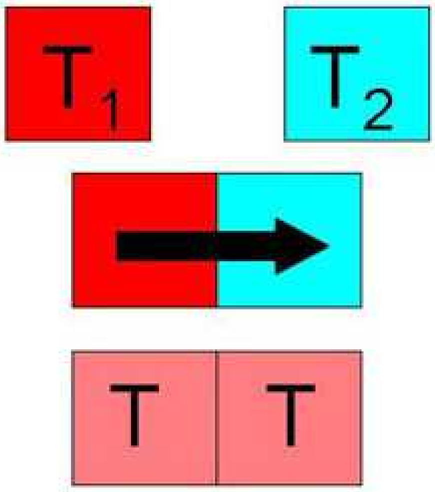
3. Heat and temperature

In daily language we often mix the words heat and temperature. When we talk about how hot is in summer or how bad hot soda drinks taste, we are referring to the temperature, the higher or lower temperature or the air or the soda drink, to that magnitude measured with the thermometer. But…

What is heat?

When tow substances with different temperatures are put in contact, they evolve in a way that it decreases in the body with higher temperature and it increases in the body with lower temperature until it is the same for both of them.

We can observe this if we add an ice cube to a glass with soda drink at room temperature. The temperature of the cube increases and the temperature of the drink decreases. In daily language we say that the drink cools and the ice heats until it turns to water.



Heat is related to the substances with different temperature. We can conclude that the substance with higher temperature has given heat to the substance with lower temperature, causing an increase.

Heat is not something that is stored in a body. A body doesn´t contain more or less heat. We can say that an object has high or low temperature, as the thermometer is showing us that it has a lot or a little thermal energy, or that the agitation grade of its particles is high or low.

If a body has a temperature of 80ºC and another body in contact with it has a temperature of 20ºC, energy moves from the first to the second until they are equal. The energy that moves from one body to the other is called heat: a waterfall is water that moves from one place to another because they are at a different height as heat is the energy that moves from one body to another because they have different temperature.

Concept of heat

Heat is defined as a **measure of the energy transmitted by a body with higher temperature to a body with lower temperatur**e.

Units of energy

The two ways of transmission of energy between bodies, heat and work, are measured with the same unit, the **joule (J)**. In order to measure heat we also use and old unit called **calorie (cal)**.

A calorie is the amount of heat that we need to supply to 1 g of water to increase its temperature in 1ºC.

The equivalence between these units is: **1 cal = 4,18 J**.

3.1 Heating substances

It is clear that when we supply energy in the form heat to a substance we increase its temperature. But, what factors are involved into this increase?

First, it is logical that we need more heat to increase the temperature when the mass of the object is high. For example, to increase 1ºC the temperature of 1000 g of water we need 1000 calories, exactly 100 times more heat than what we need to increase 1ºC the temperature of 10 g of water (10 calories).

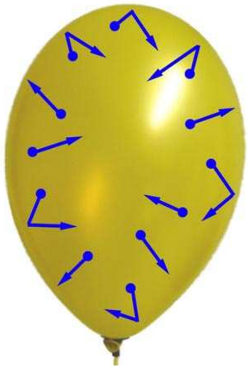
In other hand, some objects need a higher supply of energy than others to increase its temperature. For example, we need more heat to increase 1ºC the temperature of 1 g of water than of 1 g of alcohol.

Factors related to the amount of heat needed to increase the temperature of an object

The heat needed to increase the temperature of a body depends on **the mass of the object and its nature.**

4. Effects of heat

When an object heats, its volume increases. This is called **thermal expansion**. When an object cools, its volume decreases due to **thermal contraction.**



This is a very famous phenomenom. You have already checked it with gases and you have interpreted the model of particles of matter. Remember that when you increase the temperature of particles, they move faster and crash into the walls of the recipient with a higher force. If it has elastic walls, as in the case of the balloon, the volume increases.

And what about the jumping coin? It is a similar example. As the bottle can´t expand, the increase of pressure makes the coin jump.

Expansion of substances

Expansion of gases is much more intense than in solids or liquids. Gases expand 10 times more than a liquid and 1000 times more than a solid.

4.1 Expansion of solids and liquids

Expansion of solids

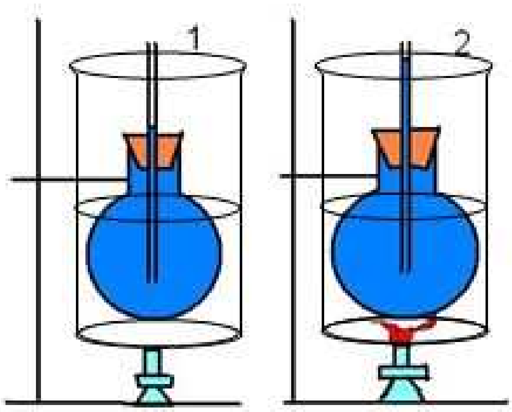
The expansion of solids is produced in all directions, but when it has extended shape, like the rails of a train, the lineal expansion is the most important.

Why do solids expand?

When a solid is heated, its **particles** vibrate more, with more energy, and are set **more separated**, so the solid increases its volume and expands.

Expansion of liquids

Like in solids, liquids also expand when they are heated, and the reason is the same**: thermal agitation of particles increases**. We can say that liquids expand five times more than solids, from example if we compare mercury and steel.



5. Propagation of heat

Mechanisms of propagation of heat

You already know that heat is the measure of the energy transferred from one body to another that is at a lower temperature. But, how is it transferred?

Heat spreads or transfers in different ways in solids, liquids and gases and also in an empty space. Now you are going to see the **mechanisms of propagation of heat** and some of its applications, amongst them the way of isolate a house to contribute to energy savings.

For starting, you have two videos about the mechanisms of propagation of heat: **conduction, convection and radiation**. Look at the effects on the chocolate rabbits!

Conduction of heat: conductors and isolators

If we try to shake a liquid that we are heating in the kitchen with a metallic spoon, the spoon soon heats and it is difficult to handle it. This happens because heat is transmitted quickly in metals.

Heat is transmitted through solids by **conduction**.

How is heat transferred?

Propagation by conduction

Metals **are good conductors of heat**. Objects that are good conductors of heat are also good conductors of electricity.

Non metallic solids like wood, plastic or glass are bad conductors of heat and electricity. Liquids are also bad **conductors of heat**.

Air and gases are generally the worst conductors of heat. Coats keep us warm because they don't allow our body to transmit the heat to the exterior.

5.1 Convection

Observe the figure on the right. You will have noticed that when there is a fire, hot air and smoke move up. The reason is the following: when air heats, it expands or increases its volume. Hot air is less dense than the cool air surrounding it, so hot air goes up and cool air occupies the lowest space.

Something similar happens when we heat water in a casserole. The flame or electric plate heats the inferior part of the casserole and it causes a dilatation of the hot water in the bottom, which becomes less dense than the rest of the water. As a consequence, the hot water goes up and the cold water occupies the lowest space.

Air and water are bad conductors of heat but they can transfer heat from one place to another by moving its less dense particles up. This process is called convection.

Air and water currents that are produced in this process are called convection currents.

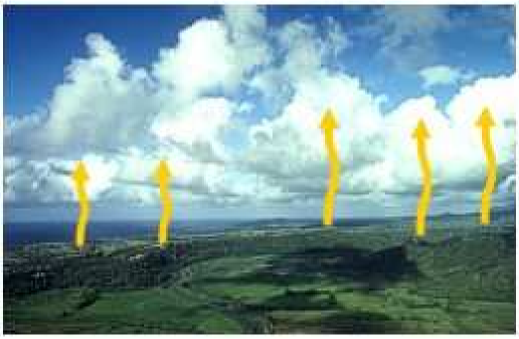
Convection and physical states

Heat propagation by convection is produced only through fluids: any gas or liquid, like air or water.

Convection and climate

The propagation of heat by convection is not only responsible for the heating of houses or the cause that hot water rises when you heat a casserole. It also produces many atmospheric phenomena that condition the climate, make the birds rise when they fly or allow a balloon or a paraglide to fly.

The air in the atmosphere is the fluid that moves. The radiation of the sun falls upon the ground, heating the rocks. When the temperature of the floor increases, the air close to the surface heats and starts to rise, creating an air bubble that is otter that the air surrounding it, and ascends through the atmosphere



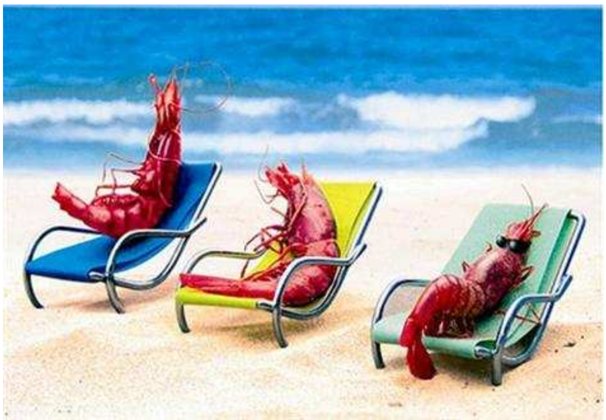
As the mass of hot air rises, the closest air, that is not as hot as it and is denser, occupies the empty space left by ascending air. This is the **fundament of wind**.

These movements of masses of hot air are responsible for the creation of small clouds or the big storms that cover big sections of the Earth. Convection currents are responsible for the meteorological processes taking place on the Earth.

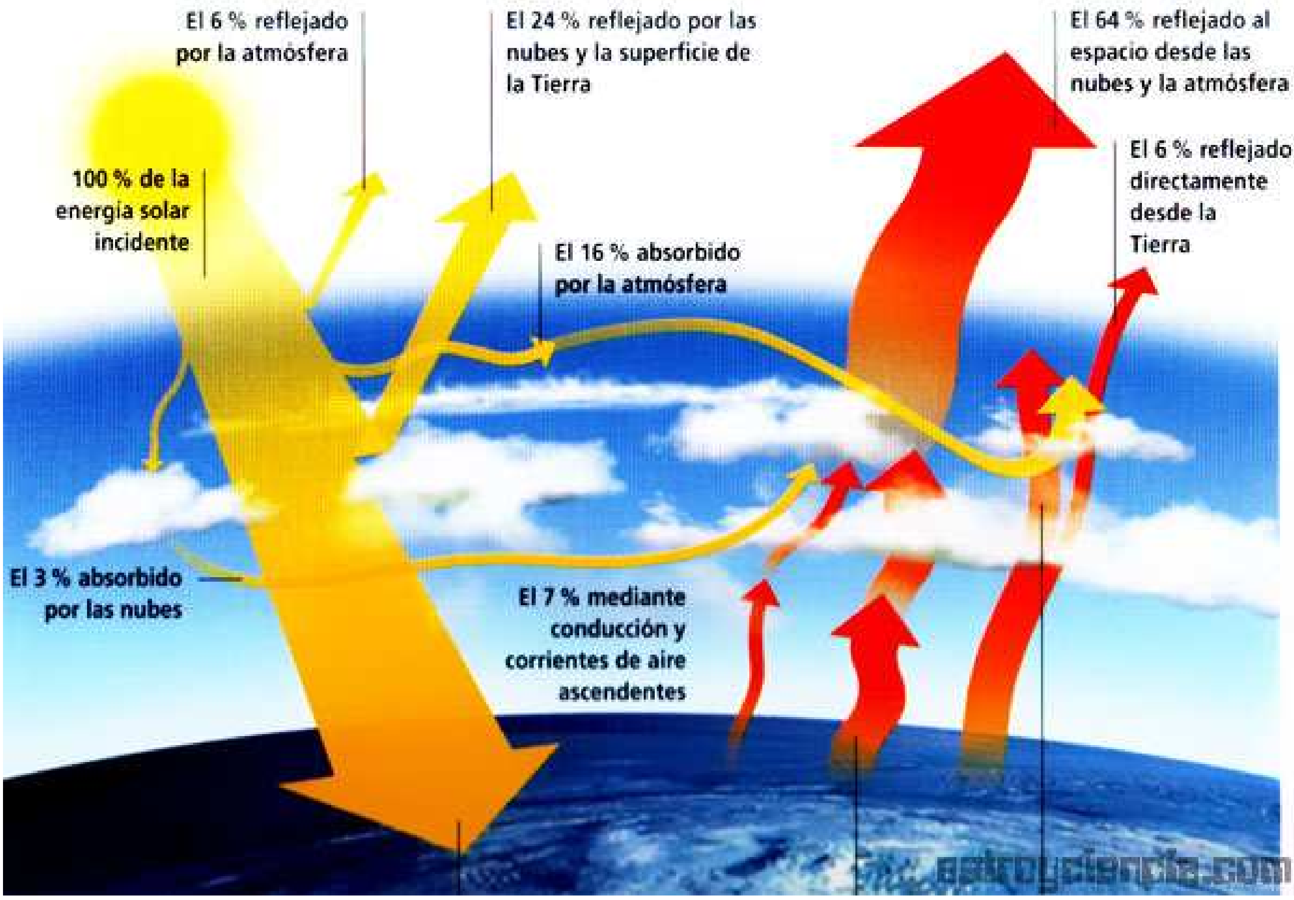
5.2 Radiation

When you are close to fire or a lightbulb, you feel hot. The energy that comes from the source of heat has spread laterally from the fire or the lightbulb to you. This heat doesn´t spread by convection because convection transports heat upsides neither by conduction because air is not a good conductor.

This heat has been spread by **radiation**. The hot parts of a flame, a lightbulb or any hot object emit heat in the form of radiation, which is spread in all directions. **The higher the temperature of an object, the more heat it transmits by radiation**.



The Sun liberates energy in the form of light rays, ultraviolet rays, which are the ones that get you a tan when you sunbathe (ultraviolet rays) and heat rays (thermal radiation).



Only a fraction of these sun rays get to the Earth because the rest are lost in space. When the radiation of the sun arrives to the Earth, one part is absorbed by the Earth itself and other part is reflected to the exterior. Thermal radiation absorbed is the one that heats the Earth.

Observe the picture and notice how the energy that the Earth receives from the Sun is absorbed and transmitted.

Propagation by radiation

5.3 Thermal isolation of buildings

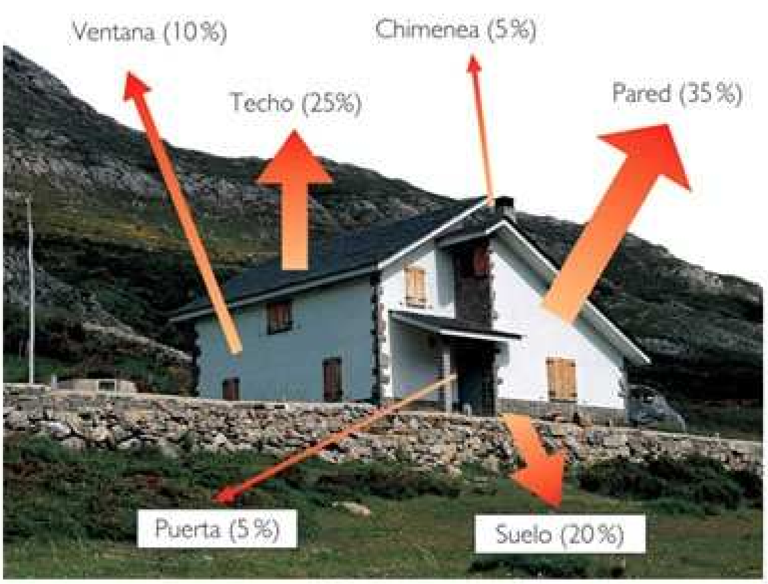
In winter we spend a lot of money in order to heat our houses. If we closed the heating system, the temperature of the house would decrease little by little and it would be less comfortable.

Temperature decreases because heat energy is transferred from the hot air of the house to the exterior. The situation is equivalent to what would happen if we wanted to keep hot the water in the sink of our house: if we want to have always the same level of water we have to open the tap in a way that it supplies as much water as it is lost in the drain.

If we want to save energy and not to pay a high heating bill, we need to reduce the losses of heat energy to the outside (thermal isolation).

Also, we will avoid the entrance of heat energy from the outside in summer, when the temperature is too high and we will save money because we won´t need to use air conditioning.

In the picture you can see the parts of the house where energetic loses are produced.



6. Sources of energy

Sources of energy are those **natural sources from which we can obtain energy.**

Fossil fuels, like **petrol**, **carbon** or **natural gas**, are the main sources of energy to heat our homes, to cook, to transport wares and people or to make factories work. These fuels are called fossil because they have been made from remains of plants and animals through processes that last millions of years.

In the refineries, petroleum derivatives are extracted that are used as fuels to move cars, airplanes or ships (gasoline, diesel, kerosene, ...) and gases used as fuels in houses and industry (propane and butane). In addition, there are deposits of natural gas, which are also used as fuel.

Fossil fuels are sources of energy that will run low in a not very far future, if its elevated consumption rhythm keeps on. For this reason, they are called **non-renewable energies**. In order to understand the importance of this problem, notice that petrol is the raw material to produce plastic. Can you imagine life without plastics?

Besides, emission of carbon dioxide (which favors greenhouse effect) and contaminant gases like sulfur oxides (that produce acid rain) make necessary to decrease these sources of energy.

It is thought that **nuclear materials** could be the substitutes of petrol and carbon of thermal centrals in nuclear centrals, as there is no emission of CO_2. Besides, the use of nuclear energy is not free from risks and dangers, due to possible radioactive leaks (very serious accidents such as Chernobyl in 1986) and the storage of radioactive waste, which is highly dangerous (low-level nuclear waste storage).

For those reasons, we are currently looking for sources of energy that do not run out, that have a low environmental impact and make it possible to save fossil fuels. These forms of energy are called renewable: **hydraulics**, **wind**, **solar**, **geothermal**, **tidal** and **biomass**.

Production of electric energy

Electric energy is the most polyvalent in our society nowadays. For this reason, other kinds of energy are transformed into electric energy in electric centrals, and it is distribute from them to the

There is a case of transformation that happens in every house built since a few years ago. It is compulsory to install solar panels in order to produce sanitary hot water.

Electric centrals

Each mechanism of transformation of different kinds of energy into electric energy has its particularities, but many processes are common to all of them. **An electric central is an installation capable of transforming different kinds of energy** (from water, gas, carbon, uranium, wind or Sun energy) **into electric energy.**

In all the next cases the procedure is the one that you already know: it is necessary to move a coil in the influence area of a magnet and then electric energy is generated. We have to make the coil turn (by hitting it with water or steam) and the device where the electric current is generated (which contains the magnet and the coil) is called alternator.

- **Hydroelectric** centrals: the water of a natural current (kinetic energy of water) or artificial, because of the effect or a difference of height (potential energy).
- **Thermal power** plants: fossil fuel, coal, fuel oil or gas (chemical potential energy) is burned in a boiler to generate heat energy that is used to generate steam that activates the turbine.
- **Nuclear** centrals: fission of uranium atoms liberates a big amount of heat energy used to obtain water vapor.
- **Eolic** centrals: kinetic energy of the wind is transformed directly into rotating mechanic energy using a wind turbine.
- **Solar thermal power** plants: the energy of the Sun heats a fluid that transforms a second fluid into steam, which drives the turbine-alternator that achieves the rotating movement and generates electricity
- **Biomass** or urban solid waste (RSU) plants: they use the same electricity generation scheme as a thermal power plant. The only difference is the fuel used in the boiler, which comes from waste

6.1 Electric centrals

Hydraulic centrals

The water stored in a dam or a swamp has potential energy because of its height (gravitational potential energy). The construction of swamps to regulate the flow of the rivers is used to install a hydroelectric central in the dam. Although it doesn´t produce wastes, it modifies the environment and causes depopulation in the area.

Now in Aragon we tend to install small electric centrals to supply to the nearest small villages.

Thermal centrals

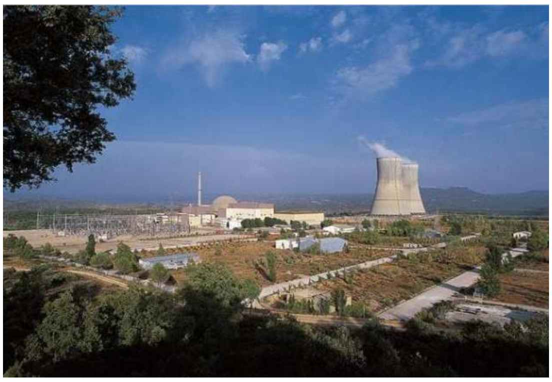
In this case, the energy necessary to move the turbine is obtained burning carbon or gas. In the picture you can see the thermal central in Andorra with its chimney with a height of 300 meters and the three refrigeration towers with a height of almost 100 meters.

In this central, carbon is burned. It comes from the near mining basin which has low quality. Although it is cheaper to import it from South Africa, it is better to consume carbon from Teruel as it has social benefits like keeping jobs and population.

Note that if the fuel contains sulfur, sulfur oxides come out of the smoke tower, resulting in acid rain. This effect caused damage to the citrus harvest of the Valencian Community, and a large investment has been necessary to eliminate these gases before expelling them into the atmosphere. Towers expel gas too, but in this case it is only refrigeration water steam.

Nuclear centrals

The fuel used is uranium, which doesn´t burn, but experiments a process called fission. An enormous amount of energy is released, but the wastes produced are radioactive and highly dangerous. Their storage is also a problem, since they do not lose their activity for hundreds of years, and they must be stored in sealed drums and in underground tanks located in geologically stable areas. However, there is currently no solution for high-activity waste, which accumulates in the plants.



Traditional and alternative energies

The previous centrals are those which have been installed since a long time ago, and correspond to **traditional energies**.

Except the hydraulic, the rest produce harmful waste for the environment and people and their raw materials are running out with the use.

The centrals that you are going to study now are in the group of **alternative energies**: they are **renewable** and the raw materials don´t run out, and they are **clean** as they don´t produce waste.

Eolic centrals

They use the power of wind to turn the blades of the turbines. They are installed in areas where the wind blows with a higher average speed during more time along the year (if the wind is too strong, the mechanisms could break).

In Aragon there are a lot of eolic parks near Ebro Valley and Teruel mountains. Note that Spain is one of the most advanced countries in this technology.

Solar Photovoltaic power stations

You have already seen the solar energy simulator in houses where there are two methods to obtain solar energy: using photovoltaic panels to obtain energy directly, or through thermal energy, to obtain hot water o electric energy.

In the photovoltaic power stations there are fields of adjustable plates, as you can see in the image. Its cost is high, but they only produce visual impact, without any damage to the environment. The electric power produced is expensive, but totally clean, so they need subsidies to make them profitable.

Solar thermal power stations

In this last case, solar energy is transformed into electric energy by two different methods: concentrating solar radiation at the highest point of a tower, producing the motion of a turbine when heating and making a liquid flow, or at a thermal power central, as you can see in the simulators. Look how the air currents are generated and used.

Biomass centrals

Energy from the Sun is used by plants to form carbohydrates, substances that store the energy in plants. Its combustion produces heat energy that is capable of moving a turbine and producing electricity. The decomposition of the vegetable mass or organic waste also produces methane gas, which is used directly as fuel.

Vegetable biomass can come from plant residues, from specific crops to generate biomass or even from animal waste, such as cow faeces, commonly used in India to generate methane used for heating, lighting and for cooking food.

It is considered as clean energy because although biomass produces CO_2, it comes from vegetable waste, consuming the same amount of CO_2 that is produced when it is burned.

Tidal power stations

It is energy that comes from the kinetic energy of waves and the movement of sea currents. In the video you can see how each of them works.

Geothermal central

It is a renewable source of energy that comes from the inside of the Earth, as temperature increases when we go deeper, and steam escapes through the cracks in the earth's crust. This steam is driven through tubes as you can see in the scheme and it can move a turbine to produce electricity. In other cases, like it happens in Iceland, steam is so hot that they use it directly for heating.

6.2 Distribution and consumption of electric energy

Once electricity is produced, we need to transport it to the consumption centers (our homes, industry...), because unlike potential energy, electric energy can´t be stored.

The way followed by electricity when it travels from its generation point to the points of consumption constitute the transport of electricity. The large conduction lines and the towers that support them are involved, as well as the substations that increase or decrease the voltage of the circulating current (the energy transported by the electric charge unit).

The lines of transport are high voltage, because that way there are less energy losses while electricity circulates through those lines.

The **high voltage lines** are constituted by a conductor cable (copper or aluminum) and by the supporting elements (high voltage towers). They carry the electric current to our homes or industry, where we need, for safety, a decrease in voltage to 220 V for domestic consumption or 380 V in the industry

Distribution of electric energy

In Spain there is Company responsible for the distribution of electric energy through the high voltage lines. It is REE, "Red Eléctrica Española". It also organizes the production depending on the energy needed in each moment.

For example, if the day allows a good working of the wind turbines, an important part of the electric energy comes from them, and the thermoelectric production decreases, as those centrals are easy to stop. Nuclear centrals can´t be stopped so easily (there are six in Spain, that provide a 20% of the electric energy consumed).

The REE website gives us information about the electric demand in real time 24 hours a day 365 days a year.

Electricity comes home

In order to have electricity at home, it is necessary to have an adequate electrical installation and a contract with the electricity distribution company, which will make the connection of the distribution network to the installation of the house.

The two most important elements are the **meter** and the **switch box**. The meter marks the amount of energy consumed at home, which will be billed by the distribution company.

The switch box contains the **general switch** of the installation, which gives input to the electric current to the house circuit, in addition to a series of small automatic switches (**PIAs**) that limit the available power (**limiter**), protect from current leaks (**differential**) or protect the different appliances (kitchen and oven, washing machine, lighting, power sockets, etc.) when there are voltage peaks (excess of electric energy).

kWh

One of the most used units of energy is the kWh, especially for energy supply (electricity and gas): 1 kWh is the energy consumed by a device of 1 kW (1000 W) when it has been working for one hour.

6.3 Saving energy

The world population keeps growing (more than 7000 millions of people!) and quality of life keeps increasing. In order to get it, **we need more energy each time**: it is estimated that the total consumption of energy has been multiplied by three since 1970.

The standard of living, directly related to the energy consumption, is not equally distributed: in Africa, where the 14% of the population live, there is a consumption of only a 3 % of the total, while in Europe, with the 11 % of the world population, a 27% of the energy is consumed.

How can you save energy?

Obviously, there must be **laws that favor energy savings**, and that are the responsibility of the different organizations that have powers, such as the Government of the country and the Autonomous Community, the municipalities, etc. For example, we pay less taxes when we buy cars that consume less fuel and emit less gas.

But what about your daily life? First of all, you should know the different types of energy you use regularly, and then think about how you can save energy when you are using them.

1. **Walk or ride a bike when you have to go somewhere, share your car or use public transport**, that use less energy per unit transported.

2. **Consume food that is produced close to you**, as you save the energy needed for the transport at the same time that you favor agriculture and cattle raising in your area.

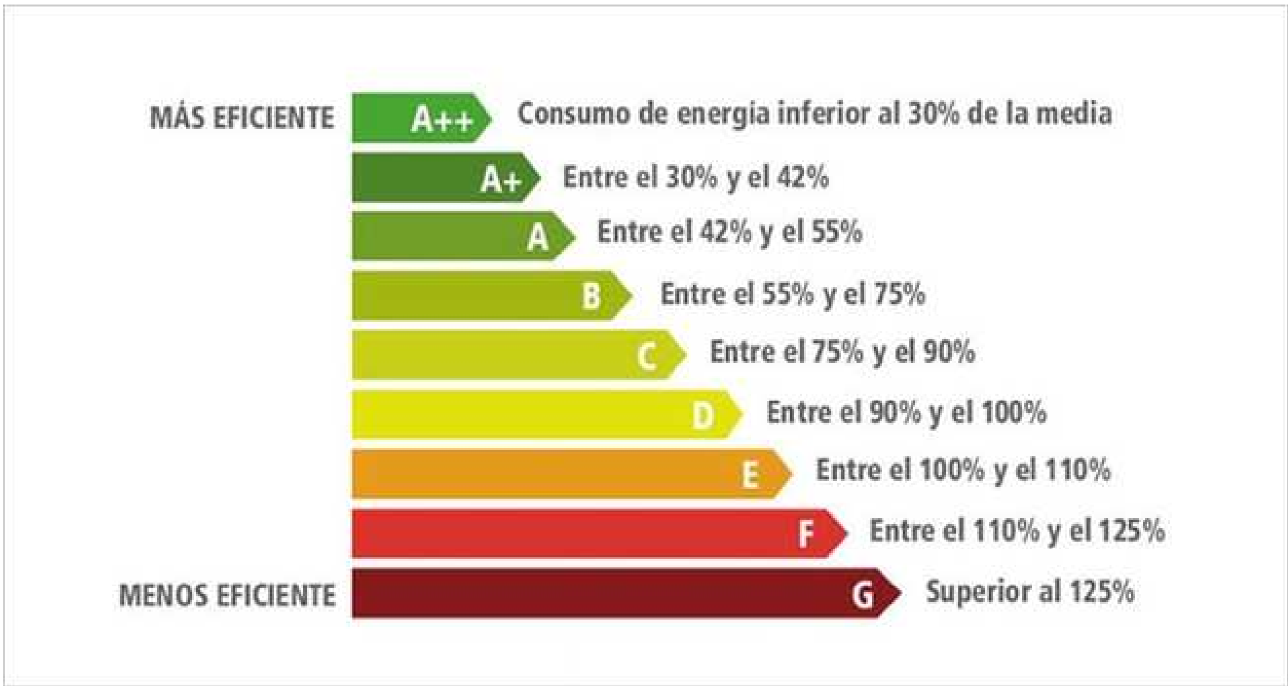
3. **Have a shower** instead of a bath in order to save hot water.

4. **Control the temperature of the heating and air conditioning**. It makes no sense that you have to wear just a t-shirt at home in winter because it is too hot.

5. **Use low-energy light bulbs, turn them on only when you need it and don´t leave your devices in standby**.

6. **Recycle** paper, glass, packages… Think that in order to obtain one kg of aluminum from recycled cans we need only a 10% of the energy needed to obtain it in the industry from bauxite (aluminum ore).

7. When you have to replace a household appliance, look at its **energetic label** in order to choose the most efficient one, as you will save energy and money. Observe in the picture that the differences in consumption are noticeable depending on the final energetic score.



7. The energy of waves

Until now you have studied two ways of transferring energy between bodies: **work** (applying a force through a distance) and **heat** (putting in contact bodies at different temperature)

But there is a third way: **waves**. In wave motion there is a transference of energy between two points of space without net displacement of matter.

Wave motions are periodic, where a series of magnitudes like position or speed repeat each certain time. Pay attention to what happens to the people swimming.

In this unit you are going to study two kinds of waves that transmit information and energy between two points: light and sound.

Sound is a mechanic wave, which needs a medium to propagate, while **light** is an electromagnetic wave, which doesn´t need it, so it can be propagated in the empty space.

Waves in a rope

With the next simulator you can see how one-dimensional wave movements are generated on a rope by pulses or in a continuous way. Look at the blue points as a reference: they oscillate from the top to the bottom, like the ball on a vibrating spring, while the disturbance moves to the right.

Waves in water

In the next picture you can see that something similar happens when raindrops fall and two-dimensional circular waves are produced. When the disturbance is transmitted, the cork oscillates vertically but doesn´t not advance or go back.

Energy of waves

It depends on a magnitude called **frequency**, which is related to the number of waves formed per second. It is measured in hertzs (Hz), so the **energy transported by a wave is proportional to its frequency.**

Light and sound, two ways of presenting energy

Light is one of the most common ways of presenting for energy: solar energy, the origin of the other sources of energy, light energy of a light bulb in our room or the light emitted by a torch, a firefly or an abyssal fish.

Sound energy appears when the horn of a car or a locomotive sounds, when emitting music amplified by the loudspeakers in a rock concert, in the bustle of a plaza full of people or in the unbearable noise of a compressor drilling a sidewalk.

The importance of both forms of energy is linked to their constant presence in our lives and to the senses with which people perceive these two types of energy: hearing and sight. These two senses allow us to interact and communicate with our environment.

Sound is a mechanical wave, which needs a material medium to propagate, while **light** is an electromagnetic wave and does not need a material medium to propagate, so that it is transmitted in the empty space.

8. Sound

There is a large variety of sounds, some nice, like music, and other, like noise, which are unpleasant. All of them are produced by the vibration of an object.

Vibration is a sway movement: the strings of a guitar produce sound when they vibrate, the tube of a flute vibrates when air comes inside and the sound produced by a drum is produced when we hit its membrane.

Properties of sound

The most important characteristics of sound are intensity and tone.

Intensity depends on the vibration of the object that produces the sound.

Tone depends on the number of vibrations per unit of time. A sound is higher or sharp when there are more vibrations per second, and is lower when the number of vibrations decreases. The unit of frequency, hertz (Hz) is equivalent to one vibration per second.

Propagation of sound

When we hit a drum, its membrane vibrates, moving in and out. When it moves out, it compresses the air around it, while when it moves in, the air expands. The membrane makes the particles of air around vibrate, and these one make the next particles vibrate. This is the way why vibration propagates, and so sound does.

The speed of propagation of sound

Sound spreads quickly in places where particles are more joined. Propagation is quicker in solids than in gases. The speed is 330 m/s in air while it is 5000 m/s in iron.

Where does sound propagate?

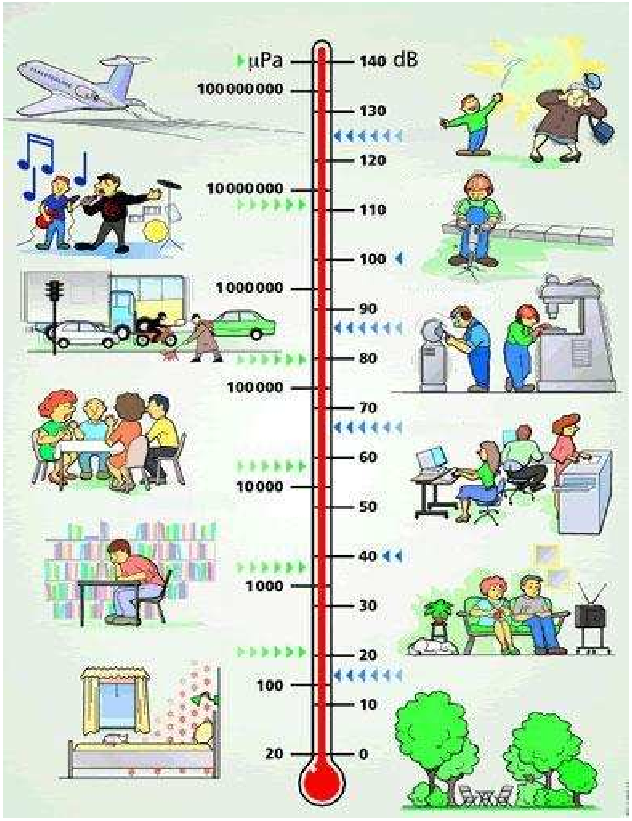
It does only in materials and **not in the empty space.**

8.1 Acoustic contamination

A problem of our society

Acoustic contamination is **the excess of intense sounds** produced by human activity, modifying the normal conditions of the environment in a determined place.

Although sound doesn´t accumulate, doesn´t move from one place to another and doesn´t remain in time, as it happens in other kinds of pollution, it can cause big damages to our quality of life if it is not controlled.



Acoustic contamination is one the biggest environmental problems in Europe**. Spain is the second country in acoustic contamination level in the world**, only after Japan. A 50% of Spanish citizens live with noise levels which are higher than the recommended.

A way of measuring sound intensity: the decibel

In our daily life we measure the sound intensity in relation to the sensation with which we perceive it by our ears. This unit of measurement is the decibel (dB) and the instrument that measures this intensity is the sonometer.

Characteristic values are the 20 dB of a murmur, the 50 dB of a normal conversation, the 80 dB produced by heavy traffic or the 100 dB produced by a pneumatic drill. The 120 dB corresponds to the pain threshold, and for that reason the labor legislation prohibits to stay more than 8 hours at a level of 90 dB to avoid hearing disorders (noises of more than 150 dB can produce the breaking off the bones of the ear).

In addition, it is not advisable to be continuously listening to music with headphones at high volume. You should notice that an increase of 10 dB means that the sound intensity is multiplied by 10, while an increase of 20 dB means that the sound becomes 100 times more intense.

9. Light

Light and the phenomena related to it have intrigued humanity for more than 2000 years: the ancient Greeks had already observed some phenomena associated with light.

You already know how important light is for people, for the chlorophyll function of plants, for climate, etc. Light is fundamental to be able to observe the objects that are around us. Thanks to it we can have a world of color.

The light that comes from the Sun is composed of a set of different waves, each one of a color (remember the rainbow). When these waves penetrate our eyes to the retina, they act on the light receptors forcing them to send nerve impulses to the brain to identify, among other things, the colors of the light received.

We can say that **light is a way of presenting energy**.

How does light propagate?

There is a series of facts that make us think that light propagates in a straight line: the straight outline of a light bulb, the shadows of opaque bodies and the eclipses.

It is often possible to see the beam of light coming from a projector or passing through a slit in a blind, because dust and smoke particles reflect part of the light towards us. The straight and sharp limits of the light beam prove that light travels in a straight line

Characteristics of light

- Light is a way of presenting energy. Is a **form of radiation**.
- Light **transfers energy** from one place to another.
- Energy is **necessary to produce light**. Materials gain energy when they absorb light.
- Light is **perceived by the human eye**.
- Light **propagates in straight line**.

9.1 Reflection and refraction of light

How do objects behave when light strikes on an object?

When light crashes into an object, there are different situations that can happen:

- It rebounds and comes back (**reflection**).

- It is absorbed by the object (**absorption**).

- It goes through the object (**transmission**) and its trajectory is deviated (**refraction**).

Most of the times, the three phenomena happen at the same time but in different proportions.

Objects that don´t let light go through them are called opaque. Bodies that let all the light go through them, like light, are called transparent. Bodies that do it only partially, so we can´t distinguish the shape, are called translucent.

Refraction of light

Solar beams are deviated when they go from some materials to others, for example from air to glass or water. This effect is called refraction and has an influence on the way we see things.

For example, when we put a pencil in a glass full of water, it seems like it is broken, or a swimming pool that looks less deep that what it really is, as you can see in the pictures.

9.2 Luminous energy

The energy of light

Light is a particular type of **electromagnetic radiation** that travels at a speed of 300 000 km/s in the empty space and more slowly in other media like air or water.

White light is a mixture of radiations of different colors, from red (lower frequency and energy) to violet (more frequency and more energy). Between red and violet, all the colors of the rainbow are collected: red, orange, yellow, green, blue and violet. The mixture of all these waves gives white light. Through the waves that constitute each of the colors**, light transports energy.**

White light can be separated into its components

As they can be mixed, they can be separated when they cross a prism, because of the different deviation of each of the colors.

Although it seems complicated, it happens constantly in the nature when the white light coming from the Sun goes across raindrops: it is the rainbow.

9.3 The color of bodies

Most of the materials can absorb some colors and reflect others. The resultant composition of the reflected colors is what we perceive as the color of the body.

This phenomenon is known as color for reflection. A body will be red if this is the only color that it reflects and cyan if it reflects blue and green.

A body is white when it reflects all the colors and black when it absorbs all of them. In this last case, black bodies are perceived thanks to the diffuse reflecting of part of the light; otherwise they wouldn't be visible.

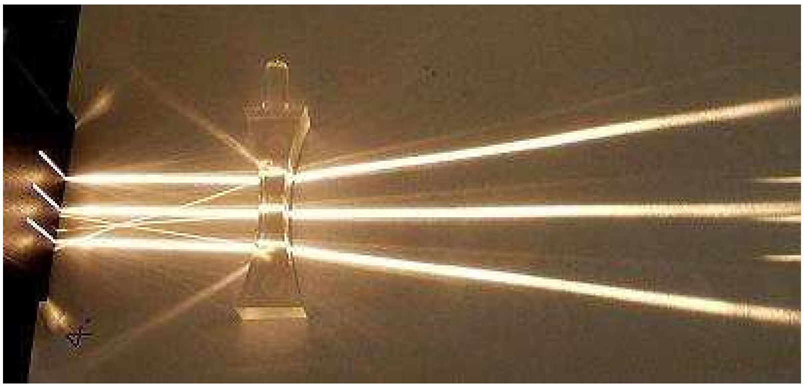
The color of objects also depends on the color of the light illuminating them: if a white body is illuminated with green light it will be able to reflect only green light and we will see it in green, but a blue object that can´t reflect green light as it absorbs every color except for blue, will be seen in black when we illuminate it with green light.

9.4 Optical devices

Mirrors and lenses

In the image you can see the effect of three reflective surfaces (mirrors): one flat, another convex (increases the field of vision by decreasing the size of objects, as in some types of car rear-view mirrors) and another concave (decreases the field of vision but increases the size, as in the magnifying mirrors for makeup).

It also takes advantage of the deviation of the light produced by traversing a glass to make lenses, which are used to focus images on projection systems and also to correct the vision defects produced by incorrect focus.



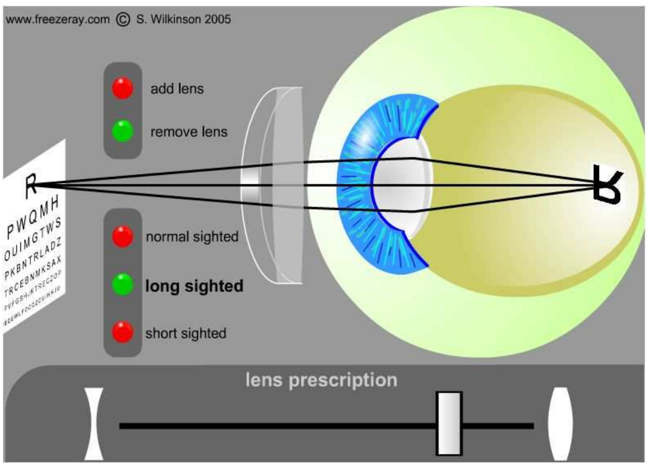
Observe in the simulator the two most common types of lenses:

- Converging, which converge the rays of light at a point called focus.

- Divergent, which separate the rays of light from a point called focus

The eye and the sight

The human eye acts as a complex optical instrument and thanks to it we can perceive the objects around us. It acts as a photographic camera where the transparent protection lens is the cornea. The iris regulates the amount of light that passes through the **pupil**.



Inside the eyeball, light is focused by a lens called **crystalline**. The image is formed in the retina, a very thin layer where receptor cells (**rods** and **cones**) are found.

Rods are excited by low intensity light, but are not sensitive to color and allow night vision (with very little light). Its insensibility to color explains that colors can not be distinguished at night. Cones are sensitive to color, are excited by intense light and are responsible for color vision under light sources.

The crystalline works like a lens, forming the image on the back of the retina. If the image is not formed in the right place, you lose sharpness, and you have nearsightedness or farsightedness.

In one way or another, vision must be corrected with lenses, using glasses or contact lenses. In the simulation you can see how the lenses act to correct both defects.

Optical devices

In addition to the glasses and lenses used to correct vision defects, the most popular optical devices include the magnifying glass, the microscope, the camera, the telescope and the periscope.

The magnifying glass, the microscope and the telescope have the function of enlarging the image that is seen of an object, while the periscope allows to see objects overcoming obstacles. The camera allows to record impressions of what is in front of a lens called objective.

9.5 Luminic contamination

It is very important to take advantage of the nocturnal artificial light, in a way that doesn´t illuminate upwards, as it is not useful in order to see and it is an unnecessary expense and energy consumption and results in a great light pollution.

Lamps in the streets

It is advisable that street lighting lamps in cities have adequate forms to reduce light pollution; they must be constructed in a way that illuminates where light is needed.