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 an 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 in every situation and every 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 energy**.

Energy has been known with different names since a lot of time ago, but science adopted this name at the starting of the 19th Century, when machines were studied and Freyman, one of the most famous physicists 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 are 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 warm 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 thermal isolation in clothes or the design of more efficient houses. Finally, you will study the 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 when you have energy. But, where do you get it?
We all know that to be active we need to feed ourselves in the same way that cars need petrol to work.

Energy is essential for life and, also, to do all our daily activities, from getting up, go to high school, studying, doing sport… So cars take the energy from petrol to move, domestic appliances work thanks to the power 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.

Energy is the magnitude that quantifies **the ability of bodies to produce changes** in themselves or their environment

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**.

1.1 Energy appears in many different ways

The first property of energy that we can see in the previous images is that **it can appear in various forms**, being possible the conversion of some forms into others.

Kinds of energy

In all these examples we have seen, energy comes in different ways. In some cases, they become evident and it is very easy to identify them: we are talking about **kinetic or movement energies** (such as the cyclist or the smooth 100 m runners, the moving train), **light energy** (the light of the flashlight), **energy heat** (the heat of a flame) or **sound energy** (the sound of a speaker).

But **there are forms of energy that do not manifest because they are stored**. In the images, you have already seen several: the energy of the water stored in a dam or of a rock on the top of a mountain or the energy stored in a compressed spring; energy stored in our body, in food, energy stored in coal, oil, natural gas, energy stored in uranium or plutonium. **These stored energies are called potential energies** and, as we have said, they are stored and we can use them whenever we want.

The energy of the water stored in a dam, the energy of a house or a rock on top of a mountain, that of a balloon at great height we will call **potential energy due to the height or gravitational potential energy**. We can recover this energy by dropping objects that are at a certain height.
The energy stored in a spring or rubber is called **elastic energy**.

The energy stored in our body, in food, the energy stored in coal, oil, natural gas, we call **chemical energy** and we can recover it by putting our body into action or by burning 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. Another use is the chained reaction in atomic bombs.

Kinds of energy

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

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

1.2 Energy is transferred

Energy is the cause of the changes that objects undergo. Thus, energy can make an object move, change shape, raise its temperature, increase its height, emit light or sound. These **changes take place when energy is transferred from one body to another.**

Potential energies

The fact that energy is necessary for transformation or change processes to take place does not mean, however, that the existence of energy must be associated with the presence of activity.

For instance, in water in a dumb, **energy is stored** in some useful form, so it is possible to use it later. There are several ways for energy storage: compressing a spring, using a battery, the water from a reservoir, etc.

1.3 Energy is conserved

Having energy is like having money. Money is only useful when we can change it for a service or 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: scientist makes a balance of the initial and final energy for each transfer. If he counts all the energy, he will conclude that **the amount of energy is the same after the transformation and before**.

Conservation of mechanical energy

Imagine that you are at the highest point of a roller coaster (beginning of the journey): as you go down, your speed increases. That's because there is a transformation from potential energy to kinetic energy. When you approach a loop when ascending you notice that your speed decreases, due to the kinetic energy being converted into potential energy.

Thus, from the beginning of the path falling from the highest point until it begins to stop, interconversion of potential energy into kinetic energy is observed and vice versa. Since **the sum of the two types of energy (mechanical) is the same throughout the entire process**, **the energy is conserved.**

Mechanical energy is conserved if no external forces act to increase it (the ascent motor) **or decrease it** (the brakes). Observe in the animation that when the wagon is climbed to the highest part of the roller coaster, the total energy increases because there is an external source of energy (an electric motor), and when it stops, the total energy decreases by the action of an external force of braking.

1.4 Energy degrades

Availability of energy

In the last years, we have heard a lot about the energetic crisis. Since 1974, the cost of petrol has varied brutally, increasing more than 10 times, decreasing after that more than 50% and increasing again. This fact has performed an important role in the 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 vary?

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 them and transform it into the kind of energy that we need. Although the energy of a process is equal to the sum of all the energies when the process 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**.

Look at a car moving on the road. The energy from petrol is transformed into different kinds of energy which provide: the motion of the wheels, the light of the headlights, the sound of the claxon. These energies are useful because they allow us to do 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 heat the road. This heat energy is not useful for us as we can´t take advantage of it. That is what we consider the fourth property of energy: **its degradation.**

The degradation of energy

In every process, the energy conserves, but **some transformed energy is 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 and the total energy used. So a process is efficient when the energetic losses are slight. Its value varies between 0 and 100 %.

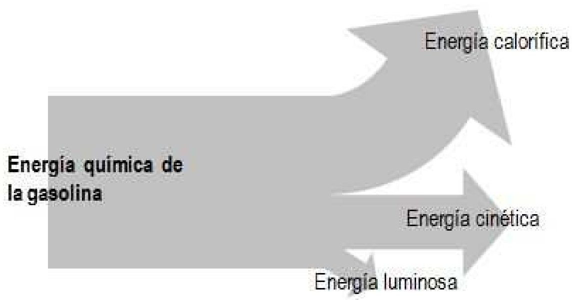
1.5 Diagrams of energy

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 kinds of energy in a process.**

b) The process of transference. The bottom of the arrow indicates the energies supplied and the top of the arrow is where we write down the energies that 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 the part of the energy which is not useful for our 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 energy properties

In the energy diagrams, the four properties of energy are revealed:

- **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 energies are useful, but the heat energy caused by friction is not useful for the process: **energy degrades.**

1.6 Work and Energy

Work, work, work….so tiring!
We usually use the word "work" when we talk about something that requires 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 stone 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 to 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 force value and the distance travelled by the object.**

Work in Physics

Work is a way of transferring energy from one body to another. The performance of work requires exerting a force and also that this force causes a displacement.

Work= force x displacement

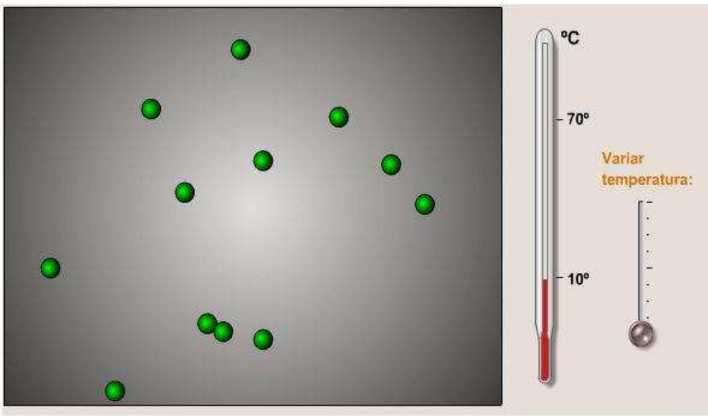
When a force moves an object, **the amount of work done depends on two factors: the force value and the distance travelled by the object.**

2. Temperature

Every day you hear about temperature: it is cold, the temperature will increase tomorrow, there is a heatwave, etc.
You have already studied that change of state temperatures are characteristic of a substance and allow us to identify it. Also, you know that we measure temperature 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".

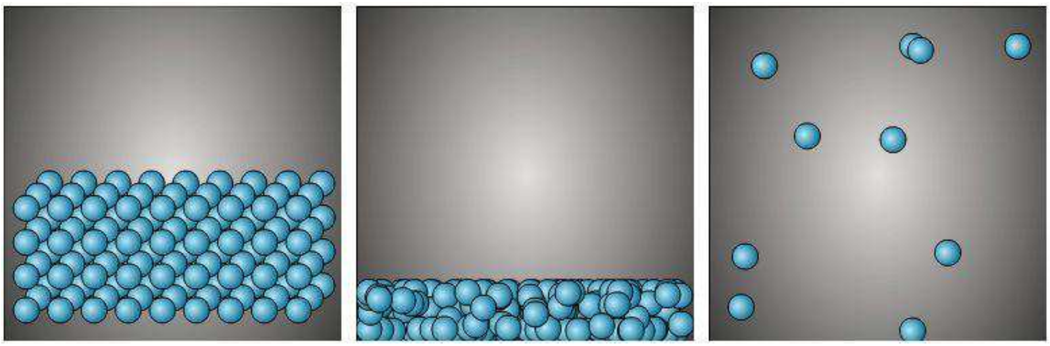
Temperature and thermal energy
To have a clear idea of what the temperature of a body is, we have to think that the objects around us are made of particles. These particles are in continuous motion in solids, liquids and gases.

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 térmica and particles motion



The temperature value marked in the thermometer is a measure of its thermal energy, directly related to the degree of movement of its particles and its kinetic energy.

2.1 Thermometers

To measure temperature we use thermometers made of a glass tube closed in the top and joined to a tiny 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. To measure the temperature of an object, the glass tube must have a **graduated scale**.

To graduate the thermometer scale we need to have two reference temperatures that we will use to compare with any other temperatures. The most common **scale is Celsius**, known as the centigrade scale, because it is divided into 100 grades.

In the 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).

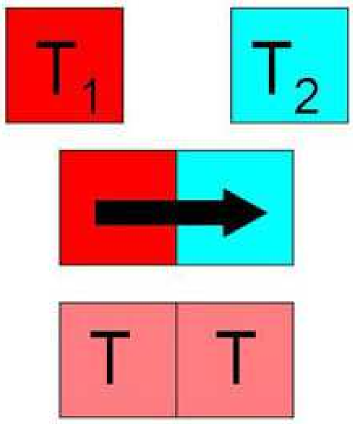
3. Heat and temperature

In everyday language, we often confuse the terms heat and temperature. Thus, when we talk about how hot it is in the summer or how bad hot sodas taste, we really mean the temperature, the higher or lower temperature of the air or the soft drinks. At that magnitude the thermometer measures us. But then...

What is heat?

When two substances are put in contact at different temperatures, **they evolve in such a way that that of the body that is at a higher temperature decreases progressively and that of the one that is at a lower temperature increases**, until **in the end, both have the same temperature.**

We can observe this by adding an ice cube to a soft drink at room temperature. The temperature of the ice cube increases and that of the soft drink decreases. On a daily basis we say that the soda "gets cold" and the ice cube "heats up" and ends up turning into water.



Heat has a lot to do with substances that are at different temperatures. We can conclude that the substance at a higher temperature has given heat to the substance with a lower temperature and causes it to increase.

Therefore, **heat is not something that is stored in a body**. An object does not contain much or little heat. What is correct is to say that an object has a very high or very low temperature since the thermometer is telling us that that body has a lot or a little thermal energy, that is, the degree of agitation of its particles (its energy kinetic) is high or small.

Imagine two bodies in contact: one of them has a temperature of 80 ºC, and the other is at a temperature of 20 ºC. The energy passes from the first to the second until the temperatures equalize. This energy that has passed from one body to another is called heat: a cataract is some water that passes from one place to another because they are at different heights, and similarly, heat is the energy that passes from one body to another because they are at different temperatures.

Heat concept

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

Units of energy

The two ways of energy transmission between bodies, heat and work, are measured with the same unit, the **joule (J)**. To measure heat we also use an 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 by 1ºC.

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

3.1 Heating substances

It is clear that when you impart energy in heat form to a substance, you make it heat; that is to say, that the temperature at which it is found increases.

But what factors depend on what is heated, the temperature variation produced?

First of all, it seems logical that the greater the mass of the object, the more particles have to increase its kinetic energy, so more heat is needed to increase its temperature by a certain value. For example, to increase the temperature of 1000 g of water by 1 ºC, 1000 calories are needed, exactly 100 times more heat than is necessary to increase the temperature of 10 g of water by 1 ºC (10 calories).

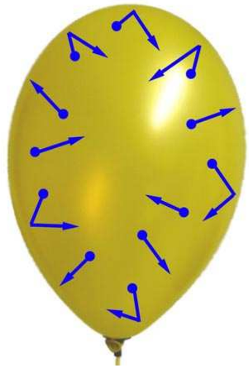
Therefore, we can say that to increase the temperature of an object we will need to add more heat the more mass it has, because the kinetic energy of a greater number of particles must be increased.

On the other hand, some objects need more heat supply than others to increase their temperature by a certain value. For example, more heat must be provided to increase the temperature of 1 g of water by 1 ºC than to increase the temperature of 1 g of alcohol by 1 ºC.

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. Heat effects



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

That is a very famous phenomenon. You have already checked it with gases and also, you have interpreted the model of particles of matter. Remember that when you increase the temperature of the particles, they move faster and crash into the recipient walls with a higher force. If this recipient 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.

4.1 Solids and liquids expansion

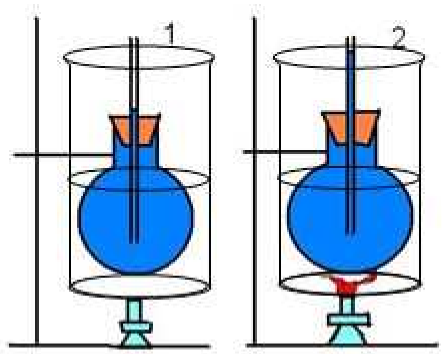
Solids dilation

Solid dilation occurs in all directions, but when it has an elongated shape, like a train rail, the dilation along the rail or linear dilation is the most important.

Why do solids expand?

When a solid is heated, **the particles** that make it up vibrate more, with more energy, and are **placed at a greater distance**. Consequently, the solid substance increases its volume in all directions and expands.

Fluid Dilation



Like solids, liquids also expand when heated, and the reason is the same: **the thermal agitation of the particles increases**. It is said that liquids expand more than solids: mercury, for example, expands five times more than steel.

The expansion of liquids is the foundation of thermometers, both mercury and alcohol, provided that the dilation is proportional to the temperature.

Substances dilation

The expansion of gases is much more intense than that of solids or liquids. Gases expand or expand ten times more than a liquid and about 1,000 times more than a solid.

5. Heat Spread

Mechanisms of heat propagation

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

How heat spreads, or transfers, is different in solids, liquids, and gases, and also in a vacuum. Now, you will see the mechanisms of heat propagation and some of its applications. The most efficient way to insulate a house to contribute to saving energy.

Start with two videos about the three mechanisms of heat transfer: conduction, convection and radiation. Check out the effect on chocolate bunnies!

5.1 Conduction

In the kitchen, when we stir a heated liquid with a metallic spoon, we observe the following situation: the spoon immediately becomes hot and becomes difficult to touch. This is because heat is transmitted through metals very quickly. On the other hand, warm clothing keeps us warm because it prevents our body from quickly transmitting heat to the outside.

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

How is heat conducted?

Propagation by conduction: Conductors and insulators

Objects that are good conductors of heat are also good conductors of electricity, a concept that you have already seen in the previous unit.

Metals are good conductors of heat.

Non-metallic solids such as wood, plastic, or glass **are poor conductors of heat**. **They are called insulators.**

5.2 Convection

Look at the figure on the right. You may have noticed that when there is fire, the hot air and fumes move upwards. The reason is the following: when the air is heated, it expands, that is, it increases in volume. This makes the warm air less dense than the cold air around you. As a consequence, **hot air rises above cold air, while denser cold air occupies the lowest place.**

Something similar happens when we heat water in a saucepan. The flame or plate heats the bottom of the pan and the water that is in contact with the bottom. This causes the hot water at the bottom to expand and has slightly less density than the rest of the water. As a consequence, the hot water rises upwards and the thicker cold water occupies the lowest place.

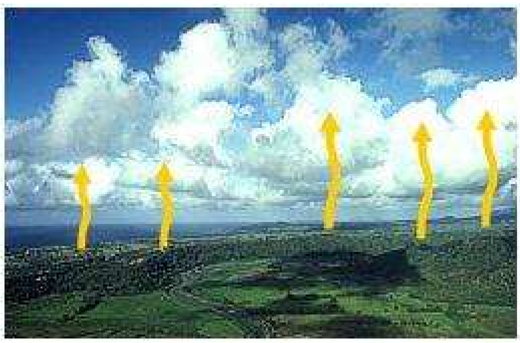
Air and water are poor conductors of heat, but they can transfer heat from one place to another by moving their less dense particles upwards. **This process is called convection.**
The air and water currents produced in this process are called convection currents.

Convection and physical states

The **propagation of heat by convection only takes place through fluids**: any gas or liquid such as air or water.

Convection and climate

The spread of heat by convection is not only responsible for heating homes or causing hot water to rise when heating a casserole. It also produces many atmospheric phenomena that condition the climate, makes birds ascend in their flight or that a balloon or a paraglider can fly.



The air in the atmosphere is the fluid that moves. The sun's radiation hits the ground, heating the rocks. When the ground temperature rises, it heats the air in the lower areas of the atmosphere, which begins to rise, forming an air bubble that is warmer than the rest of the nearby air. This air bubble rises through the atmosphere.

As the warm air mass rises, the nearby air that is less warm and denser fills the void left by the rising air. This process is the **foundation of the wind**.

These movements of hot air masses are responsible for the formation of small clouds or large storms. **Convection currents are responsible for the meteorological processes that take place on Earth.**

5.3 Radiation

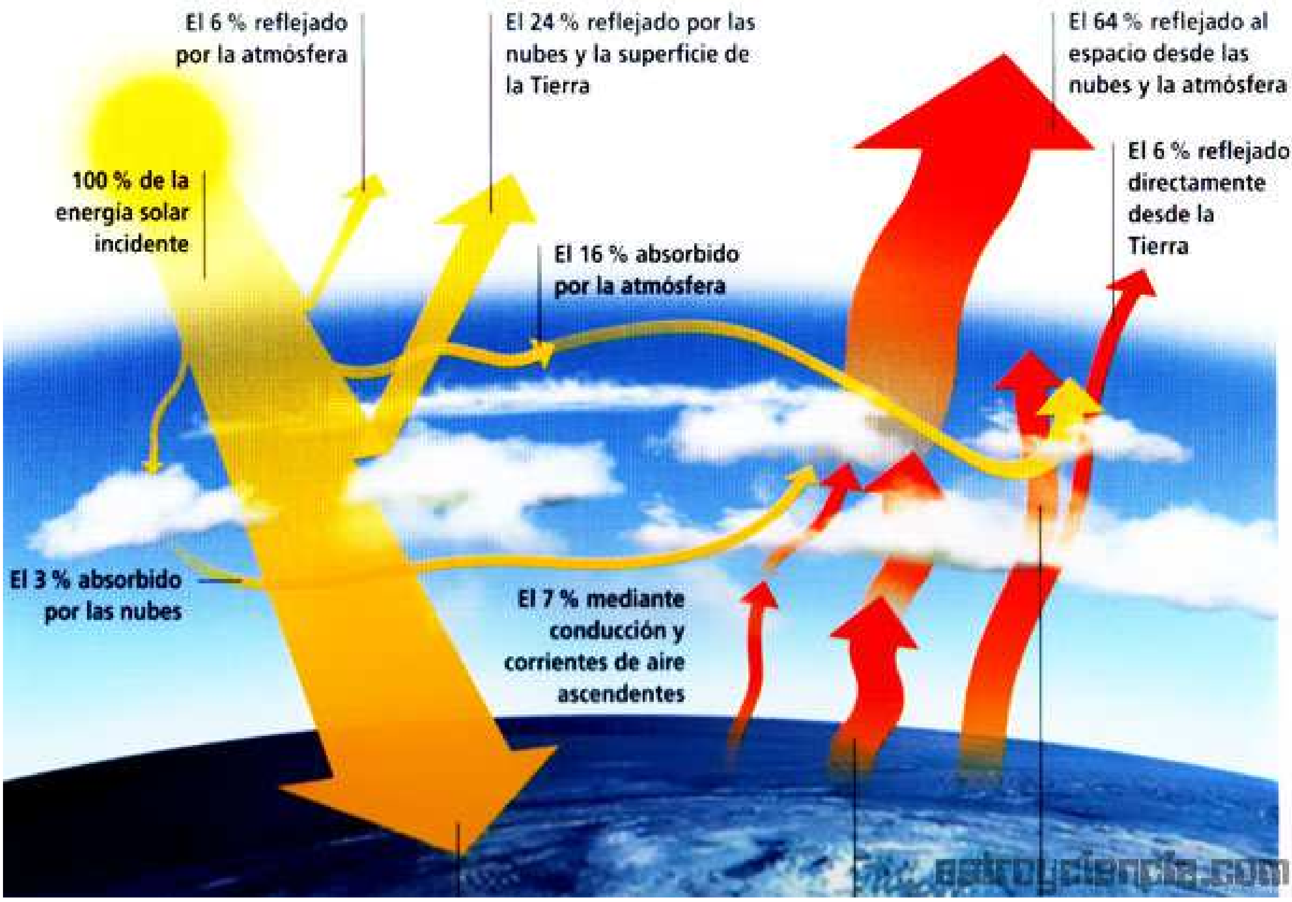
When you are close to a fire or a light bulb, you notice that it gives you heat. The energy that comes from the heat source has propagated from the fire or from the light bulb to you. This kind of heat is propagated neither by convection (because convection carries hot air upwards) nor by conduction (because air is not a good conductor).

This heat spreads by radiation. The hot parts of a flame, a light bulb or any hot object emit heat in the form of radiation that spreads in all directions. **The higher the temperature of an object, the more heat it transmits by radiation.**

The Sun releases energy as light rays and ultraviolet rays, which tan you when you are exposed to the Sun (ultraviolet radiation), and heat rays (thermal radiation).

Only a fraction of these solar rays reach Earth because the rest are lost in space. When radiation from the Sun reaches Earth, some is absorbed by the Earth itself and some reflect outside. The absorbed thermal radiation is what heats the Earth.

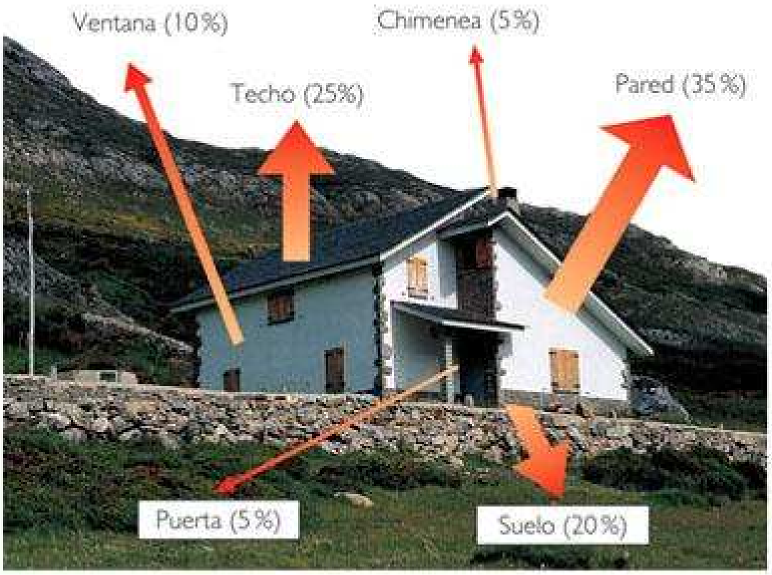
Look at the image and see how the energy received from the Sun is absorbed and emitted.



Propagation by radiation

5.4 Thermal insulation of buildings

In winter we spend a lot of money heating our houses. If we turned off the heating, the house temperature would gradually drop so the environment would be uncomfortable.



The temperature decreases because energy is transferred in the form of heat from the warm air in the house to the cold air outside. The situation is equivalent to that which occurs if we wanted to maintain the level of water in the sink in our house: if we want to always have the same level of water, we must open the tap in such a way that it supplies us with as much water as the one that is going through the drain.

If we want to save energy and not pay a very high heating bill, it is necessary to minimize energy losses in the form of heat to the outside, that is, to thermally insulate our house.

In addition, by the way, we will ensure that energy does not enter in the form of heat from the outside when the temperature is very high in summer, thereby avoiding electricity consumption in the air conditioning.

In the image, you can see in which areas of house energy losses occur.

6. Energy sources

Energy sources are those **natural resources from which energy is extracted for use by human beings**.

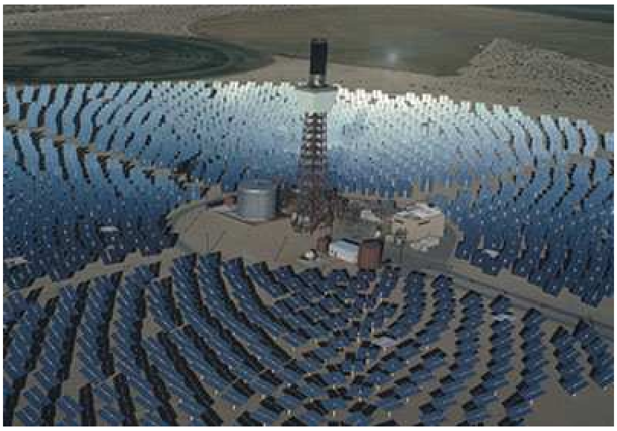
Fossil fuels such as oil, **coal** and **natural gas** are the main sources of energy to heat our homes, cook, transport goods and people, to run factories. These fuels are called fossils because they have been formed from the remains of plants and animals through processes that have lasted millions of years.

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

Fossil fuels are sources of energy that will be depleted in the not too distant future, especially if their high rate of consumption continues. For this reason, **they are called non-renewable energies**. So that you realize the problem that the depletion of oil would pose, note that it is the raw material for the manufacture of plastics. Can you imagine a life without plastics?

Furthermore, the emission of carbon dioxide (which favours the greenhouse effect) and polluting gases such as sulfur or nitrogen oxides (which produce acid rain) make it necessary to reduce the use of these energy sources as much as possible.

It is thought that **nuclear materials** could replace oil and coal from thermal power plants in nuclear power plants since no CO_2 is emitted during their operation. However, using nuclear energy carries risks and dangers: possible radioactive leaks (very serious accidents such as Chernobyl in 1986) and the highly dangerous storage of radioactive waste (nuclear waste warehouses of low activity).



For these reasons, energy sources are currently being sought that do not run out, have a low environmental impact and make it possible to save fossil fuels. These kinds of **energy** are called **renewable: hydroelectric, wind, solar, geothermal, tidal, and biomass.**

6.1 Electric Power Production

Electric power is the most versatile in today's society. For this reason, other types of energy are transformed into electrical energy in power plants, and from there, it is distributed to consumption centres.

Each mechanism of transformation of different types of energy into electrical energy has its peculiarities, but many processes that take place in this transformation are common to all of them. A **power plant** is an **installation capable of converting energy from different sources** (from water, gas, coal, uranium, wind or solar energy) **into electrical energy**.

In almost all cases, it is necessary to move a set of copper coils located in the area of influence of a magnet (turbine), thereby generating electrical energy. The turbine rotates when water, steam or air impacts it.

Classification of power plants

They can be classified in three main ways:

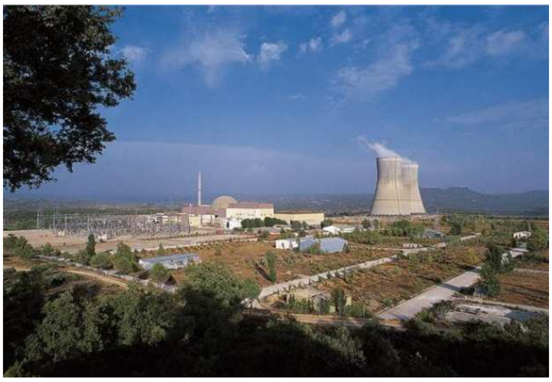
Traditional and alternative: if they have been used for a long time (thermal, nuclear and hydroelectric), they are conventional, and the rest are alternatives.
Non-renewable and renewable: if the raw material spent, they are non-renewable (thermal and nuclear) and otherwise, they are renewable.
Dirty and clean: if they produce polluting waste or alter the environment, they are dirty power plants (thermal and nuclear), and the rest are clean.

6.2 Energy production from non-renewable energy sources

Thermal plants

In this case, the energy necessary to move the turbine is obtained by burning fossil fuel (coal, fuel oil or gas, which have stored chemical energy) in a boiler that generates thermal energy. This thermal energy is used to generate steam, which is what drives the turbine. In the image, you can see the thermal power station of Andorra (Teruel), recently closed, with its 300-meter high smoke chimney and its three cooling towers of almost 100 meters.

Note that if the fuel contains sulfur, sulfur oxides come out of the smoke tower, causing acid rain. This effect caused damage to citrus crops in the Valencian Community, and a large investment had to be made to eliminate these gases before expelling them into the atmosphere. The three cooling towers also expel gas, but in that case, it is simply water vapour.



Nuclear Power Plants

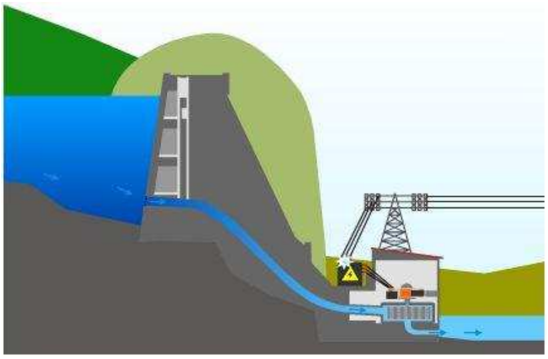
In this type of power plant, the fission (rupture) of the nuclei of the uranium atoms releases a large amount of heat energy (thermal) that is used to obtain water vapour.

A huge amount of energy is released, but the waste produced is 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 deposits located in geologically stable areas. However, there is currently no solution for high-level waste, which accumulates in the same plants.

6.3 Energy production from renewable energy sources

Hydroelectric power plants

The energy necessary to move the turbine comes from natural current water, (kinetic energy of water) or artificial, due to the effect of a slope (it is stored in a dam or swamp). In this way, the potential energy due to the height of the water in the said dam is used (**gravitational potential energy**). When the water is falling, this gravitational potential energy is released and is transformed into kinetic energy by moving the turbines of the plant, where it is transformed into electrical energy.



The construction of swamps to regulate river flows is used to install a hydroelectric plant in the dam. Although it does not produce waste, it alters the environment and leads to the depopulation of the areas where the swamp is. Currently, in Aragon, there is a tendency to install small power plants to supply small and nearby population centres.

Wind power plants

They take advantage of the kinetic energy of the wind to turn the blades of the wind turbines. They are installed in areas where the wind blows during most of the year with an average speed (if the wind is very strong, the rotors do not work, because their mechanisms could be damaged).

In Aragon, there are many wind turbine fields, especially in the vicinity of the Ebro valley and in the Teruel mountains. Keep in mind that Spain is one of the most advanced countries in the world in this technology.

Photovoltaic solar plants

You have already seen in the solar energy simulator in houses that there are two mechanisms for obtaining the use of solar energy: through photovoltaic panels to obtain electrical energy directly or through thermal energy, to obtain sanitary hot water or electrical energy.
In photovoltaic power plants, there are fields of orientable plates, as you can see in the image. Their cost is high, but they do not produce more than a visual impact, without any harm to the environment. The electrical energy produced is expensive, but clean, so they need subsidies to be profitable.

Thermal solar plants
In the latter case, solar energy is transformed into electrical energy by two different mechanisms: either by concentrating solar radiation at the highest point of a tower, moving a turbine when heating and making a liquid flow (solar furnace), or in a solar thermal power plant, as you can see in the simulators. Take a look at how hot air convection currents are generated and harnessed.

Biomass plants

Solar power is used by plants to form carbohydrates, which are substances that store chemical energy. Its combustion produces thermal energy that is capable of moving a turbine and producing electricity. The decomposition of vegetable mass or organic waste also produces methane gas, which is used directly as fuel.

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

It is considered clean energy because although biomass produces CO_2, it comes from plant waste, which has consumed to form the same amount of CO_2 that is produced when burned, so it does not contribute to global warming.

Tidal power plants

It is energy that comes from the kinetic energy of waves, the movement of ocean currents or tides. In the video, you can see how one of them works.

Geothermal power plants

It is a renewable energy that comes from inside the earth since the temperature increases with depth and steam escape through the cracks in the earth's crust. The water vapour that comes out of the interior of the earth, conducted through pipes as you can see in the diagram, can drive a turbine to produce electricity. In other cases, given the high temperature of the water vapour, it is used directly for heating, as in Iceland.

Power plants

- **Thermal power plants:** fossil fuel, coal, fuel oil or gas, (chemical potential energy) is burned in a boiler to generate heat energy, which generates water vapour to power the turbine.
- **Nuclear power plants**: the fission of uranium atoms releases a large amount of heat energy that is used to obtain the water vapour that turns the turbine.
- **Hydroelectric plants**: the water in a natural or artificial stream transforms potential energy into kinetic energy due to the effect of a slope, which impacts the turbine and makes it rótate.
- **Wind power plants**: the kinetic energy of the wind is transformed directly into rotating mechanical energy by means of a wind turbine.
- **Photovoltaic solar plants**: the Sun's energy heats a fluid that transforms another second fluid into steam, which drives the turbine-alternator that achieves the rotary movement and generates electricity.
- **Solar thermal power plants**: the Sun's energy heats a fluid that transforms another second fluid into steam, which drives the turbine-alternator that achieves the rotary 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.

6.4 Distribution and consumption of electrical energy

Once electricity is produced, it must be transported to consumption centres - our homes, industry, ... - since electrical energy, unlike potential gravitational or chemical energies, cannot be stored.

Electricity transport

Electricity is transported through high-voltage lines made up of a conductive cable (copper or aluminium) and supporting elements (high-voltage towers). These lines conduct electrical current to substations that reduce the voltage of the current that circulates to our homes (220 V for domestic consumption) or industry (380 V).

Electric energy distribution

There is a company in Spain, Red Eléctrica Española (REE), responsible for the electrical energy distribution through high voltage lines. In addition, it is in charge of organizing production according to the amount of electrical energy that is needed at any given time.

For example, if the day allows a good operation of wind turbines, a good part of the electrical energy produced comes from wind turbines, and in return, thermoelectric production decreases, since these plants are easy to stop. However, nuclear power plants cannot be stopped easily (in Spain there are five nuclear power plants in operation, which provide approximately 20% of the electrical energy consumed).

The REE website provides information on the demand for electricity in real time 24 hours a day, 365 days a year.

Electricity comes home

For having electricity at home, it is necessary to have an adequate electrical installation and a contract with the electricity distribution company, which will connect the distribution network to the home installation.

The two most important items are the counter and the switch box. The meter marks the amount of energy consumed in the home, which will be the amount that the distribution company will bill.

The switch box contains the general switch of the installation, which allows the entry of electric current to the house circuit. Also contains a series of small automatic switches (PIAs) that limit the available power (limiter), protect from leakage of current (differential) or protect the different appliances (kitchen and oven, washing machine, lighting, power outlets, etc.) when there are voltage peaks (excess electrical energy).

The kWh

One of the most widely used energy units is the kWh, especially in the energy supply (electricity and gas): 1 kWh is the energy consumed by a 1 kW appliance (that is, 1000 W) when it is operating for one hour.

6.5 Energy saving

The world's population continues increasing (almost 8 billion people!) And the quality of life also improves. To achieve this, **more and more energy is needed**: it is estimated that from 1970 to today, total energy consumption has tripled.

It is also very relevant that the standard of living, directly related to energy consumption, is distributed very unevenly: in Africa, there is 14% of the world's population, which consumes 3% of energy, while in Europe, with 11% of the population consumes 27% of energy.

How can you save energy?

Obviously, there must be **laws that favour energy saving**, and that are the responsibility of the different bodies that have powers, such as the Government of the country and the Autonomous Community, the Town Halls, etc. For example, cars that consume less fuel and emit less gas pay less tax when purchased.

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

1. **Get around on foot or by bicycle,** and **share the car** or **use collective means of transport,** which use less energy per unit transported.

2. **Consume food products that are produced nearby,** because this saves energy in transport, in addition to favouring agriculture and livestock in the area.

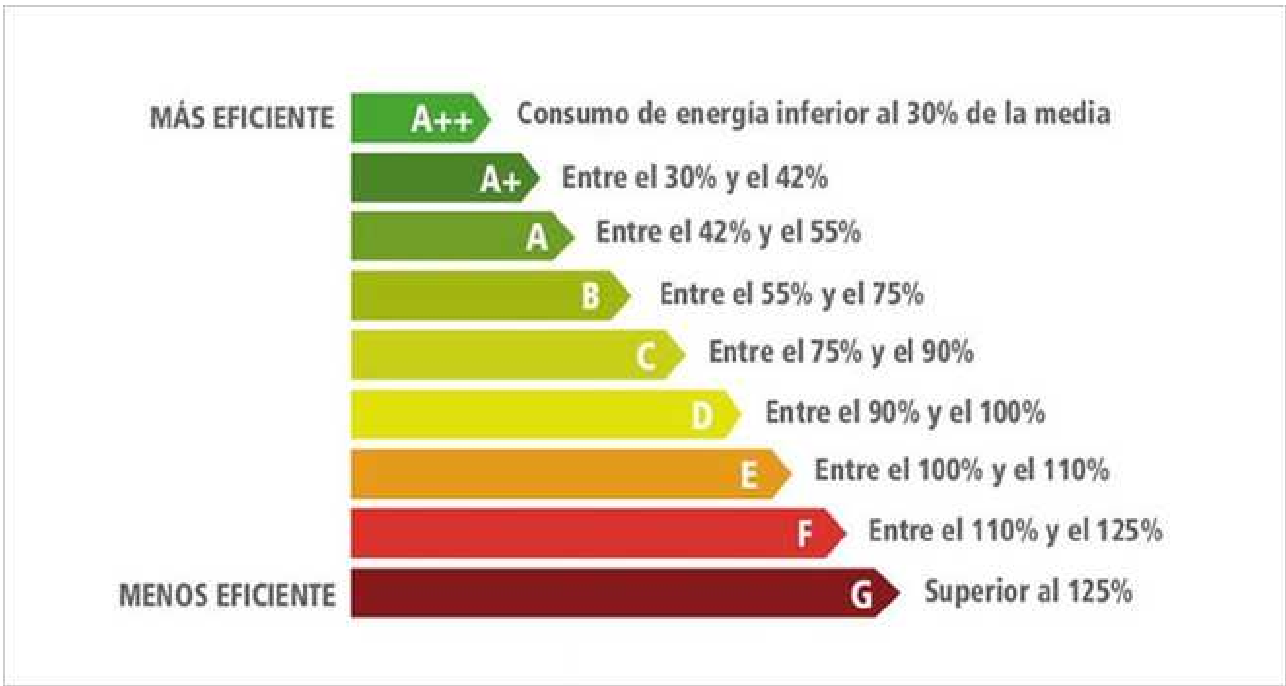
3. **Take a shower instead of a bath,** because it saves hot water.

4. **Control the temperature of the heating and air conditioning in your house:** it is absurd that you have to be in a shirt in winter because it is hot inside your house.

5. **Use energy-saving light bulbs,** turn them on only when you need them, and **try not to have the devices on standby**.

6. **Recycle** paper, glass, containers, etc. Think that obtaining one kg of aluminium from recycled cans consumes only 10% of the energy necessary to obtain it industrially from bauxite (aluminium ore).

7. When you have to replace electrical appliances, you must be very attentive to their **energy label** to choose the one that is most efficient, because, in addition to saving energy, its cost on the electricity bill will be lower. Observe in the image the appreciable difference in consumption depending on the final energy rating.



7. The energy of the waves

So far, you have seen two ways of transferring energy between two bodies: **work** (applying a force that causes the displacement of a body) and **heat** (putting bodies in contact with different temperatures)..

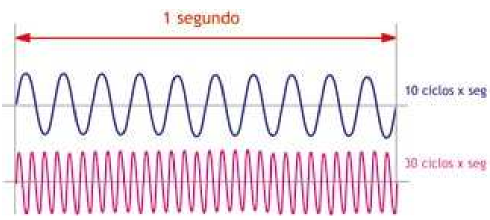
But there is a third way: the waves. In wave motions, energy is transferred between two points in space without a net displacement of matter.

Waves on a rope
With the following simulator, you can see how wave movements are generated in a string, both by pulses and continuously. Look at the blue dots as a reference: they swing up and down, like a vibrating ball on a spring, while the disturbance drifts to the right.

Waves in the water
Take a look at what happens to bathers. When the disturbance is transmitted, the wave advances, but the bathers oscillate vertically; they do not advance or retreat, that is, energy is transmitted but not matter.

Waves energy

It depends on a quantity called **frequency**, which is related to the number of waves that are formed per second. It is **measured in hertz (Hz)** so that **the energy carried by a wave is directly proportional to its frequency**.



Light and sound, two ways of presenting energy

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

Sound energy appears when a car horn honks, when amplified music is played through speakers at a rock concert, in the bustle of a crowded square; or the unbearable noise of a compressor drilling into 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 such as air or water. Instead of it, **light** is an electromagnetic wave and does not need a medium to propagate, so it is transmitted in a vacuum.

8. Sound

There is a great variety of sounds: some pleasant, such as music and others, such as noise, unpleasant. However, they are all produced by a vibrating object.

A vibration is a back and forth movement: when the strings of a guitar vibrate produce sound, when the air enters a flute the tube vibrates, and the sound emitted by a bass drum is produced when its membrane is struck, which starts to vibrate.

Sound properties

The two most important characteristics of sound are intensity and tone.

The **intensity** of a sound is given by the greater or lesser vibration of the object that produces the sound.

The **tone** is determined by the number of vibrations per unit of time. A sound becomes higher or higher in pitch when the number of vibrations per second is increased, and it becomes lower or lower in pitch when the vibrations are decreased. The unit of frequency, the hertz (Hz), equals one vibration per second.

Sound propagation

When we hit a drum, its membrane vibrates moving in and out. When the membrane moves outwards it compresses the air around it, while when it moves inwards, the air around it expands. The drum membrane vibrates the air particles that are closest to it and these vibrate the neighbouring ones and so on. In this way, the vibration is propagated and so, the sound.

The speed of sound propagation

Sound travels faster in media where the particles are closer together. Therefore, the propagation of sound is faster in solids and slower in gases: into the air, the propagation speed is 340 m / s, while in iron it is 5000 m / s.

Where does the sound propagate?

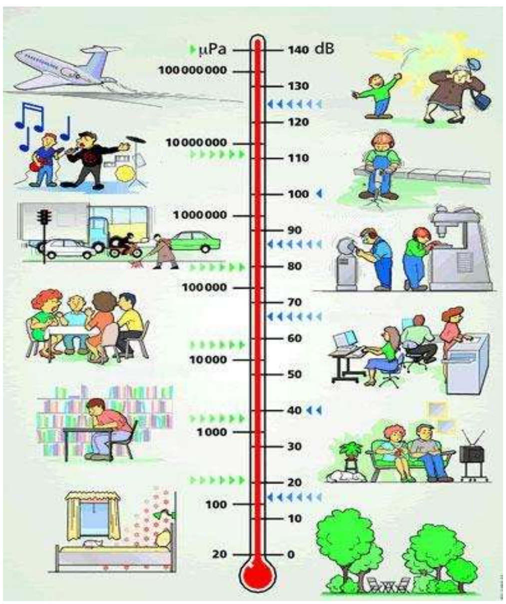
Sound propagates only in a material medium and **does not propagate in a vacuum**.

8.1 Acoustic pollution

A problem in our society

Noise pollution **is the excess of intense sounds** produced by human activities, which alters the normal conditions of the environment in a certain place.

Although noise does not accumulate, does not move from place to place or is maintained over time, as happens in other types of pollution, it can also cause great damage to people's quality of life if it is not controlled.



Noise pollution is one of the main environmental problems in Europe. **Spain is the second country with the highest level of noise pollution worldwide after Japan:** 50% of Spanish citizens endure noise levels higher than those recommended.

One way to measure loudness: the decibel

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

Characteristic values are the 20 dB of a whisper, 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 that is why the labour legislation prohibits staying more than 8 hours at a level of 90 dB to avoid hearing disorders (noises of more than 150 dB can cause the bones of the ear to break).

In addition, it is not recommended to continuously listen to music with headphones at high volume.

You must bear in mind 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 related phenomena intrigue humanity since more than 2000 years ago: the ancient Greeks had already observed some phenomena associated with light.

You already know how important light is for man, plant photosynthesis, the climate, etc. Light is essential to be able to observe the objects that surround us. Thanks to it we can have a coloured world around us.

The light that comes from the Sun is composed of a set of different waves, each one of a different colour (remember the rainbow). Well, 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 colours of the light received.

Thus, it can be said that **light is a way of presenting energy**.

How light spreads?

There are a number of facts that make us think that light propagates in a straight line: the straight contour of a light source, the shadows cast by opaque bodies, and 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 some of the light towards us. The sharp, straight boundaries of the light beam show that the light travels in a straight line.

In reality, **light is a particular type of electromagnetic radiation that travels at a speed of 300,000 km/s in a vacuum** and more slowly in other media such as air or water.

Characteristics of the light

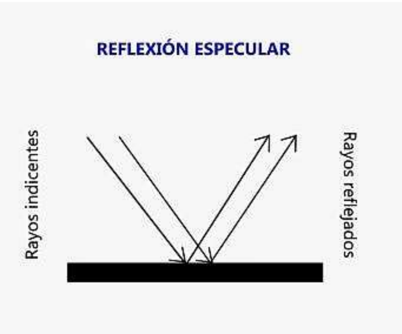
- Light is a way that energy is presented. **It is a form of radiation**.
- **Light transfers energy** from one place to another.
- **It takes energy to produce light**. Materials gain energy when they absorb light.
- Light is **detected by the human eye.**
- Light **propagates in a straight line.**
- White light can be broken down into its component colors by passing it through a prism.

9.1 Reflection and refraction of light

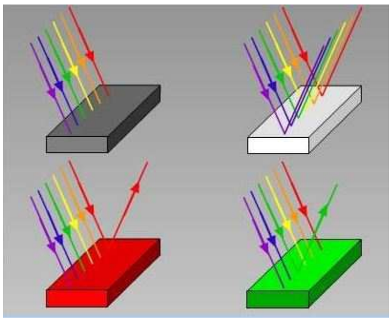
How do objects behave when light falls on them?

When light "strikes" an object, one of the following can happen:

- It bounces off the object and returns backwards (**reflection**). You observe this phenomenon when you stand in front of a mirror, the light rays hit the mirror, which "returns" your image, or on a calm water surface.



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

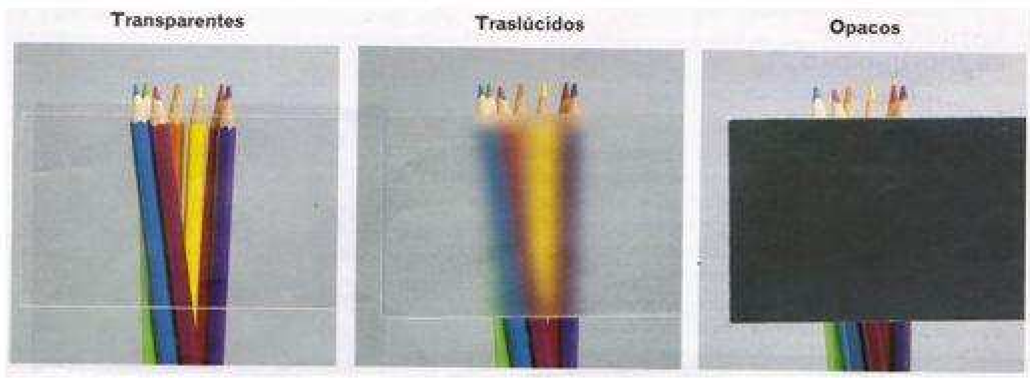


- It passes through the object (**transmission**) and can deflect its path (**refraction**). Light rays are deflected when they pass from one material to another, such as if passing from air to glass or water. This effect is called refraction and influences how we see things.

For example, when inserting a pencil or a straw into a glass of water, it appears broken, and a pool appears shallower than it is, as you can see in the images.

Most of the time all of the three phenomena take place simultaneously but in different proportions.

The bodies that do not allow light to pass through are called **opaque**. Bodies that let light through them completely, such as glass, are called **transparent**. Bodies that partially allow light to pass through, but cannot allow distinguishing the shape, are called **translucent**.



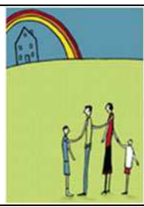
Refraction of light
Light rays deflect when they pass from one material to another, such as when they travel from air to glass or water. This effect is called refraction, and it influences how we see things.
Thus, when inserting a pencil into a glass of water, it seems broken, and a pool appears shallower than it is, as you can see in the images.

9.2 Luminous energy

The energy of light

The energy of light
Light is a particular type of **electromagnetic radiation** that travels at a speed of 300 000 km/s in empty space and more slowly in other media like air or water.
White light is a mixture of radiations of different colours, from red (lower frequency and energy) to violet (more frequency and more energy). Between red and violet, all the colours 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 colours**, 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 colours.
Although it seems complicated, it happens constantly in nature when the white light coming from the Sun goes across raindrops: it is the rainbow.

9.3 The colour of the bodies

Most materials can absorb some colours and reflect others. The resulting composition of the reflected colours is what is perceived as the colour of the body.
This phenomenon is known as reflection colour. Thus, a body will be red if this is the only colour reflected; a body will be cyan if it reflects blue and green, the mixture of which is provided by cyan.

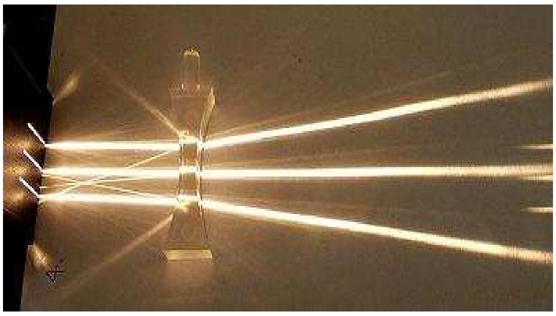
A body is white when it reflects all colours, and it **is black when it absorbs all colours and reflects none**. In the latter case, black bodies are perceived by the diffuse reflection of part of the light; otherwise, they would not be visible.

On the other hand, **the colour of the bodies depends on the colour of the light that illuminates them**: if a white body is illuminated with green light, it will only be able to reflect that light and it will be green. However, a blue object cannot reflect green as it absorbs all colours except blue; for this reason, any blue object that glows green will appear black.

9.4 Optical devices

Mirrors and lenses

In the images in the web book, you can see the effect of three reflective surfaces, **flat and curved mirror**s: the flat mirror returns the image as it is, but curved mirrors can increase the size of objects (such as magnifying mirrors for makeup, concave) or lower it (as in some types of car mirrors, convex).

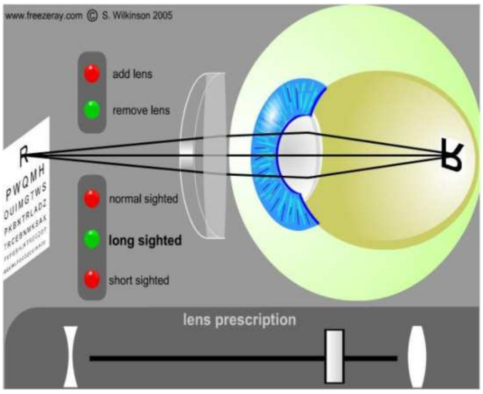


The light deflection produced when passing through the glass is also used to make lenses. Lenses are used to focus images in projection systems and, also, to correct vision defects caused by incorrect focus.

The eye and sight

The human eye is a complex optical instrument thanks to which we can perceive the objects surrounding us. It acts like a photographic camera in which the transparent protective 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 the **crystalline**. The image is formed in the **retina**, a thin layer where the receptor cells, **rods and cones** are found.



The **rods** are excited by low-intensity light, but are not sensitive to colour, and allow night vision (in little light). Its insensitivity to colour explains why we cannot distinguish colours at night. **Cones** are sensitive to colour, are excited by intense light, and are responsible for colour vision under light sources.

The crystalline works as a lens, forming the image on the retina backside. If the image is not formed in the right place, you lose sharpness, and you have myopia or hyperopia.

One way or another, vision must be corrected with glasses, for which glasses or contact lenses are used. In the simulation, you can see how the lenses act to correct both defects.

Optical Devices

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

The magnifying glass, microscope and telescope have the function of enlarging the image seen of an object. The periscope allows seeing objects overcoming obstacles. The photographic camera allows recording impressions of what is in front of the lens called objective.

9.5 Light pollution

It is crucial to take advantage of artificial light. It is not desirable that lighting lamps shine upwards because it is not useful to see, it is an unnecessary expense and consumption of energy and it leads to great light pollution.

Lighting lamps in the streets

Street lighting lamps in cities should have adequate shapes to reduce light pollution. That is, must be constructed in a way that illuminates only where the light is needed.