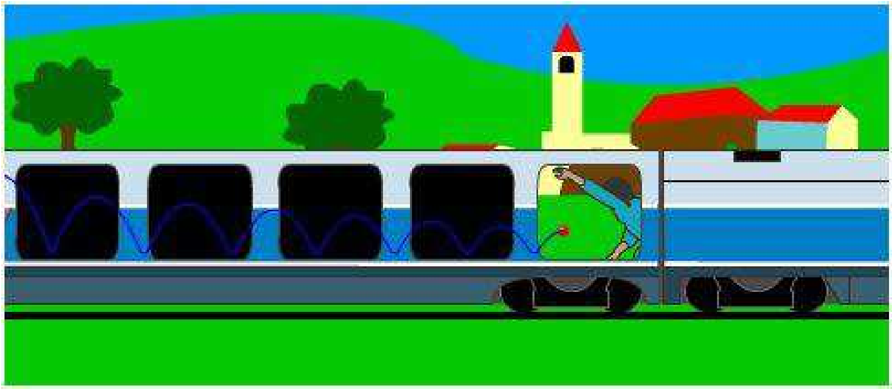
Unit 2. Motion and forces

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 different kinds of forces (elastic, gravitational, electric, magnetic...).

1. The speed of mobiles

In the next simulator, you can see a child with a ball in his hand and he lets it fall. 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 they 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 units 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 in case 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 an object moves, that is to say, the space travelled by the mobile in the 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 kilometres 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 to travel the same space during the same time.

What is the acceleration?

When a mobile changes its speed 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 informs about the space travelled by some mobile during a time big enough. If this time is short, 0,1s for example, 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 the 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 value, actually the speed is not constant. There is something that changes in its movement: the direction it takes is changing. Remember, the unique case where direction doesn´t change is in the 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? What kind of motion does it have? And when we throw it vertically upsides? These kinds of movements are very frequent and now 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. 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 seconds 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 to define the rotational speed.

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 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, rps or hertz, 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 move is because forces are acting on you, and even when you are quiet you experience different forces. The particles forming your body are also connected due 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" game or the car, the people involved are applying a force to the rope or the car, changing the speed of these objects. The bigger the force, the bigger the change that produces.

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

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

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

What is a force?

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

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

As the force is the result of the interaction between those two bodies, is not something that can be stored inside them: a strong person is someone capable of making a great force, but incapable of storing this force inside.

Easily, we could say that a force 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 differentiate 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. Saying that a force is strong or very intense doesn't give us enough information so we define a unit that allows us to assign a numerical value to intensity of a force. 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 honour for their achievements. The intensity of a force is measured in Newtons as a tribute to the great Isaac Newton.

The application point of forces

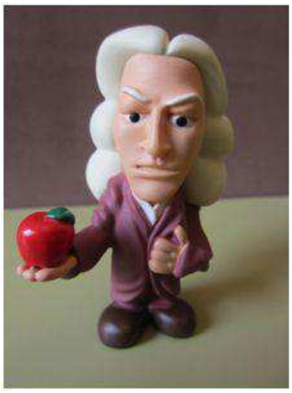
The application point is the exact place where the force is applied. It is very important to determine the effects of a force on a body. For example, it is not the same if you close the door pushing from its extreme than when you close it pushing near to the axis.

Characterizing a force

Besides the **direction** and **sense**, 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, which is 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 colours, 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, for what 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 planets movement and the movements in the surface of the Earth.

2.2 Measuring forces

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 of thick 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.

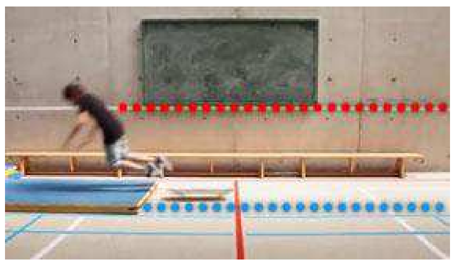
2.3 First law of Newton

Inertia

An idea that persisted for 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.

The first law of Newton or inertia law

If there are no forces applied to a body, it maintains the same motion that it had initially (it will keep moving straight or it 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.

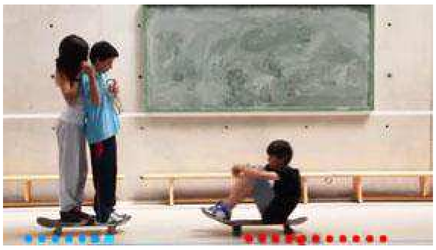
2.4 Second law of Newton

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

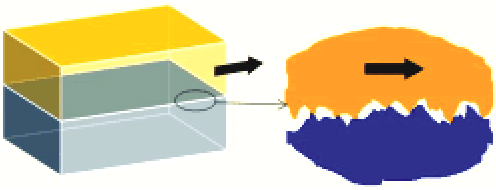
The third law of Newton, or **action-reaction law**, says that forces are not presented alone, they go in couples. When two bodies interact, body 1 applies a force to body 2, the second body also interacts with the first one applying a force to him. Both forces have the same intensity and direction but 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 force to 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 but with opposite sense.

3. Frictional forces



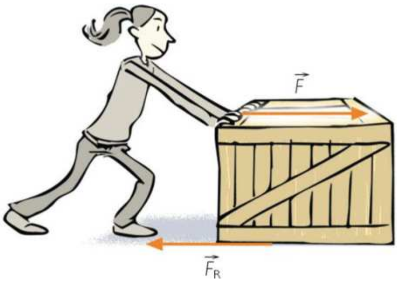
Friction is a force that appears when there are two bodies in contact. Is the force that avoids that one body slides over the other. Friction allows us to walk and depends, mostly, on the nature of the surfaces in contact: if they are very rugged, they stuck when they try to slide one over the other,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

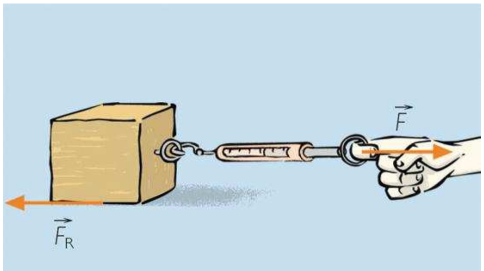
You know that it is not the same to walk on asphalt than on ice. When you try to walk on ice, friction is much lower so it is much more difficult to move.

Diagrams of forces

When we push or pull an object to move it over a surface the friction appears.

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, the surface applies over the object a force that we call Friction.





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

Frictional forces

Friction 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

If there wasn't an atmosphere, all bodies will fall with the same speed because there won't be any frictional force, so they will take the same time to fall.
The 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, that appear as the result of the interaction of bodies that are separated by a certain distance.

The first force that we are going to study is the gravitational force. The gravitational force is the force that any object experiment because of having mass. This force is responsible for our weight and also of the movement of our planet, that as you know is spinning around the Sun.

Back to Earth

We observe on the surface that the Earth attracts any object with a force that we call weight. **Weight is caused by the mutual attraction between a body and the Earth, and it is caused because both objects have mass**: the higher the mass is, the bigger the attraction between them will be (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 mass and weight are not the same! In our daily life, we use these words as if they were the same, but in physics, we have to distinguish between mass and weight because they have a different meaning.

Mass and weight

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

Mass is the amount of matter that an object has, and it doesn't change depending on where the object is but weight can vary depending on its location. It is measured in kilograms (kg).

How do we calculate the weight of a body?

You know that we measured the weight with a dynamometer but, what if the body is too big? In this case, we use a balance. The balance gives us the mass of the body, so, if we use the relationship P=mg, where m represents the mass of the body and g is a constant of the surface of our planet that has a value of 9,81 N/kg, we can calculate the weight of our object.

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

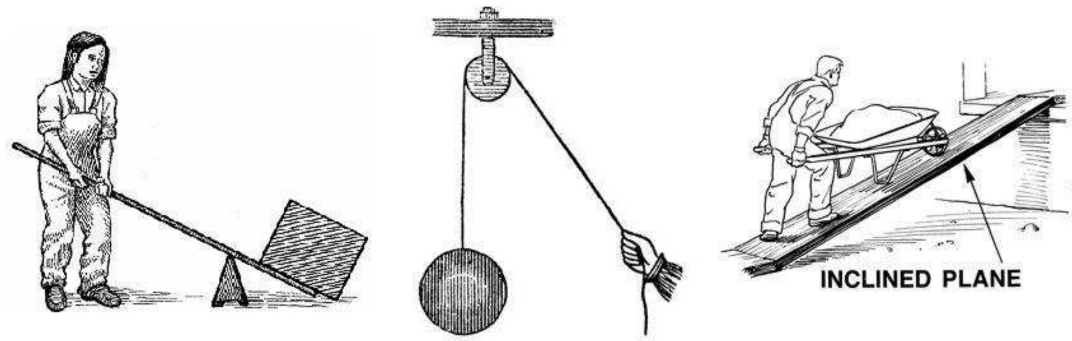
The meaning of g

On the Earth, it has a value of 9,81 N/kg. It means that the Earth attracts each kilogram of mass with a force of 9,81 N.

5. Machines

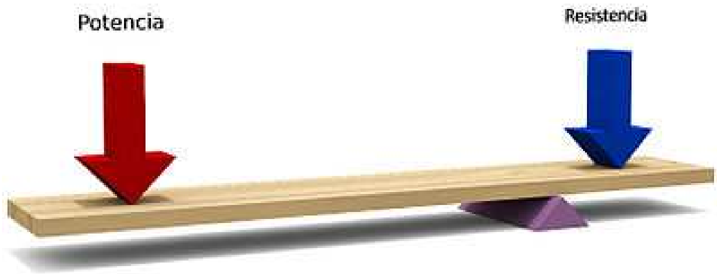
We spend a lot of time applying forces in our daily life: brushing our teeth, opening a door, walking on the street… They are activities that require the action of a force, and the list is never-ending!

Over history, human beings have tried to make the different processes that require the action of big forces easier. To achieve this we have invented mechanisms that allowed us to do different tasks more simply, reducing the force required.



Some of the simplest machines are the lever, the pulley and the inclined plane. Let's study them.

The lever



A lever is a machine composed of a rigid bar that oscillates over a support point. We can apply two different forces on both sides of the bar: power and resistance. The resistance is the force that we want to overcome and the power is the force we are going to apply.

Levers are used because they allow us to overcome big resistances applying smaller powers.

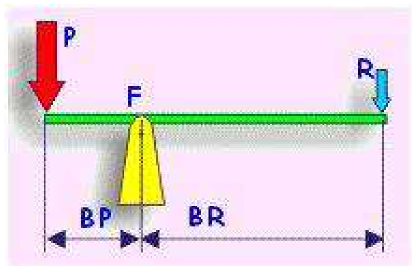
Different kinds of levers can be classified into three groups: first grade, second grade or third grade. It depends on where the support point is located in relation with the application points of the forces. Here you can see some examples:

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 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 the support point (BP).

P·BP=R·BR



6. Electric forces

A bit of History

In 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.

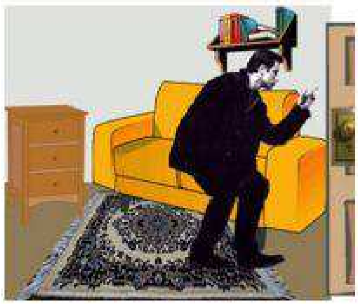
In the XVIII century, the french Charles du Fray observed that identical materials rubbed in the same way repelled themselves, so he concluded that there were two different kinds of electric phenomena: attractive and repulsive.

In the middle of that century, American scientist Benjamin Franklin established the theory of electric fluid. Electrical phenomena were caused by the motion of the electric fluid from one body to another. He made the kite experiment and invented the lightning 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, the comb attracts it. 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 can attract little pieces of paper.
- When you put on or take off a sweater maybe 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 get generated.

You can try the balloon experiment at home, but it is more spectacular to charge our 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 as 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

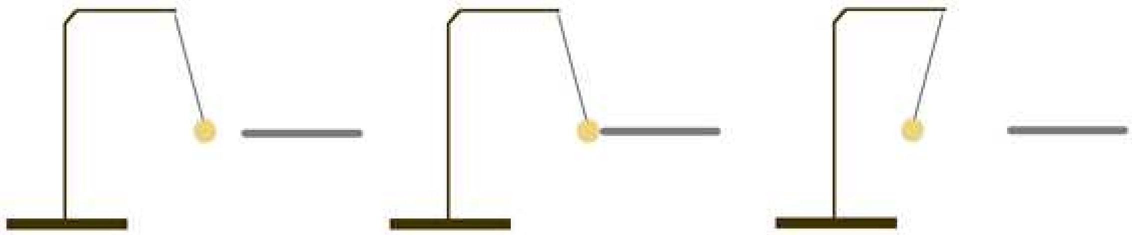
When you rub the plastic ruler or the pen, they acquire the property of attracting light bodies like confetti move or deflecting the waterjet.

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 a **negative charge**. They are assigned this way by agreement.
- Bodies with a charge of 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, the scientists discovered some particles with a negative charge and called them **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 the 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 loses electrons loses negative charge and becomes positively charged. The body that gets electrons is negatively charged.

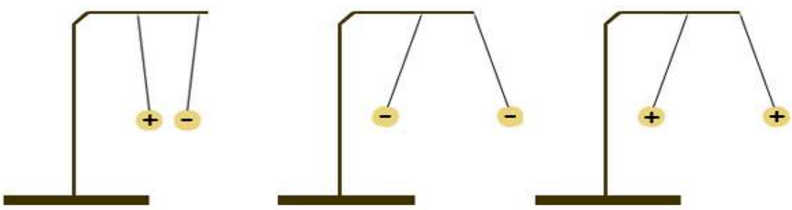
Electrification by friction is the result of the transference of electrons between two bodies.

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

Electrification by contact

When you put in 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.

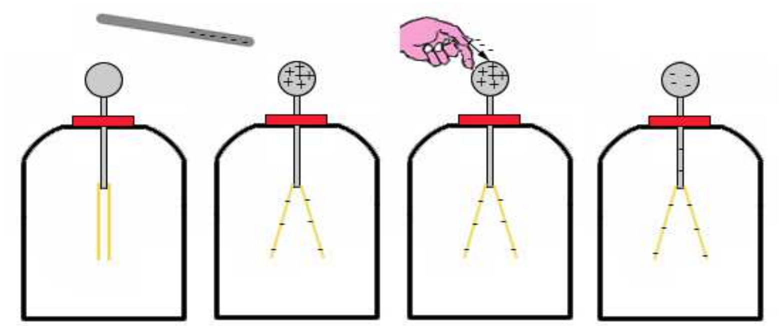


Electrification by contact

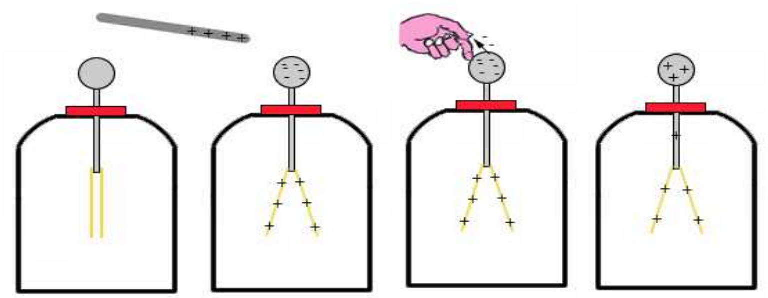
Is the result of the redistribution of electrons between two bodies, that move from the body with negative charge to the body with a positive charge.

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 of electrons and the furthest area has an excess. You can charge the electroscope as it is shown in the pictures.



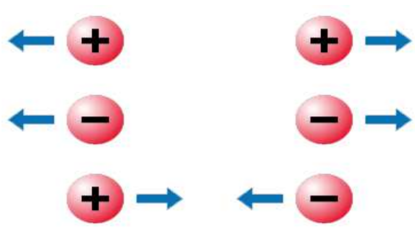
Electrification by induction

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 the charge (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



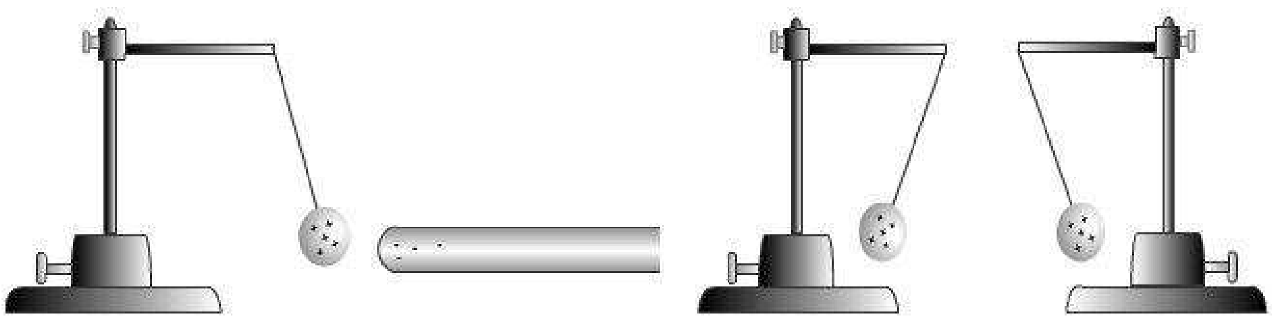
Kinds of charges

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.

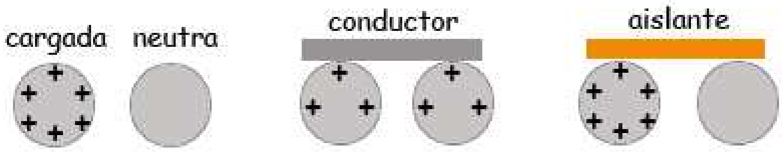
The charge of a body is always a multiple of the charge of the electron.

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.

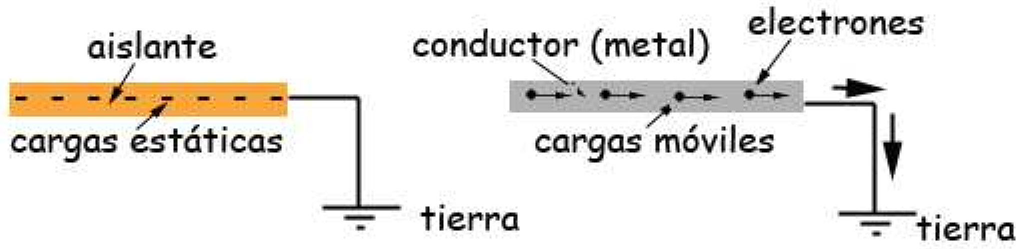
This is because in a neutral body charges are distributed in a situation of balance. When the body gets electrified, two things can happen: the first one is that the charges (the electrons) distribute through the body and the second one is that they remain where they were. Materials of the first kind 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 electric devices: illumination, the computer or your mobile phone.

The discovery and development of electricity and electric devices caused a huge change in society. Our lives won't be the same without this technology. To work, these machines need the motion of electric charges through a conductor.

As you have already seen, the force between charges is different depending on their sign. When we put in contact two charged bodies, one negatively (with an 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 the electric current?

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

Electrons and electric current

Electric current is produced when charges move through a medium that allows its passage, that is 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.

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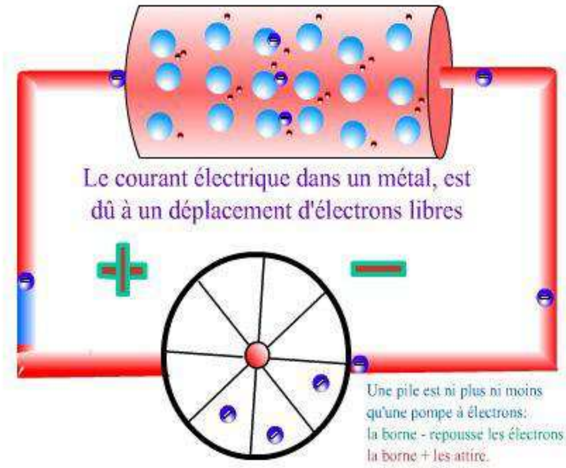
When scientist discovered electric current for the first time, they did not know electrons yet and considered that it was made of positively charged particles. They were wrong. The sense of the current was defined as directed from the positive pole to the negative pole because the positive charge of 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 of the 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 an 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

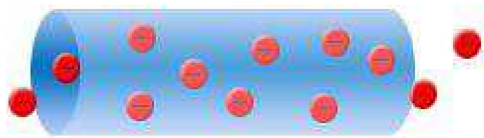
The three characteristic magnitudes of an electric circuit are:

- Intensity (I).
- The potential difference(V).
- Resistance (R).

7.1 Intensity (I), voltage (V) y resistance (R)

The intensity of electric current

If you want to indicate the amount of water in a river you use the word “flow”. The more water that goes per unit of time, the greater the flow will be.



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

Intensity (I)

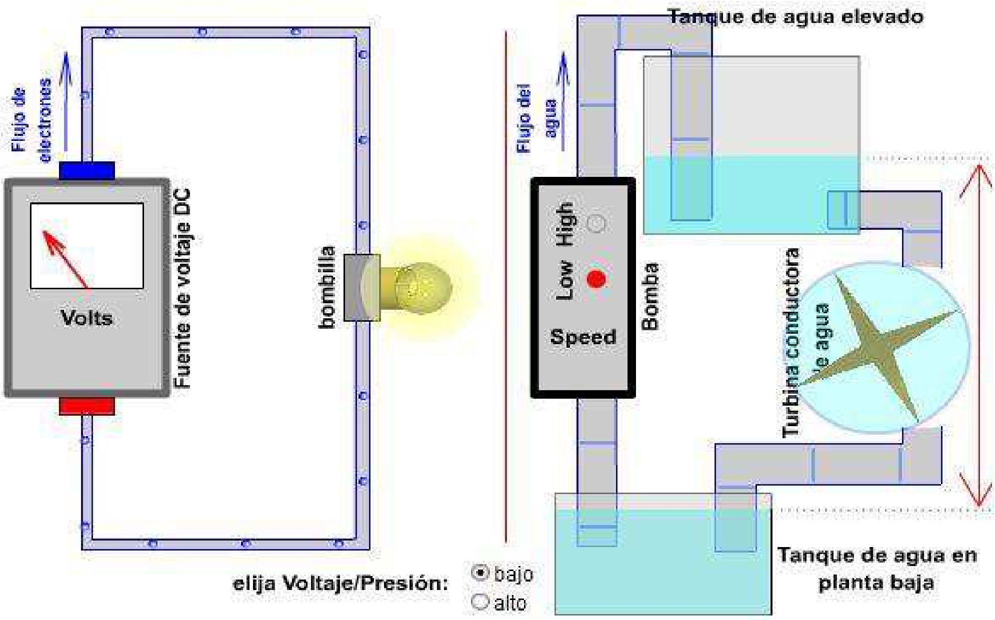
The intensity of the electric current (**I**) is the number of electrons moving through a section of a conductor per second. The unit in the IS is the **Amper** (**A**), which is a charge of 1 Coulomb going through a section of a conductor per second (1 A = 1 C/ 1 s).

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). To understand it, look at the next animation that compares the behaviour 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: the intensity of the current. Just as 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 a generator.

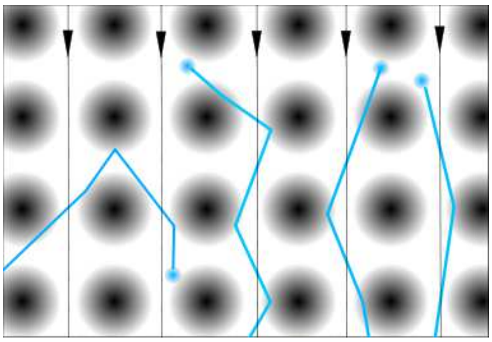
Objects fall because of their mass, moving from higher to lower points. The same thing happens to charges: they move because of the potential difference between two points of the circuit. The higher it is, the faster the electrons move, and the higher the intensity of the current will be.

Voltage (V)

The 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 the 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, losing speed and energy.

The amount of energy lost depends on **the kind of conductor**: if it is a good conductor it will lose just a bit of energy but if it is an isolator it will lose a lot of energy or even all of it. To understand this behaviour, the hydraulic simile is again very useful. The increase of resistance corresponds to a narrow pipe, 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 to do calculations in circuits, as you will do in Technology.

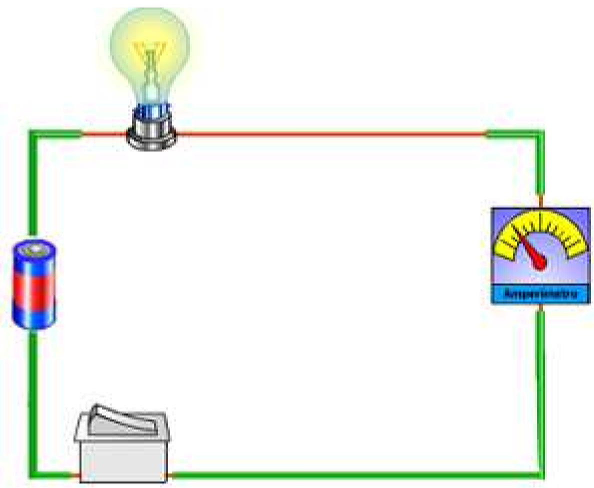
The intensity is higher when the electrons have more tendency to flow (V) and lower when there is more opposition to the flow (the resistance R).

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

Electric circuits

To have an electric current that allows our electric devices to work, we need to plug them to the distribution network of our house or to use batteries if the consumption 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 a 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 one 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 fewer 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. An 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).