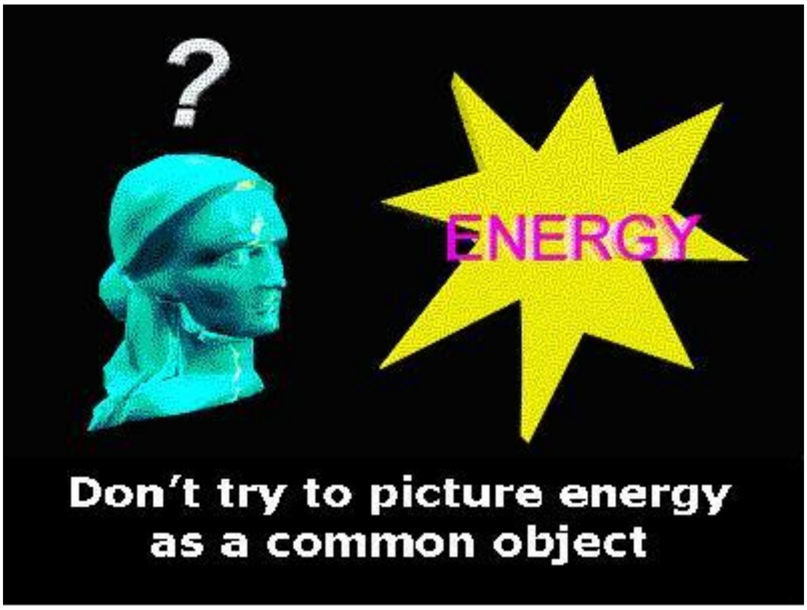
ENERGY

1. WHAT IS ENERGY?

One of the most important and difficult physical concept is energy. We can't imagine, we can’t touch the energy but we can feel its effects. The energy is a mysterious thing even though everything around us, including ourselves, contains it. All the living things need energy to survive. You can start thinking about this question: **what is the origin of the energy we use for living?**

We have another problem. We often speak of energy: food is energetic, that a person is very energetic, electric current has a lot of energy, etc. But the daily sense is different from the physical sense. That makes it difficult for us to understand the concept of energy because we don´t distinguish both meanings.

In this unit we are going to study the physical concept of energy.



A.1. Write down the meaning of «energy» for you.

A.2. Visit the next flash animation about energy and answer these questions:

a) Write down five objects that produce energy and five more that consume energy.

b) In your opinion, can we say our source of energy is the Sun?

c) In your opinion, can we say that rivers exist because of the Sun energy?

We can now analyze some changes that normally occur in nature or everyday life, for example, electric current produces music on a loudspeaker. We could say that the movement of electrons is transformed into the movement of a loudspeaker membrane. Another example: the air moves a wind generator. We can understand this process like a transformation of the movement of air molecules into the movement of generator blades.

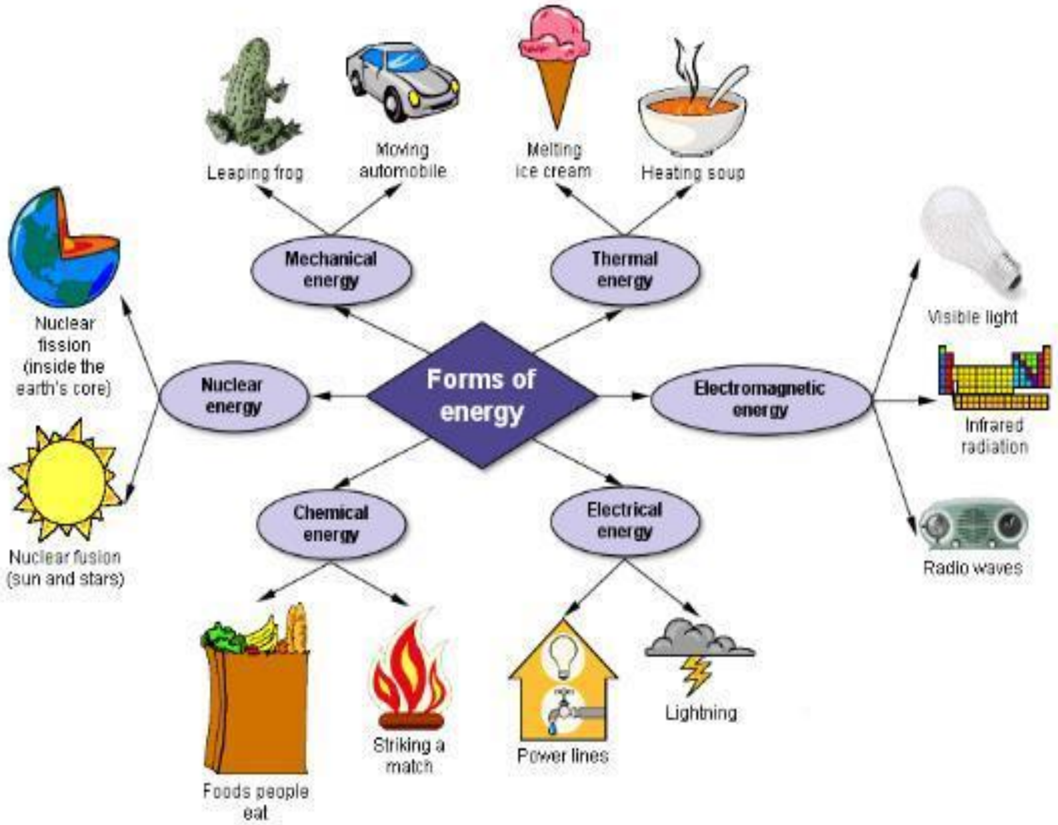
A.3. Identify in several systems the main change happening and the change causing it. Complete the table.

System	Main change	Change causing it
A drop on a roller coaster	Speed increases	
A crane lifts a load		The engine spends petrol or electricity
A lynx eating a rabbit	The lynx wins vitality	
A gas cooker heating water		
An electric cooker heating water		We take electricity from the grid
A lift taking up people		
A parachutist falling from a plane		Height decreases
Somebody going up stairs		
A battery moving a toy car		Some chemical reactions are happening in the battery
Someone throwing a ball up		

In all the previous cases we have a certain transformation causing another transformation. We say that the first transformation involves a form of energy and the second transformation, caused by the first one, a different form. In all the above examples one type of energy has changed into another type of energy. **In general the idea of energy is associated with the idea of change or transformation**. If a system has energy, it can cause changes. If a system doesn't have energy, it cannot change.

We can say that something has **energy** when it has the property to produce **changes or transformations**

2. DIFFERENT KINDS OF ENERGY



Like money, energy can take many different forms, different currencies we might say, that can be exchanged with each other following precise conversion rules. We will classify the different types of energy although it is clear that this division only has the advantage of facilitating the study because energy is one thing, one concept. Later we will study how energy types are changing continuously into others in nature.

Kinetic energy: a body has this energy if it moves.

For example: a car, the air, a bullet, etc.

Potential energy: a body has this energy if it has height.

For example: the water of rain, the water in a marsh, a plane, etc.

In certain situations it is useful to mention the addition of the two previous forms as **Mechanical energy**.

Internal energy: associated with chemical composition or the temperature of a body.

For example: petrol, gunpowder, hot water, etc.

In some cases, as in the diagram above, we speak separately about chemical energy and thermal energy

If you are curious and want to know more about chemical energy, you can consult the following link.

Electrical energy: associated with the effects caused by an electric current.

For example: a heater, an electric motor, a computer, etc.

If you are curious and want to know more about electrical energy, you can consult the following link.

Luminous or Electromagnetic energy: this is transmitted by electromagnetic radiation

For example: the sun light, a solar calculator, a microwave, etc.

If you are curious and want to know more about luminous energy, you can consult the following link.

Nuclear energy: associated with the nucleus of atoms.

For example: in a nuclear power plant, in the Sun, etc.

If you are curious and want to know more about nuclear energy, you can consult the following link.

Energy units

The energy unit according to the International System is called **joule** (J). We can use also another unit, **the calorie** (cal). One calorie is the energy which 1 gram of water needs to increase the temperature by 1 degree.

1 cal = 4,18 J

The joule is a very small unit. It is the energy that you spend to put an object of 100 grams one meter up at a constant speed. If you burn 1 kg of petrol we can obtain 40 million of joules of energy.

2.1. Kinetic energy

Do you think a body can cause changes simply by being in motion? To imagine that, try to give a correct answer to the next question: what type of energy had the meteorite that caused the extinction of the dinosaurs 65 million years ago?

The conclusion is clear: **bodies have this energy when they move**. Movement can cause transformations

A.4. Say if these systems have energy:

a) A car before crashing.
b) A glass of water on a table.
c) A bullet in motion.
d) A stone without movement.

Why?

But what factors have influence on kinetic energy?

A.5. a) There are two identical motorbikes, but one goes faster than the other. Which motorbike has more kinetic energy? Why?

b) Now there is one car and one lorry travelling at the same speed. Which has more kinetic energy? Why?

What factors influence kinetic energy?

Kinetic energy depends on two factors: the mass and the speed of the body. You can calculate the kinetic energy with the formula:

$$Ec = \frac{1}{2}mv^2$$

Speed has more influence than the mass in kinetic energy. Why?

In this formula when we put the mass in kg and the speed in m/s (metres per seconds), we obtain the energy in J.

A.6. Calculate the kinetic energy of:

a) A bullet with 80 g mass and 300 m/s speed.

b) A plane 400 tonnes of mass and 1000 km/h speed.

c) A Formula 1 with 720 kg mass and 413 km/h maximum speed measured.

A.7. The peregrine falcon is the fastest bird in the world. Their wings have a design that allows them to fly horizontally at 160 km / h. By retracting the wings the falcon is capable of a speed record to the birds of 320km / h. If the mass of a peregrine falcon is 1 kg:

a) What is its kinetic energy into horizontal flight?

b) What is its kinetic energy at the end of the swoop?

A.8. In the following link you can see a flash animation on the formation of the Chicxulub crater in Mexico 65 million years ago. Calculate the amount of Hiroshima's atomic bombs equivalent to the meteorite fall, knowing that its speed was approximately 54,000 km/h and its mass was about $7.5 \cdot 10^{12}$ tonnes. The explosion of Hiroshima released energy of about $8.4 \cdot 10^{13}$ J.

Do you think that the shock wave reached the entire Earth? In what other ways could living things become extinct after the impact?

A.9. The damage that a car receives in an accident depends on, among other factors, the vehicle's kinetic energy. Compare the damage we can get at a given speed with the damage at double speed. Also at triple and quadruple speed.

Wind energy

We can also use energy from the wind. We have used wind for sailing boats and windmills for centuries, but now there is another interesting application: wind power plants for producing electrical energy.

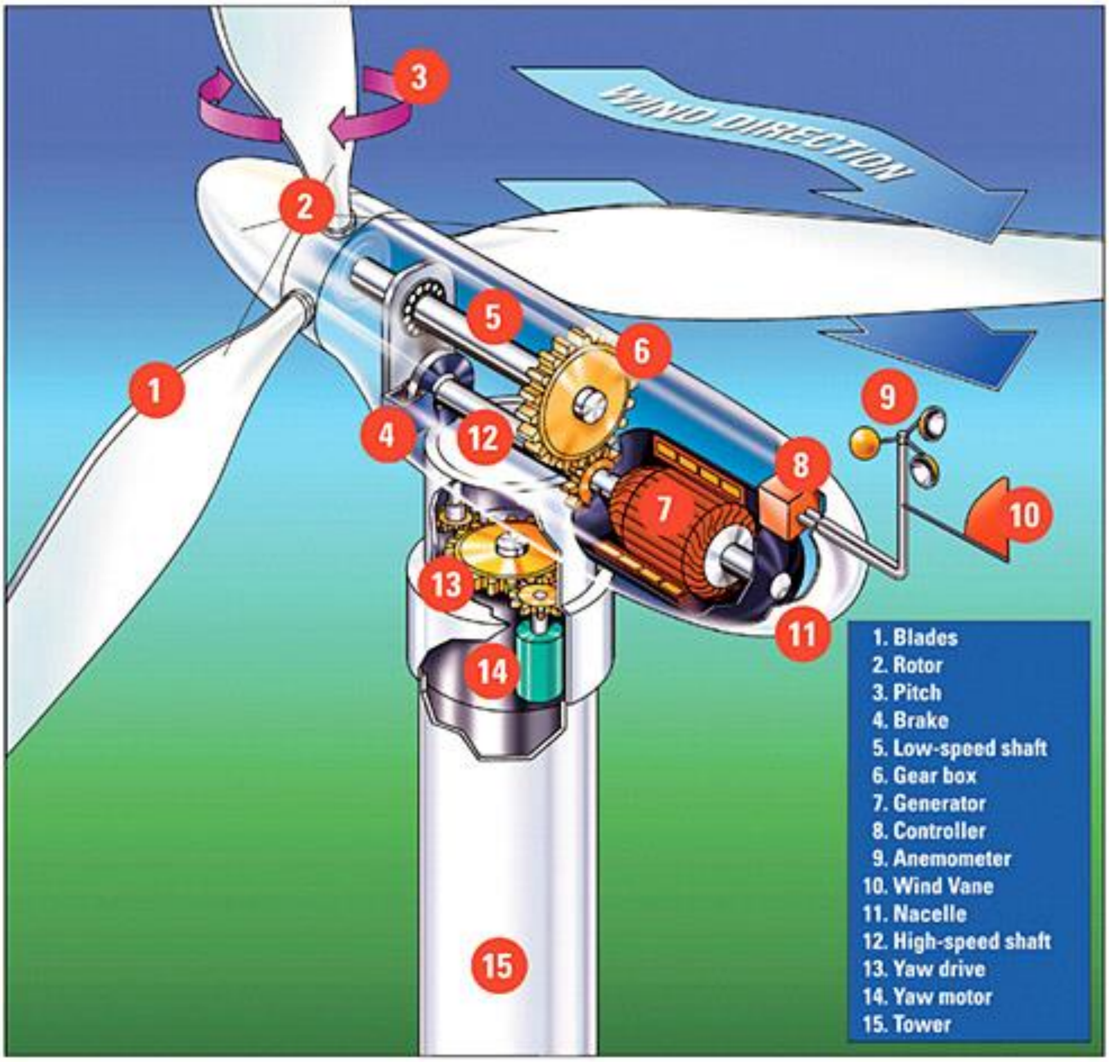
The problem with wind power plants is that they are geographically conditioned. They are only profitable in areas where the wind blows strongly regularly. In Spain, for example, on the coast of Galicia, in the Strait of Gibraltar, in Albacete, in the Ebro river basin and in the Canary Islands.

A.10. In the following link you can see a flash animation about wind energy. Visit the website and answer the questions:

a) What is the origin of the wind energy?

b) What places are the best to install wind farms?

c) What advantages and disadvantages do you think wind energy has?



2.2. Gravitational potential energy

Bodies have this form of energy for its position above the Earth.

A.11. Do you think that bodies with height have energy? Why?

Remember that energy means the possibility of changes or transformations.

But what factors influence gravitational potential energy?

A.12. a) When does one object have more gravitational potential energy, on the ground or at a given height? Why?

b) When does one object have more gravitational potential energy, with less mass or more mass? Why?

c) When does one object have more gravitational potential energy, on the Earth or on the Moon? Why?

Potential gravitational energy depends on three factors: mass (or weight), height and the gravity of the planet or satellite where you are. You can calculate this energy with this formula:

$$E_p = Weight \cdot height$$

For us, normally the mass and the weight have the same meaning, but they are not the same property for bodies. For example, if you go to the moon your mass is the same but your weight is smaller and you can jump very high. For us normally both magnitudes are similar because they are proportional. The formula that connects weight and mass is:

$$Weight = Mass \cdot g$$

Where **g** equals **gravity acceleration**, it is 9,8 m/s^2 on the Earth, but it is smaller on the Moon. In general **g** depends on the mass of the planet or satellite where we are. In the last formula mass is in kg and weight in N (newtons, the force unit).

A.13. Calculate the potential energy in these situations:

a) A body with 5 kg mass and 8 m high.

b) A bell with 40 kg mass on the ground.

c) The same bell but 20 m higher.

d) The change of potential energy in the bell.

A.14. Calculate the potential energy in these situations:

a) A reservoir that stores $6{\cdot}10^{13}$ kg of water at an average height of 100 m.

b) A 400 tons plane at an average altitude of 1000 m.

Hydraulic energy

A very big mass of water has a lot of potential energy if it is high. When the water falls down the movement is transmitted to a mechanism called turbine. This mechanism transforms the movement into electrical energy when it is coupled to a generator.

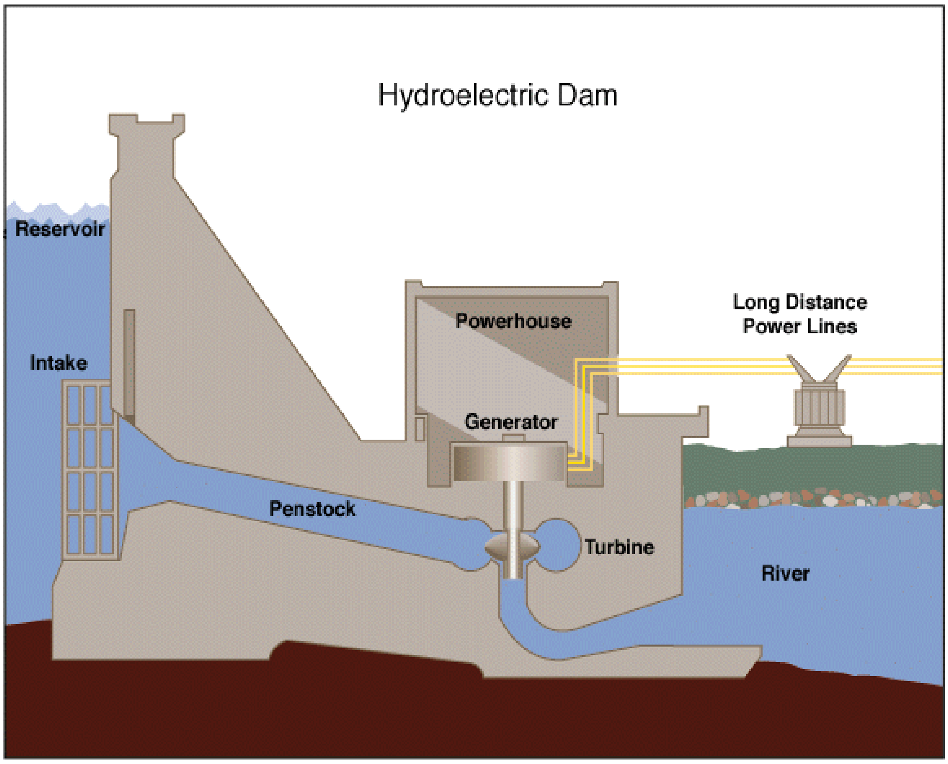
A.15. In the following link you can see a flash animation about hydraulic energy. Visit the website and answer the questions:

a) What is the origin of the reservoirs' hydraulic energy?

b) Looking for information on what a turbine and how it manages to generate electricity from the movement.

c) What advantages and disadvantages do you think hydraulic energy has?

You can view a summary of the operation of a hydroelectric dam in the next video.



2.3. Internal energy

Bodies have energy because of their chemical composition or their temperature. Some substances, for their high chemical reactivity, can release large amounts of energy. We can say that these substances have a lot of internal energy. Some hot substances have a lot of internal energy too.

A.16. Say which of the following bodies have energy:

a) Gunpowder.

b) Rock.

c) Cold water

d) Food.

e) Petrol.

f) Hot water.

g) Sand on the beach.

Why?

Different bodies have different quantities of energy because their chemical compositions are also different. Some of them have a lot of energy but some of them have a little amount of energy.

If we want to measure internal energy of different substances we can use the calorific power:

The energy liberated by combustion of the mass unit (1 kg) normally expressed in kJ.

A.17. The calorific power of one type of petrol is 43680 kJ/kg. What is the meaning of this measure? How can we use this energy?

But the internal energy also depends on temperature. How?

A.18. Answer these questions:

a) If you have a piece of metal, when does it have more energy, when it is hot or cold? Why?

b) If you have some liquid, when does it have more energy, when it is very hot or cold? Why?

c) When are tornadoes and hurricanes more likely to be formed, with a warmer or colder atmosphere? Why?

You can see an incredible (and beautiful) tornado in the next video.

In the next video, you can see the hurricane Katrina (one of the most destructive hurricanes) from a satellite.

If we heat a body its internal energy increases.

If we cool a body its internal energy decreases.

The energy of foods

First you have to read these tables:

The energetic value of foods (kcal/100g)	
Fat	902
Olive oil	884
Cured cheese	392
Dry pasta	371
Chocolate cake	367
Bread	274
Roast chicken	232
Lamb (leg)	191
Boiled egg	155
Boiled rice	130
Boiled cod	105
Milk	64
Orange	46
Spinach	23

Energetic requirements of the organism (kcal/hr)	
Sleeping	65
Studying	98
Walking	163
Riding a bike	325
Running	455
Athletics	1000

What is the meaning of both types of numbers?

The human body obtains the energy it needs (movement of the muscles, activities of the various different organs, etc.) from nutritional products.

A.19. Look at the previous tables. They show the relative energetic capacity of different types of food and the energetic contribution required for different activities.

a) What kind of food stores the most energy? And the least energy? Compare the energy provided by meat and fish. What conclusions do you reach?
b) Imagine that the doctor recommends you go on a diet with a high-energy content. What food would you eat? Would it be recommendable to have only one kind of food? Why?
c) Do we all need the same amount of energy? How does the type of activity we are doing influence our energetic needs?

A.20. a) One adult that works needs approximately 2500 kcal/day. What is the meaning of this measure? Can you live if you get all your daily calories from only one type of food?

b) What are the differences and similarities between petrol for cars and food for people.

3. SYSTEMS CHANGE. ENERGIES ASSOCIATED ALSO CHANGE.

If a system has transformations, we always have changes also in the type of energies involved. We need to analyse these situations.

For example: if a loudspeaker sounds the energy transformation occurs between the grid electric energy and the kinetic energy of the membrane and the air in contact with it. Schematically:

Electric energy (grid)
↓
Kinetic energy (membrane)
↓
Kinetic energy (air)

Another example: the air moves a wind generator. We could express this process as the transformation of the kinetic energy of the air into the kinetic energy of the generator blades and finally into electric energy. Schematically:

Kinetic energy (air)

↓

Kinetic energy (generator blades)

↓

Electric energy (grid)

A.21. Can you make the same analysis in all the situations described in the table of activity number three?

A.22. Can you make the same analysis in the situations described in the next flash animation?

3.1. Energy conservation

In the last two flash animations you have seen the successive transformations between kinetic and potential energy. The sum of both, which is the mechanical energy, has remained constant. However in the end the total energy has apparently disappeared. What happens when one type of energy disappears? A lot of energetic transformations end by heating the **surrounding area**, but normally we can´t observe this heat because the increase in temperature is very small.

A.23. Analyze the changes and energetic changes when:

a) A car in movement until the petrol finishes.

b) A bullet embedded in a tree.

c) A roller coaster going up or down but, at the end, it stops.

A.24. Do you know about elastic balls? They bounce a lot. Do you think if we drop one of these balls, without initial speed, from a height of 2 meters, it can go up 2,5 meters? Why?

Energy conservation law

The type of energy can change but it can´t appear or disappear. If one system increases its amount of energy another system always decreases its amount of energy. For example if a body falls down, its kinetic energy increases but its potential energy decreases.

It´s impossible to obtain energy from nothing. One system can increase its amount of energy but only if another system decreases its amount of energy. We don´t have any modern device that can produce energy without a complementary expense of energy.

3.2. Degradation of Energy

A.25. Visit the following link and answer the questions:

a) If energy is conserved, why are we worried about the depletion of energy sources?

b) Why do you think that we say “lost energy”, when we refer to heat?

c) Is electrical energy useful? Is petrol useful? Why?

d) Is the heat produced in the energetic transformations of the electricity and petrol useful?

We can define degradation of energy as the process of reduction of energy to forms in which it cannot be used by human kind.

Some physicists have talked about **the heat death of the Universe**. This concept corresponds to the state in which all useful energy is finally converted into heat. From this state any transformation would be possible, even life of course.

4. HEAT

Normally we get confused with the concept of heat and temperature. Temperature is a characteristic property of bodies and heat is always a transfer of energy between two or more systems.

4.1. Dilatation: the volume of bodies change with temperature

A.26. A little experiment: in small groups, you have to design an experiment to demonstrate the dilatation of bodies (in solid, liquid and gas state). Afterwards you have to do this experiment in the laboratory and write a report (or edit a video).

We speak about dilatation of a body when its volume increases because of a temperature increase.

We speak about contraction of a body when its volume decreases because its temperature decreases.

4.2. The measure of temperature

We can measure temperature in different scales:

The Celsius or centigrade scale

This is the normal scale for us. The temperature is measured in degrees centigrade (ºC).

The scale is defined by two points on the thermometer:

- ✓ 0ºC for the freezing point of water.
- ✓ 100 ºC for the boiling point of water.

The Kelvin scale or absolute scale

This scale is used principally in scientific areas. The temperature is measured in degrees kelvin (k).

The scale is defined by two points on the thermometer:

- ✓ 273 k for the freezing point of water.
- ✓ 373 k for the boiling point of water.

The Fahrenheit scale

This scale is used principally in Anglo-Saxon countries. The temperature is measured in degrees Fahrenheit (ºF).

The scale is defined by two points on the thermometer:

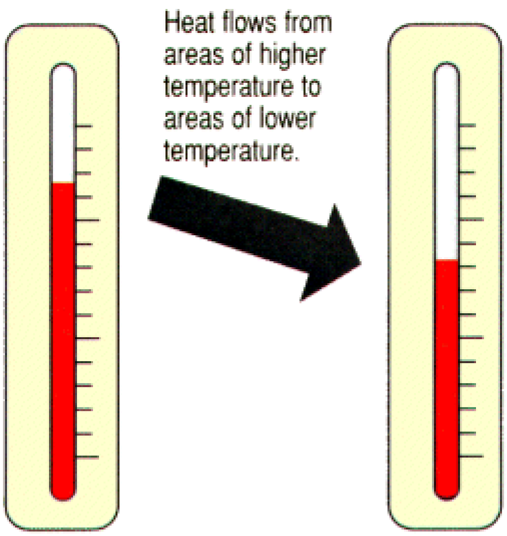
- ✓ 32 ºF for the freezing point of water.
- ✓ 212 ºF for the boiling point of water.

4.3. Heat, temperature and internal energy

What happens if you mix two bodies with different temperatures?

A.27. Describe what happens when you put a piece of hot metal in cold water. Try to use the different concepts, heat, temperature and internal energy, correctly.

The **temperature** is a property which informs us of the state of a body. If one body has a high temperature its **internal energy** is also high but the internal energy depends also on its chemical composition. When two bodies with different temperatures are in thermal contact, they exchange internal energy. The body with the higher temperature gives internal energy to the body with the lower temperature. So the first body decreases in temperature and the second one increases in temperature. This process continues until both bodies have the same temperature. This situation is called **thermal equilibrium**. The amount of internal energy which is transferred between the bodies is called **heat**.



5. SUMMARY

A.28. Try to make a mind map that summarizes the previous unit.

6. EDUCATIONAL RESOURCES ON THE INTERNET

- Energy Quest
- Current and future energy sources (flash animation)
- Rational use of energy (flash animation)
- Energy consumption today and in the past (flash animation)
- Where does the energy we consume come from? (flash animation)
- The Sun: a form of energy available everywhere (flash animation)
- Biofuels, a “green” alternative to oil? (flash animation)
- Resources and reserves: how much energy is left underground? (flash animation)
- Geothermal power: heat (flash animation)
- Nuclear energy: when atoms explode (flash animation)
- Gas: lightweight fossil energy (flash animation)
- Coal: plant debris more than 200 million year old! (flash animation)
- The route taken by energy: “From the power station to the computer” (flash animation)
- Song about energy (video)
- Energy WebQuest: An investigation of energy
- Energy WebQuest: Power! Power! We need more power!
- Energy WebQuest Student Process

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APPENDIX 1: GENERAL VOCABULARY OF THE UNIT

APPENDIX 2: SPECIFIC VOCABULARY OF THE UNIT