Unit 11:
Temperature and heat

1. **Thermal energy**
2. **Temperature**
3. **Heat and thermal equlibrium**
4. **Effects of heat**
5. **Transference of heat**
6. **Conductors and insulators**

Think and answer

a. Is it the same heat than thermal energy?

b. Why are the handles of cooking utensils usually made of plastic?

c. How can we melt ice?

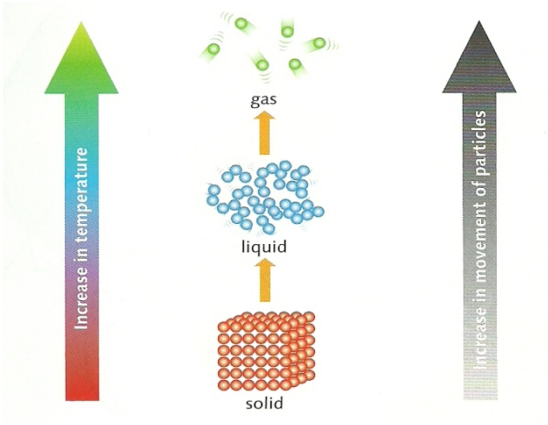
d. What is a thermometer?

UNIT OBJECTIVES

In this unit you will learn:

- To distinguish among thermal energy, heat and temperature.
- To understand the effects of heat.
- To identify changes of state in matter and their relation with the changes in the thermal energy.
- To distinguish the three ways heat is transferred.
- To identify insulators and conductor substances.

1. Thermal energy.



The inside of a substance (solid, liquid or gas) is never at rest.

- The atoms or molecules in **solids** vibrate a little, but they can't move around.

- The atoms or molecules in **liquids** vibrate and they can also move around but keeping the distances between them.

- The atoms or molecules in **gases** move around freely: their movements are constant and random.

As the temperature increases, a body changes from a solid state to a liquid state, and finally from a liquid state to a gas state. So, we can say that temperature is linked to the movement of the different particles (atoms and molecules) that make up substances.

All particles have a certain amount of **kinetic energy** (or internal energy) due to the fact that they move: this energy increases as the temperature increases. However, because a small amount of matter can contain thousands of billions or even trillions of particles, it is more precise to talk about the average kinetic energy of the particles or their thermal energy.

Thermal energy is the average kinetic energy of a very large group of atoms or molecules.

READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:

Remember: you must make complete sentences.

1.1. When has a liter of water more internal energy when it is at 50ºC or when it is at 90ºC? Why?

2. Temperature.

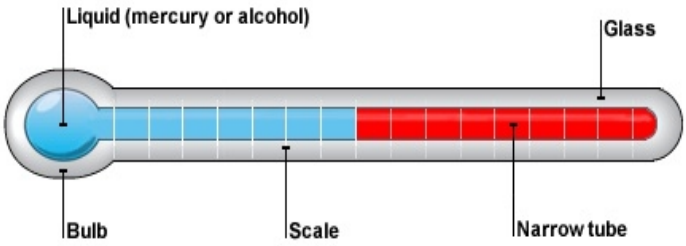
Temperature is the measurement of a substance's thermal energy.

So, when we say that a body has a higher temperature than another body, what we really mean is that its atoms or molecules are moving more quickly.

a) Temperature measurement

We use **thermometers** to measure temperature. Most thermometers contain liquids which expand and contract when there are changes in temperature.

There are different types of thermometer: mercury, coloured alcohol, or digital.



- Mercury thermometers

Mercury is a liquid metal at room temperature. It changes into a solid at -39 °C, so mercury thermometers are not useful at temperatures around this value.

An ordinary thermometer consists of a bulb or reservoir, which contains a small amount of mercury, and a long, thin, glass tube. When the temperature increases, the mercury expands. As this expansion only occurs along the length of the tube, it is easy to see with the naked eye.

- Alcohol thermometers

This type of thermometer is very useful at very low temperatures, because ethanol changes into a solid at — 114°C.

Alcohol is colourless and it is easy to dissolve dyes in it, so we use coloured (dyed) alcohol in alcohol thermometers to make them easier to read. Most thermometers that are used to read outdoor temperatures are made with alcohol.

- Digital thermometers

These thermometers use thermistors. A thermistor is a type of resister that increases its electrical conductivity when its temperature increases (the opposite to metals).

Inside the thermometer is a microprocessor that measures the temperature as a function of the resistance of the thermistor. The temperature is displayed on a liquid crystal screen. Nowadays, most thermometers used in the home are digital.

b) Temperature scales

To measure temperature we can use three different scales: the Celsius scale, the Fahrenheit scale and the Kelvin scale.

- Celsius or centigrade scale (°C)

This is a scale we use to measure normal temperatures. In this scale the value:

- **0** is the temperature at which **water freezes** in conditions of normal atmospheric pressure.
- **100** is the temperature at which **water boils** in conditions of normal atmospheric pressure.

The interval between these two values is divided into one hundred equal parts; each of the parts corresponds to **one degree Celsius** (1°C).

- Kelvin or absolute scale (K)

This is the real or physical scale that is directly linked to the movement of particles. The **kelvin** (K) is the unit of temperature in the International System of Units (S. I.).

The value **0** in this scale corresponds to the temperature at which there is no movement in particles: when a substance's thermal energy is zero. **Absolute zero** or zero kelvin (0 K) indicates the natural limit of temperatures: lower temperatures are not possible, because temperature is the measurement of the movement of particles.

On this scale, water freezes at around 273 K, so 0°C = 273 K.

The divisions of this scale are the same size as those of the Celsius scale, so the temperature at which water boils is 100°C = 373 K.

To convert degrees Celsius into kelvin we have to add on 273.

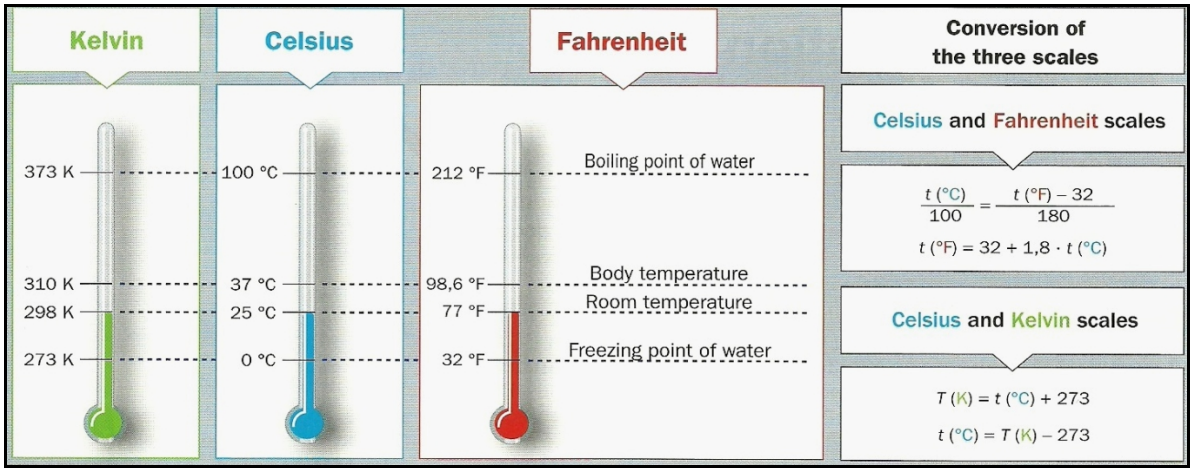
$$T\,(K) = t\,(°C) + 273$$

- Fahrenheit scale (°F)

This scale is usually used in Anglo-Saxon countries instead of Celsius scale. The freezing point of water is 32°F and its boiling point 212°F. The degrees of this scale are different of those of the Celsius scale.

To convert degrees Celsius into degrees Fahrenheit we have to use this expression:

$$t\,(°C) = \frac{t\,(°F) - 32}{1.8}$$



READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

2.1. Answer the questions:

a. What properties of matter do mercury and digital thermometers use?
b. Why must the tube of liquid inside a traditional thermometer be very thin?
c. How many degrees Celsius does absolute zero (0 K) correspond to?
d. What type of thermometer will we use in polar regions where temperatures can reach -40°C? Why?

CALCULATING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must extract *data*, develop *operations* and give a *solution*.

2.2. Change these temperatures into kelvin (K). Are any of them impossible? Why?

a) -270°C
b) 14,000°C
c) 25°C
d) -190°
e) -534°C
f) 425°C

3. Heat and thermal equilibrium.

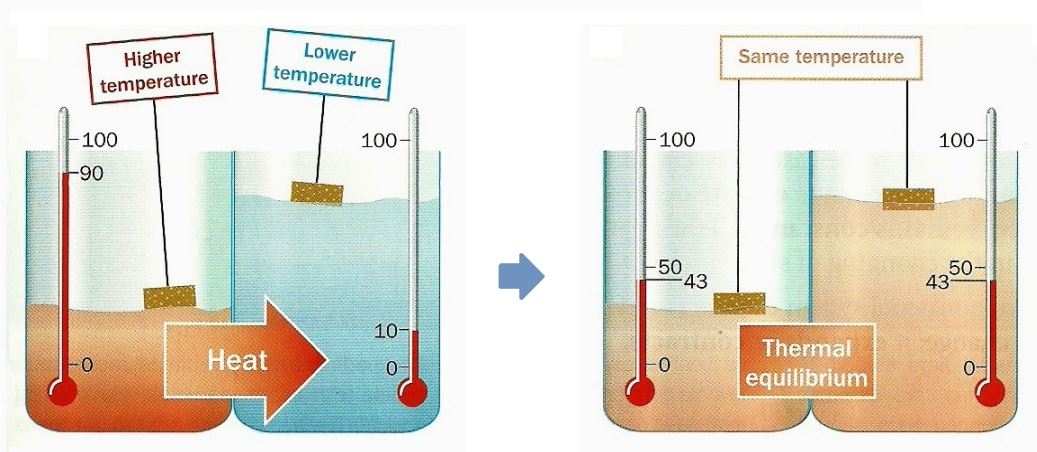
When two bodies come into contact, the particles with more kinetic energy transfer some of their energy to the other particles with less energy.

This energy transfer occurs because the particles collide with each other: finally, all the particles have the same amount of kinetic energy.

In this process:

- The body that had a **lower temperature** has gained thermal energy and so its temperature has increased.
- The body that had a **higher temperature** has lost thermal energy and so its temperature has decreased.

Both bodies finally have the same amount of thermal energy, so they also have identical temperatures. This state is called **thermal equilibrium**.



Initial situation Final situation

Heat is the transfer of thermal energy between two bodies when they are at different temperatures.

Heat is always transferred from the body with the highest temperature to the body with the lowest temperature, **independently** of their respective **sizes**. The transfer of energy stops when both bodies Reach the same temperature.

READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

3.1. Answer the questions:

a. Is heat a type of energy?
b. Is the same temperature than heat?
c. Which is the unique condition to transfer of heat occurs between two bodies?

3.2. If you hold a copper rod supporting one of its ends on a block of ice, you will observe that the rod will cool down quickly. Does it mean that cold has been transferred from the ice to the rod? Explain your answer.

4. Effects of heat.

Heat produces two main effects on matter:

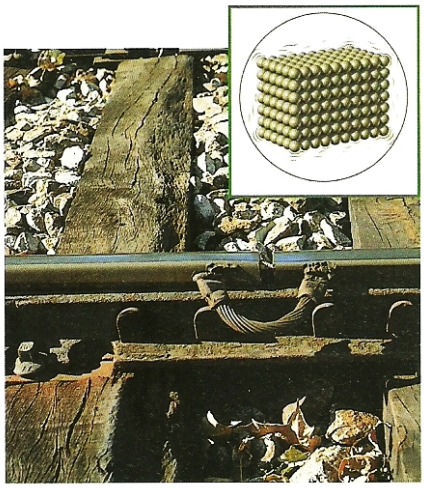
- Changes of volume
- Changes of physical state

4.1. Changes of volume

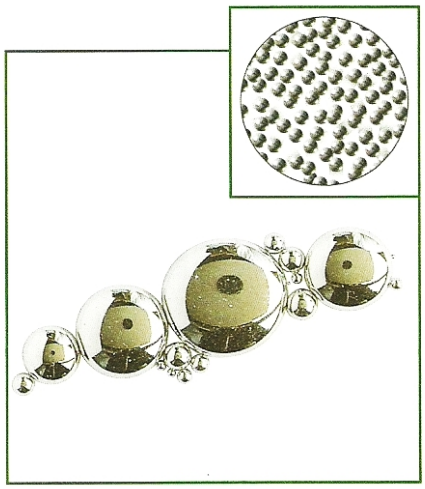
Matter changes volume when it exchanges energy with its surroundings. Bodies expand or contract when they gains or lose thermal energy.

- **Expansion**.
  This is the increase in volume which occurs when a body gains heat.
  Its particles start to move faster and therefore occupy more space.
- **Contraction**.
  This is the decrease in volume which occurs when a body lost heat.
  It is particles start to move slower and therefore occupy less space.

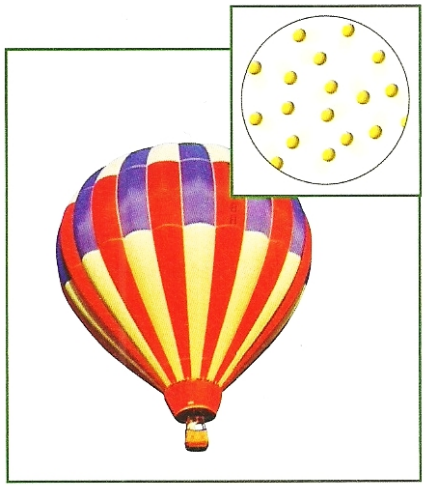
Normally, gases expand more than liquids and liquids more than solids. This is because the forces among particles in solids are very strong and it is necessary more energy to separate them, while in liquids, and specially in gases, the forces among particles are very weak and it is not necessary so much energy to separate them.



Railway tracks are laid with **expansion joints** between them. These separate the tracks so they can expand when it is hot. Otherwise the tracks would bend.



The particles in liquids move more freely than in solids. Therefore a liquid (mercury) expands more easily when heated.



The particles in gases are far apart and move more freely than in liquids.
A balloon is easily inflated because the gas inside expands when heated.

4.2. Changes of state

They are changes in the aggregation state of the matter. That is the arrangement of particles in matter.

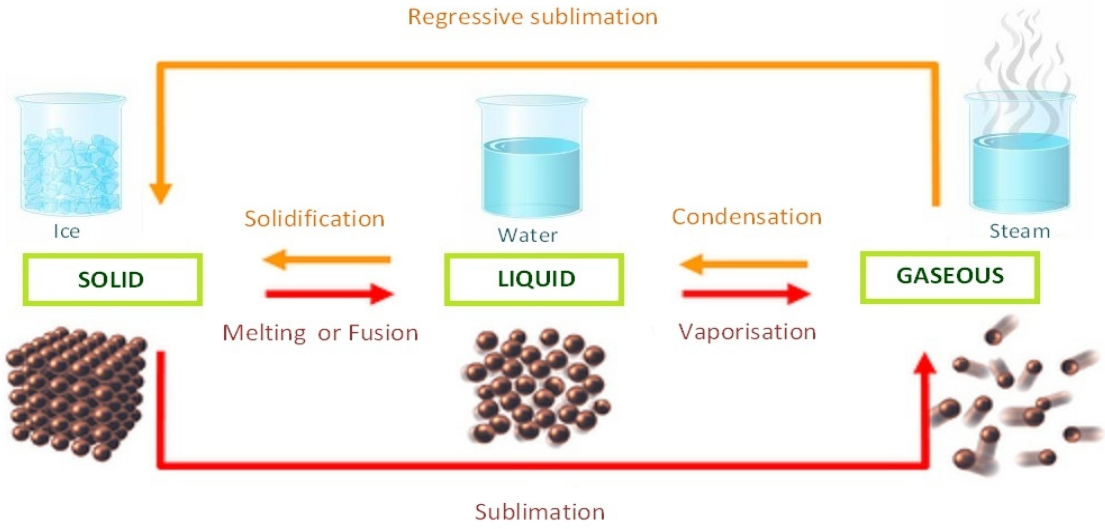
- In **solids**, particles occupy fixed positions (they vibrate but not displace) and the distance among them are also fixed.
- In **liquids**, particles do not occupy fixed position although they keep fixed the distances among them.
- In **gases**, particles move freely and they try to keep so separate as possible.

When a body in any state of matter gains or loses enough heat , it undergoes a change of state, that is a change in the arrangement of its particles.

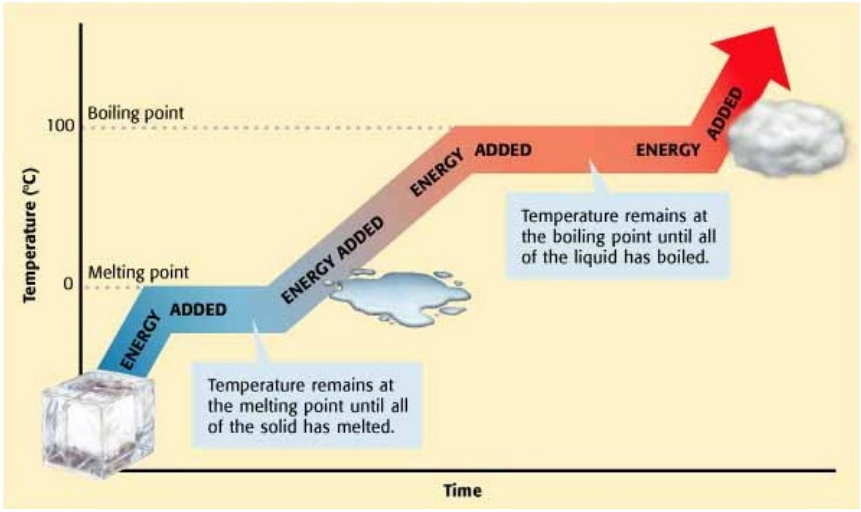
- The changes produced by absorption of thermal energy are **melting**, **evaporation** and **sublimation**.
- The changes produced by heat loss are **solidification**, **condensation** and **regressive sublimation**.

Every substance changes from one state to another at a specific temperature:

- From solid to liquid and vice versa this temperature is called **melting** or **solidification point.**
- From liquid to gas and vice versa this temperature is called **boiling** or **condensation point**.



When a substance is changing its physical state its temperature does not change, in spite of the fact that it is absorbing energy.



This is because the heat is used to break the forces that keep join together the particles of the matter during the change of state. This energy is called **latent heat** and it is different to each substance.

READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

4.1. Answer the questions:

a. Why are small gaps placed between sections of a road?
b. Why does the density of a liquid or a gas decrease when heated?

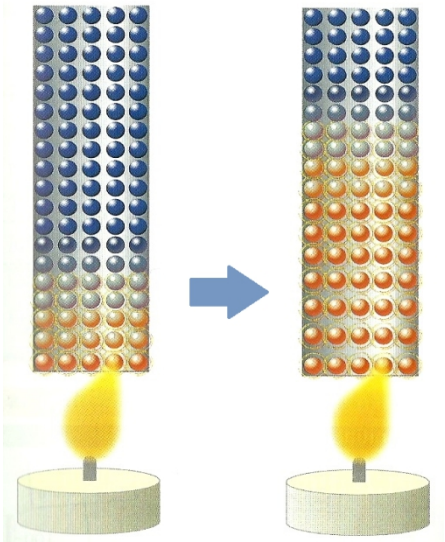
4.2. We put a certain amount of a substance in solid state within a container with a thermometer and start to heat it. The initial temperature is 15 ºC and it increases little by little until to reach 90 ºC at 5 minutes from the beginning of the experiment. In this moment the temperature remains constant and the solid starts to melt. 2 minutes later, temperature starts to rise up again. When it reaches 130°C, 6 minutes later it remains steady while the liquid boils.

a. Represent the graph.
b. In which state will the substance be at 50ºC? And at 150ºC?
c. Indicate the boiling point and the melting point of the substance
d. What is happening during the time that temperature does no increase?

5. Transference of heat.

The propagation of heat between two bodies can be made in three different ways: by conduction, by convection and by radiation.

5.1. Conduction



It is the way heat propagates in solids.

For transference of heat takes place, solids have to be in direct contact between them or with the source of heat. Heat will flow from the hotter body to the cooler body, until both are the same temperature.

When the solid is heated up, its atoms start to move much more quickly, and this increases their kinetic energy. These atoms start to collide with the atoms next to them, and transmit some of their energy to these atoms.

In conduction thermal energy is transmitted, but no matter. The particles vibrate more and separate, but they don't change their positions.

5.2. Convection

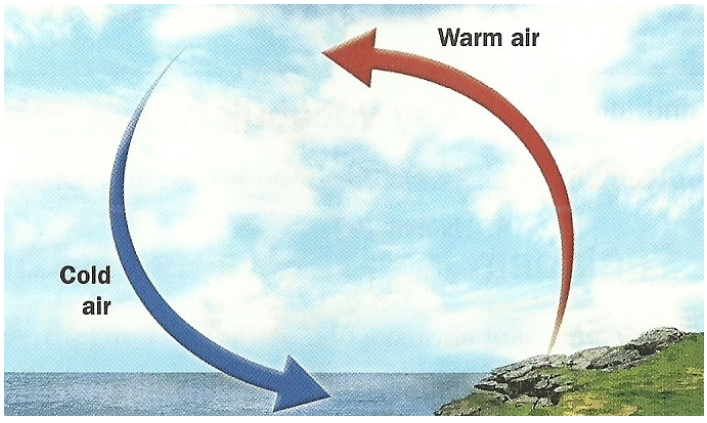
It is the way heat propagates in fluids (liquids and gases).

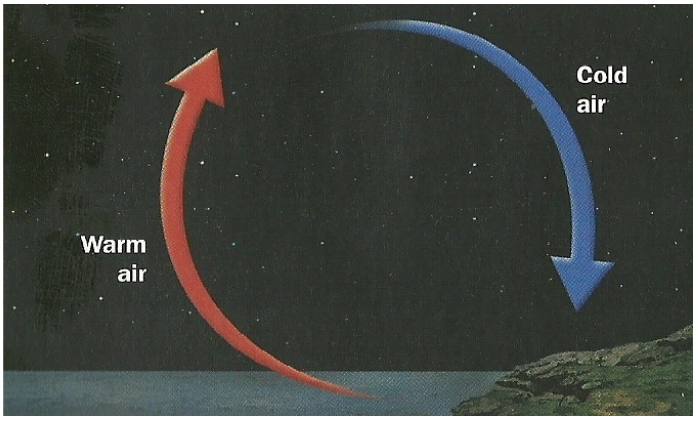
In this case it is also necessary the direct contact between both bodies or with the source of heat, but there is transmission of matter.

When a liquid is heated up in a container, the liquid at the bottom of the container starts to get warm first. As the temperature increases the liquid at the bottom expands and becomes less dense: the particles (molecules or atoms) move quickly separating from each other and occupying more volume (they increase their kinetic energy).

The liquid on the surface is colder, so it's also denser and it fails. The liquid that has fallen to the bottom then heats up and the water that has risen, cools down. It forms a cyclical circulation called **convection current**.

As the particles move, the thermal energy is transferred.



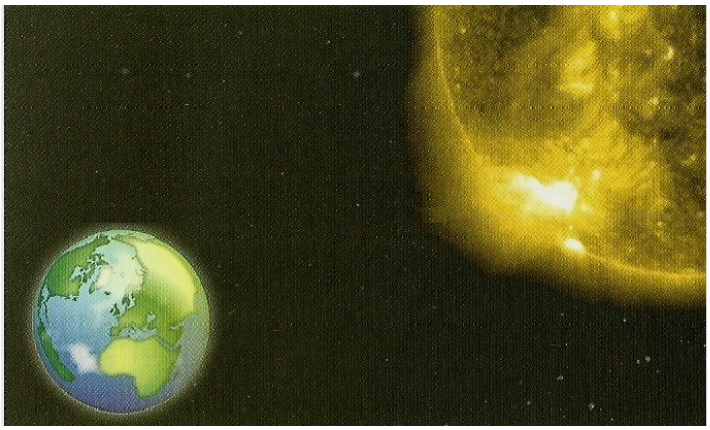


5.3. Radiation

Radiation is the process of heat transfer between bodies in the **vacuum**. So that it is not necessary the direct contact between them and matter is not transmitted.

The energy emitted by bodies during this process is called **radiant energy** (electromagnetic waves). So, for example, the Earth receives radiant energy from the Sun.

All matter absorbs radiation, but it can also reflect (throw back) some of it.

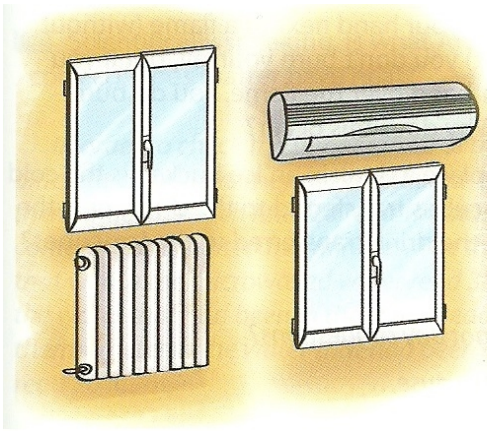


READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

5.1. Answer the questions:

a. Why are small gaps placed between sections of a road?
b. Why does the density of a liquid or a gas decrease when heated?
c. Why are heaters placed usually under windows near the floor while air conditioning units are placed close to the ceiling?



5.2. Indicate which type of transference of heat occur in each case:

a. In the handle of a pan that is put to the fire.
b. In the stove that is heating a room.
c. In the water of a saucepan that is put to the fire.
d. In chops that are grilled on a barbecue.

6. Conductors and insulators.

Thermal conductivity is the capability of substances to conduct heat. We can differentiate between thermal conductors and thermal insulators.

- **Thermal conductors** transmit thermal energy quickly from one point to another: for example, silver, copper, aluminium and all other metals.

- **Thermal insulators** transmit thermal energy slowly from one point to another: for example, porous or fibrous substances that have air inside, such as brick, wood or cork.

READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

6.1. Classify the following substances as thermal insulators or thermal conductors:
copper, glass, water, steel, wood, brass, aluminium, iron, cork, plastic, porexpan, tin, air, silver.

6.2. Thermos flasks are containers used to store liquids that we want to keep at the same temperature for many hours. The container is a hermetic bottle which structure is shown in the picture. Explain how the thermos flask prevents heat's loss by conduction, convection and radiation.