Chapter

9

SOURCES AND EFFECTS OF HEAT ENERGY

STUDENTS' LEARNING OUTCOMES

After studying this chapter, students will be able to:

- ☑ Describe the sources and effects of heat.
- ☑ Explain thermal expansion of solids, liquids and gases.
- ☑ Explore the effects and applications of expansion and contraction of solids.
- ☑ Describe the uses of expansion and contraction of liquids.
- ☑ Explain the peculiar behaviour of water during contraction and expansion.
- ☑ Investigate the processes making use of thermal expansion of substances.
- ☑ Identify the damages caused by expansion and contraction in their surroundings and suggest ways to reduce these damages.
- ☑ Investigate the means used by scientists and engineers to overcome the problems of expansion and contraction in everyday life.
- ☑ Describe the working of a thermometer.

Heat is an essential requirement for life. In addition to keeping our bodies warm, we need heat for ripening crops and fruits, keeping the Earth's environment warm, melting of ice on the mountains and in the preparation of a large number of industrial products. In this chapter, we will learn about the sources, effects and uses of heat in different processes.

9.1 Sources of Heat

(I) Sun is the biggest source of heat. Sun's heat reaches the Earth in the form of radiations. Solar radiations keep the Earth environment warm at a suitable temperature for the survival of life (Figures 9.1and 9.2).

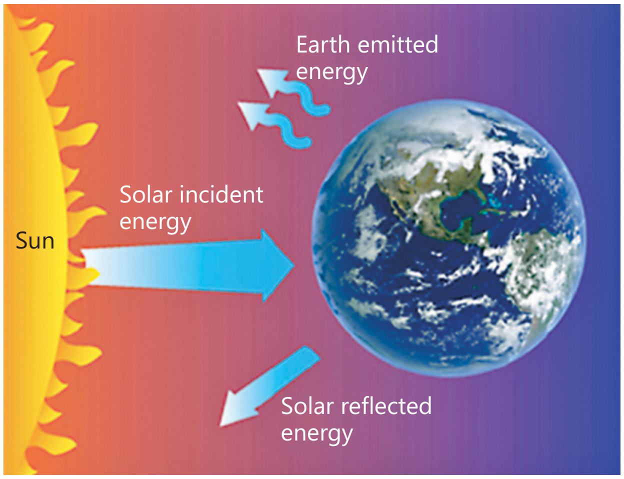


Figure 9.1: Solar radiations keep the Earth warm

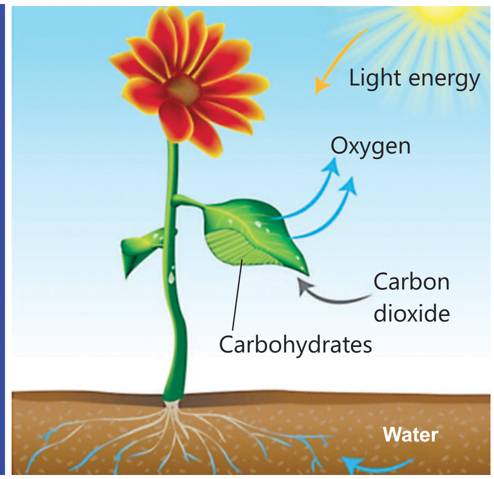


Figure 9.2: Solar radiations used by plants

(ii) We keep our bodies warm and alive by the heat produced from the food during its metabolism in the body cells.

(iii) Heat is also produced by burning of wood, coal, oil and gas, etc. We cook food (Figure 9.3) and warm our rooms by the heat produced by burning of wood and natural gas, etc. Heat produced by the burning coal and oil etc. is used to produce electricity in thermal power stations (Figure 9.4).

Figure 9.3: Heat cooks food

Figure 9.4: Thermal power plant

(iv) Electricity is also used to produce heat (Figure 9.5).

Figure 9.5: Electric heater

9.2 Effects of Heat

All kinds of material objects are made up of tiny particles such as atoms and molecules. When an object is heated, the object expands. This expansion of material objects on heating is called **thermal expansion**. On the other hand, when an object is cooled, the object contracts. This contraction of material objects is called **thermal contraction**.

9.2.1 Thermal Expansion and Contraction of Solids

We know that material objects are made up of tiny particle; atoms and molecules. In solid objects these particles are strongly packed with each other. The motion of particles in solids is vibratory only, i.e., they move to and fro about their fixed positions. When solids are heated, the vibratory motion of their particles (atoms and molecules) becomes fast and they begin to push each other farther apart (Figure 9.6). This results into expansion of solids. Similarly, when solids are cooled, particles slow down and solids contract (Figure 9.7).

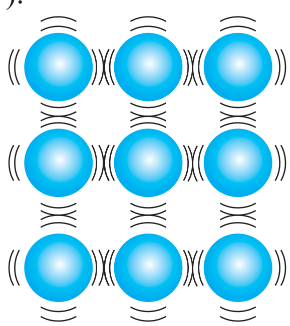


Figure 9.6: Motion of molecules when heated

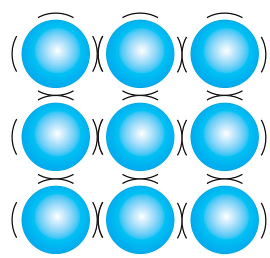


Figure 9.7: Motion of molecules when cooled

Activity 9.1

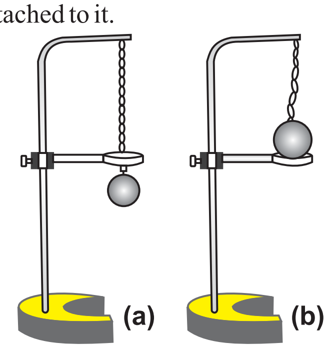
Material Required

Metal bob and ring apparatus (metallic sphere, ring, chain), stand, burner or spirit lamp

Procedure

- Take a metallic sphere which can pass easily through a ring as shown in figure (a).
- Remove the sphere out of the ring with the help of the chain attached to it.
- Heat the sphere to a high temperature and put it on the ring in order to pass it through the ring as shown in figure (b).
- Does it pass through the ring after heating?
- If not, why does it happen so?
- Let the sphere cool at room temperature and observe whether it passes through the ring or not.

If yes, why does it happen so?



In this activity, we see that solids expand on heating and contract on cooling.

The degree of expansion and contraction in solids depends on the nature of substances. Some solids expand or contract very little and we may not notice their expansion or contraction on heating or cooling. Different metals expand or contract at different rates. For example; one metre long brass rod increases 1 mm in length when its temperature increases by 100 $^{\circ}$C but iron rod of the same length expands only 0.6 mm for the same increase in temperature.

Activity 9.2

Material Required

Bimetallic strip, burner or spirit lamp

(bimetallic strip consists of two different metals such as iron and brass which are joined together)

Procedure

- Take a bimetallic strip and notice that it is straight at room temperature.
- Heat the bimetallic strip over a gas burner.

What happens to the bimetallic strip on heating?

Why does it happen so?

- Let the bimetallic strip cool down to room temperature and observe what happens to it on cooling?

Why does it happen so?

Bimetallic strip before heating

Bimetallic strip after heating

For your information

In fire, the thermal expansion of steel beams, concrete and glass can cause considerable damage.

9.2.2 Thermal Expansion and Contraction of Liquids

Activity 9.3

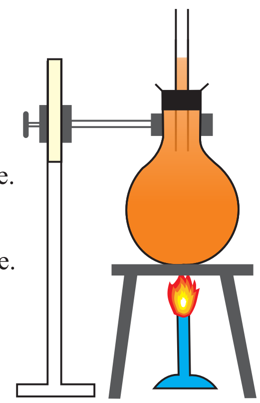
Material Required

Round bottom glass flask, cork or rubber plug which can be fitted at the mouth of flask, narrow glass tube, coloured water

Procedure

- Take a round bottom glass flask and fill it fully with coloured water.

- Pass a glass tube which is open at its both ends through a cork or rubber plug and fit the rubber plug into the mouth of the flask tightly as shown in the figure.
- Water will rise up in the glass tube to a small height.
- Note the level of the coloured water in the glass tube.
- Now heat the flask over a burner or spirit lamp.
- Observe what happens to the level of the coloured water in the glass tube.
- Record what do you observe?
- Now switch off the burner and let the hot water cool at room temperature.
- Note the level of the water again.
- What conclusion do you draw from this activity?



As you start heating the water, you will notice that the level of water in the tube first falls and then begins to rise up.

Why does it happen so?

9.2.3 Thermal Expansion and Contraction of Gases

Like solids and liquids, gases also expand on heating and contract on cooling. Let us perform the following activity to demonstrate it.

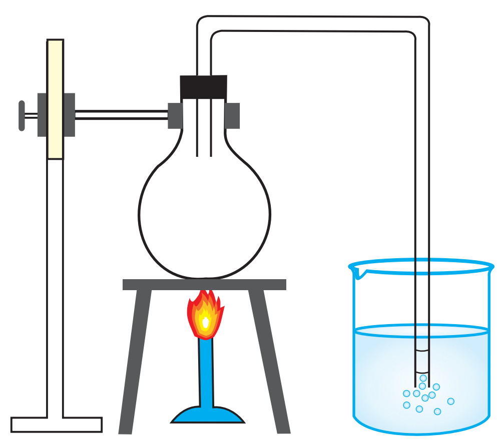
Activity 9.4

Material Required

Empty flask, thin U-shaped glass tube, cork or rubber plug with bore, stand, burner or spirit lamp, beaker, water

Procedure

- Take an empty flask and fit a cork or rubber plug into the mouth of the flask. Pass short limb of the U-shaped glass tube through the cork.
- Clamp the flask in a stand as shown in the figure.
- Dip the long limb of U-shaped glass tube in the water contained in the beaker as shown in the figure.
- Note and mark a line at the level of water in the glass tube.
- Heat the flask.



What do you observe in the water?

- Stop heating and let the system cool down to room temperature.

Observe and note the level of water in the glass tube again.

Is there any change in the level of water in the glass tube?

If yes, why does that happen?

This activity would make you learn that air in the flask expands on heating and leaves the flask producing bubbles in water. On cooling, the air inside the flask contracts, as a result, a suction is created in the flask which pulls the water level in the glass tube up.

? Do you know?

If air is filled into the car tyres to the fullest in the evening. The tyres may burst in the hot afternoon next day. This is because of expansion of air on getting heat from the surrounding.

9.3 Applications of Expansion and Contraction of Solids

Thermal expansion and contraction are used for different purposes. A few examples are:

1. Riveting

A rivet is a small, cylindrical and smooth shaft whose one end is swollen (called head) while the other end is flat (called buck-tail) (Figure 9.8). Hot rivets are used to join the metal plates. The process in which two metal plates are joined together by means of rivets is called riveting. For joining the two steel plates, they are placed one above the other and holes are drilled through them. The rivet is heated to make it red hot and is inserted in the holes of the plates (Figure 9.9-a). The ends of the rivet are then hammered into a round shape (Figure 9.9-b). When the rivet cools and contracts, it firmly grips the plates together (Figure 9.9-c).

Figure 9.8: Metal rivets

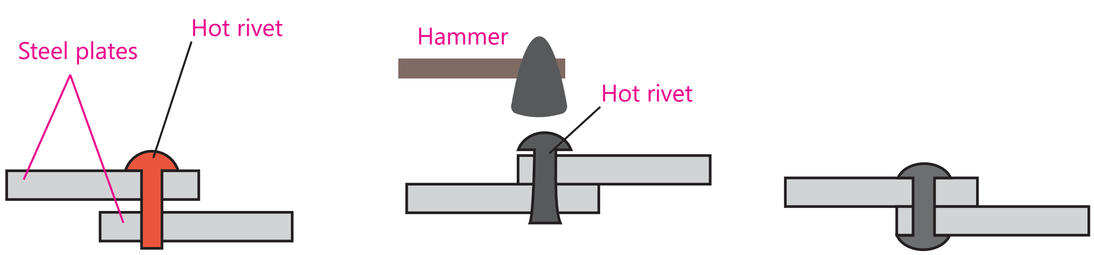


Figure 9.9: Riveting

2. Fixing a Metal Tyre Over the Wheel

The metal tyres which are fixed over the wooden wheels of the carts are slightly smaller than the wheels when they are cold. On heating, the metal tyre expands and its diameter increases. Then hot tyre can easily be fitted onto the wheel. On cooling, the metal tyre contracts and fits over the wheel tightly (Figure 9.10).

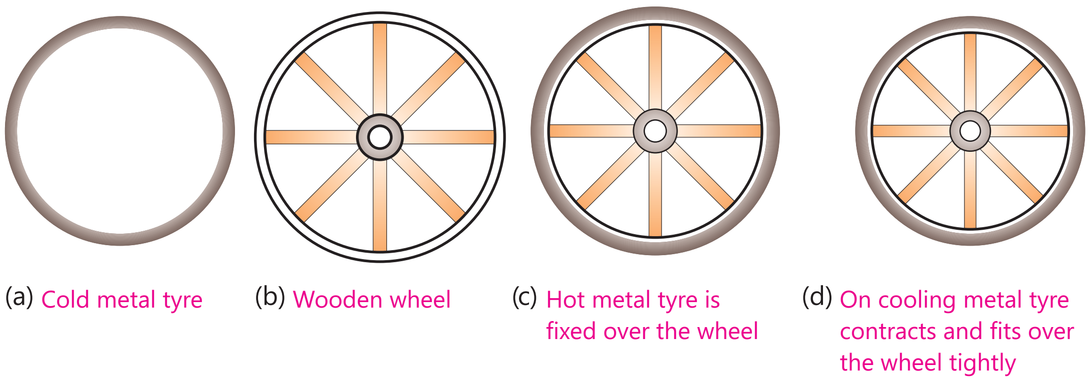


Figure 9.10: Fixing a metal tyre over the wheel

3. Fixing Axle into a Wheel

This method is mostly used to fit in the axle of train wheels. In this method, contraction is used instead of thermal expansion. The diameter of the axle is slightly larger than the hub of the metal wheel. The axle is placed in liquid nitrogen which is below -196 °C temperature. The axle cools and contracts. It is then inserted into the hub of the wheel and is allowed to come at room temperature. At room temperature, axle expands and fits into the wheel tightly (Figure 9.11).

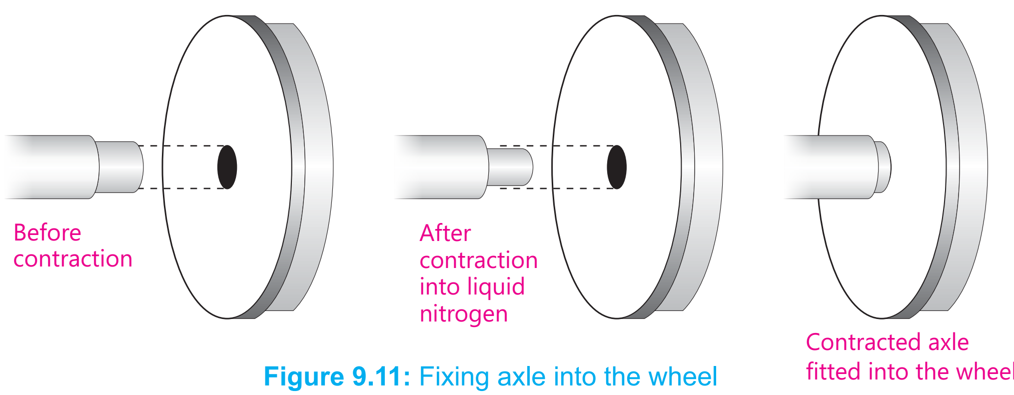


Figure 9.11: Fixing axle into the wheel

Applications of Bimetallic Strips

Bimetallic strips are used in thermostats. A thermostat is a device that is used to control temperature in electrical appliances such as electric irons, heaters, refrigerators, air conditioners, ovens, and stoves etc. It is also used in fire alarms.

1. Electric Iron

In an electric iron (Figure 9.12), when electric current flows through its heating element, it becomes hot. The bimetallic strip connected with the heating element through a spring also begins to heat up. On getting hot, bimetallic strip bends and is disconnected from the heating element. This makes the circuit open and switches OFF the electric iron. On cooling, the bimetallic strip straightens. The circuit is again closed and the iron is switched ON.

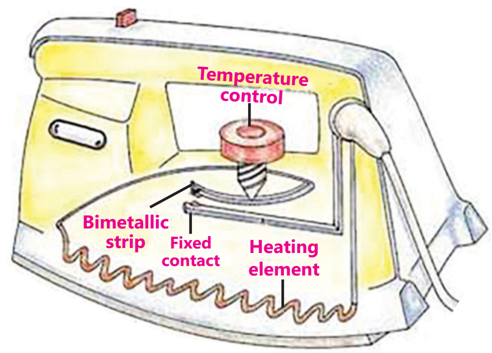


Figure 9.12: Electric iron

2. Fire Alarm

In case the fire breaks out, the bimetallic strip used in the fire alarm gets hot and bends to touch with the contact point of the battery. In this way the circuit is completed, and the bell connected in the fire alarm circuit begins to ring to warn of the fire (Figure 9.13).

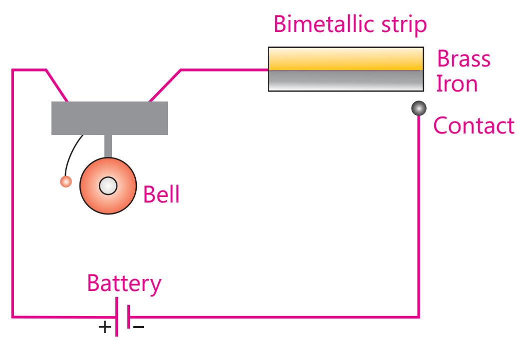


Figure 9.13: Fire alarm circuit diagram

9.3.1 Effects of Expansion and Contraction of Solids in Everyday Life

In our daily life, we pay special attention to deal with thermal expansion and contraction of solids in various construction projects. In order to avoid the harmful effects of thermal expansion and contraction of solids, the techniques used in different projects are as follows:

1. Expansion Gaps in Concrete Roads

In hot summer, the concrete used to build roads expands. If no space is provided for its

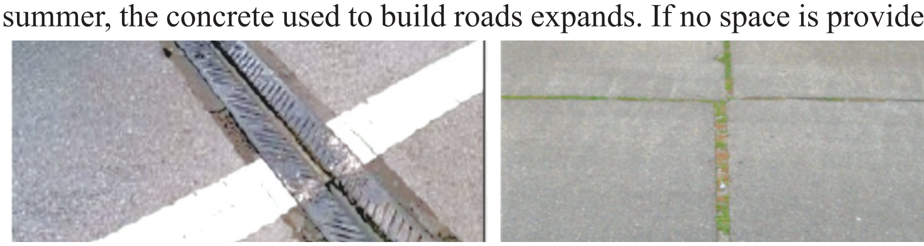


Figure 9.14: Gaps in roads and footpaths

expansion, the road surface cracks. To avoid such damage, small gaps are left after every few metres in the construction of concrete roads or footpaths (Figure 9.14).

2. Railway Tracks

Two sections of a railway track are not welded together. Instead they are laid with gaps between them (Figure 9.15). This allows expansion and contraction of rails during summer and winter seasons. If there are no gaps in the sections of railway tracks, they may de-shape due to expansion in summer.

Expansion gap in railway track

De-shaped railway track

Figure 9.15: Railway tracks

3. Expansion of Bridges

Iron girders are used in the construction of bridges. One end of each girder is fixed while the other end rests on the rollers. A gap is also left at this end (Figure 9.16). In this way, the girder can move forward or backward during expansion or contraction. If there is no expansion gap, bridges may get damaged.

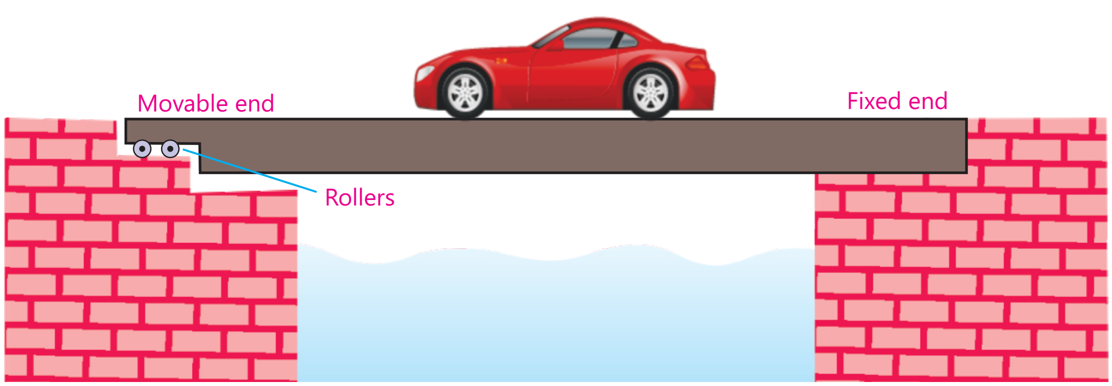


Figure 9.16: Rollers in bridges

4. Overhead Power Lines and Telephone Wires

Overhead telephone and electricity wires installed on poles expand during hot weather and contract in cold weather. The wires between two poles are given a certain amount of sag so that they may contract in winter without snapping (Figure 9.17).

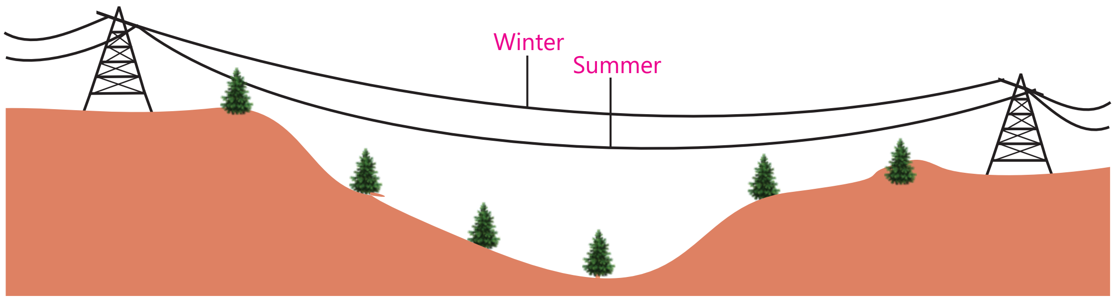


Figure 9.17: Overhead power lines

5. Large Bends in Pipes

The pipes through which hot or cold liquid or gas flows are often given bends so that they may expand or contract without cracking (Figure 9.18).

Figure 9.18: Pipes carrying hot or cold liquids

9.4 Uses of Expansion and Contraction of Liquids

Thermometer

The expansion and contraction property of liquids is widely used in different techniques. For example; liquids like mercury and alcohol are used in thermometers. A thermometer is a device that is used for measuring temperature (Figure 9.19). When the bulb of the thermometer is touched with some hot object, the liquid inside the narrow tube of the thermometer expands and rises up and the temperature of the hot object can be read on the scale.

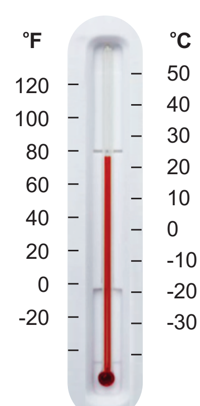


Figure 9.19: A thermometer

For your information

- The air filled in vehicle tyres, volleyballs and basketballs etc. expands in hot weather. As a result, the tyres and balls can burst in hot weather.
- While filling up the bottles with soda water, some space is left above the liquid surface for allowing the expansion of liquids in hot weather.

9.5 Peculiar Behaviour of Water

The behaviour of water with rise or fall in temperature is different from other liquids. When temperature of water is increased from 0 °C to 4 °C, it contracts, its volume decreases and its density increases. On cooling from 4 °C to 0 °C, water begins to expand, its volume increases and its density decreases. At 0 °C water freezes.

Figure 9.20: Peculiar behaviour of water

Due to this peculiar behaviour, when water freezes, it expands and density of ice becomes less than water. That is why ice floats on water surface (Figure 9.20). In this way, aquatic life (fish, etc.) survives underneath frozen lakes and ponds (Figure 9.21).

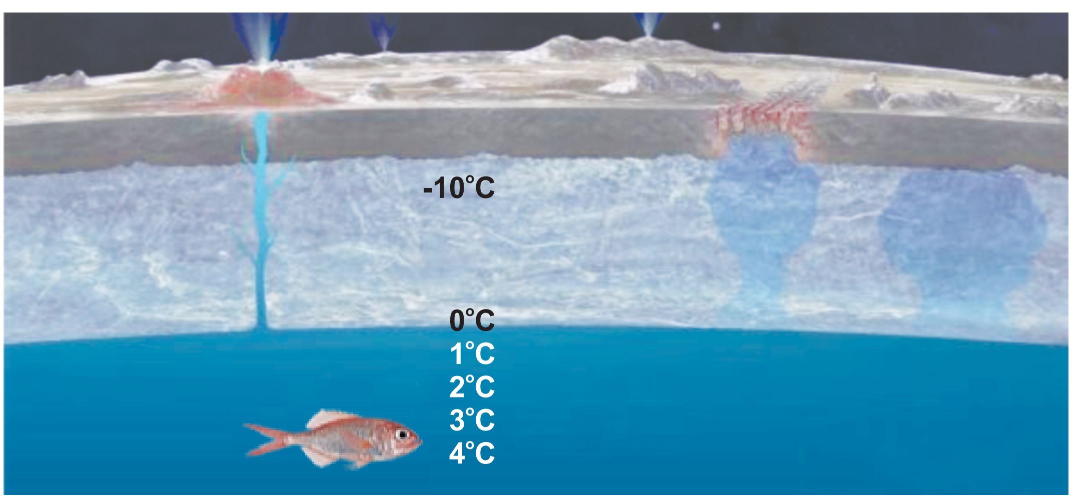


Figure 9.21: Fish living under frozen water

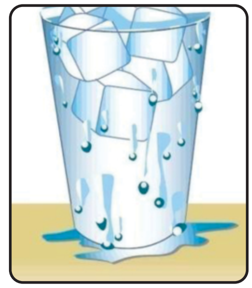
Activity 9.5

Material Required

Glass or beaker, ice cubes, water

Procedure

- Take some ice cubes in a glass.
- Add water in the glass and fill it up to the brim.
- Wipe up the overflowed water from the outer sides of the glass.
- Wait for complete melting of ice cubes.



Observe what happens to the water level in the glass.

Why does it happen so?

What do you conclude from this activity?

KEY POINTS

- The Sun, fire and electricity are the main sources of heat.
- All material objects expand on heating and contract on cooling.
- Some solids expand or contract very little and we may not notice their expansion or contraction. However, some solids expand or contract significantly on heating or cooling.
- Expansion of solids during a hot day can cause damages.
- Hot riveting is a common method for joining two metal plates firmly.
- Bimetallic strips are used in thermostats. A bimetallic strip is made up of two different metals (iron and brass). It bends when heated or cooled due to uneven expansion or contraction of metals.
- Thermostat keeps the temperature constant. It is used in electrical appliances such as electric iron, heaters, refrigerators, airconditioners, ovens, stoves, etc.
- When a liquid is heated, its particles begin to move fast, inter particle distances increase. This makes the liquid expand. The reverse happens when the liquid is cooled down.
- Water behaves differently at the temperature range between 0 °C to 4 °C. In this temperature range, water expands on cooling and contracts on heating.
- When a gas is heated, its particles move fast, and inter particle spaces increase. As a result, the gas expands and its volume increases. The reverse happens when the gas is cooled down.

QUESTIONS

9.1 Encircle the correct option.

(i) Which of the following is the biggest source of heat energy?

a. Burning of fuels b. Electricity
c. The Sun d. Food

(ii) When an object is heated, the movement of its particles:

a. stops b. is not disturbed
c. decreases d. increases

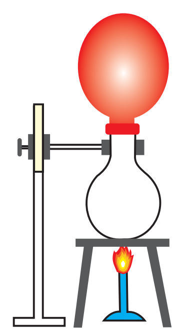
(iii) Thermal expansion is not involved in:

a. automatic fire alarm b. thermostat
c. fixing metal tyres over the wheels d. wooden stick

(iv) Activity of metallic ball and ring shows:

a. solid objects expand on heating b. solid objects contract on heating
c. solids change their nature on heating d. there is no effect of heat on solids

(v) What will happen to the inflated balloon as shown in the figure, if the burner is removed?



a. Its volume will decrease
b. Its volume will increase
c. It will burst
d. Nothing will happen to it

(vi) The rise of liquid in the thermometer is due to:

a. evaporation b. contraction
c. expansion d. condensation

(vii) The contraction of the objects on cooling is due to the:

a. reduction in size of the particles b. increase in size of the particles
c. increase in inter particle distances d. decrease in inter particle distances

(viii) When ice melts and water reaches at 4 °C, its density:

a. increases b. decreases
c. decreases 4 times d. remains the same

(ix) An empty steel container is sealed and heated, which of the following properties of the gas present in this container increases?

a. Mass
b. Pressure
c. Volume
d. Density

(x) The instrument which uses the property of expansion and contraction of liquids is:

a. barometer
b. thermometer
c. manometer
d. speedometer

9.2 Give short answers.

(i) Write down the effects of heating and cooling on solids.

(ii) Write down the effects of heating and cooling on gases.

(iii) Why is water not used instead of mercury in thermometers?

(iv) Why one end of the iron girders is placed on rollers in construction of bridges?

(v) Why gaps are left between two sections of a railway track?

(vi) Why do hot air balloons rise up?

(vii) Why do gases expand faster than liquids and solids?

(viii) When a vessel containing a liquid is heated, the level of liquid initially falls and then rises up. Why does it happen so?

9.3 Descriptive questions.

(i) What is meant by thermal expansion? Explain expansion of solids with the help of an experiment.

(ii) Demonstrate how a bimetallic strip works in a thermostat.

(iii) Explain the peculiar behaviour of water during contraction and expansion.

(iv) Explain the damages which are caused by expansion or contraction by giving two examples.

(v) Describe the effects of expansion and contraction of solids.

(vi) Explain the expansion of liquids with the help of an experiment.

(vii) Describe a simple experiment to study the thermal expansion of gases.

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