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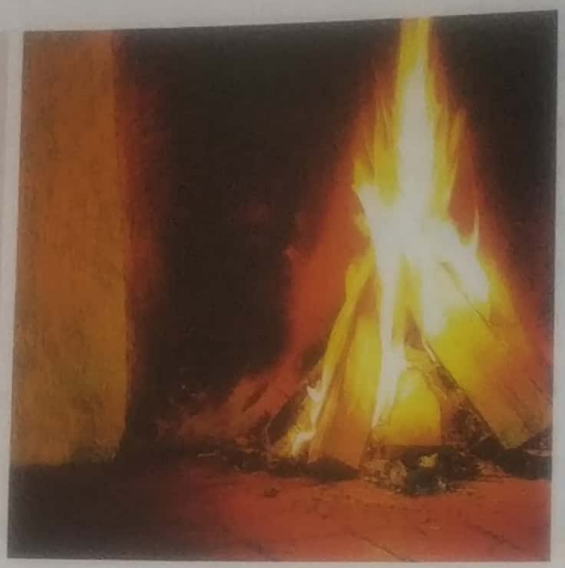


Heat and Its Effects

WHAT IS HEAT?

Until the end of the eighteenth century, scientists believed that heat was a kind of fluid, which was gained by a body when it was heated, and lost when it was cooled. This fluid was named 'caloric'. However, this theory could not explain several observations, for example, why two bodies when rubbed together become warm.

The experiments conducted by **Count Rumford** and **James Prescott** in the beginning of the nineteenth century established that heat is a form of energy, known as **thermal energy**. Many other forms of energy can be converted to heat energy, and heat energy can be converted to other forms of energy. For example:

- When you rub your hands together, mechanical energy gets converted to heat energy and your hands become warm.
- When fuel is burnt, chemical energy stored in the fuel gets converted to heat energy.
- The heat energy of burning petrol is converted to mechanical energy in a car.
- In an electric heater electrical energy is converted to heat energy.
- In a powerhouse, heat energy of burning coal is converted into electrical energy.

When a solid, a liquid or a gas is heated, its molecules gain energy and start moving faster. The more we heat the substance, the faster its molecules move. Heat energy is, therefore, the energy of movement of molecules.

IN THIS CHAPTER

WHAT IS HEAT? ◆ EFFECTS OF HEAT ◆ EXPANSION IN SOLIDS, LIQUIDS AND GASES ◆ TEMPERATURE AND ITS MEASUREMENT

EFFECTS OF HEAT

Fill a vessel up to the brim with water. Drop a few pieces of vegetables in it. Heat the vessel, and observe the changes that happen. You will observe the following:

- The water becomes warmer, that is, its temperature rises. Thus, heat causes increase in temperature.
- As the water heats up, some of it overflows, i.e. its volume increases. Thus, heat causes expansion.
- As the water boils, steam comes out of the water, i.e. water changes its state. Thus, heat causes change of state.
- After the water has boiled for a few minutes, the vegetables become soft and their taste changes, i.e. the vegetables get cooked. Cooking of vegetables is a chemical change. Thus, heat causes chemical changes.
- If the water is examined under a powerful microscope before and after boiling, it is found that many bacteria that were earlier present in the water have died. Thus, heat affects living organisms. This is because every organism can tolerate a definite range of temperature. Its activities and survival get affected at temperatures higher or lower than the normal temperature.

EXPANSION

Suppose that a number of children are standing in a corner of a hall. They are moving around a little to talk to each other. Suddenly music is switched on. The children start dancing and moving around more. Naturally, they will spread out more and occupy a larger part of the hall.

Similarly, when we heat a substance the movement of its molecules increases. This increases the average distance between the molecules. Therefore, the space occupied by the molecules, that is, the volume of the substance, increases. We say that heat causes expansion.

Expansion in solids

We can perform the following activity to show expansion in solids.

ACTIVITY 1 (Experimental investigation)

Take the ring-and-ball apparatus. This apparatus consists of a metal ring and a metal ball. At normal temperature, the ball just passes through the ring (Fig. 5.1a).

Now heat the ball and try to pass it through the ring. It will not pass through (Fig. 5.1b). The ball has expanded on heating. Cool the ball to normal temperature. It will pass through the ring again.

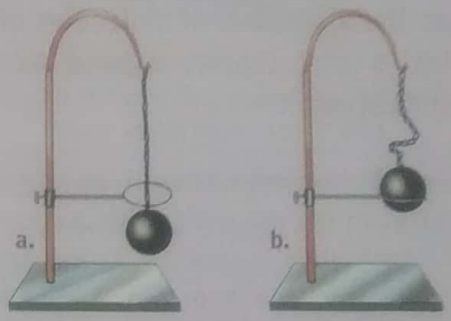


FIG. 5.1 The ring-and-ball apparatus showing that solids expand on heating

If the above apparatus is not available, you can carry out another activity.

ACTIVITY 2 (Experimental investigation)

Take a metal rod, about 50 cm long. Lay it horizontally on two wooden supports. Keep one of its ends against a wall. Rest the other end on a round pencil (Fig. 5.2). Attach a paper pointer to the pencil. Heat the rod. You will notice that the paper pointer rotates to the right. Why? The more you heat the rod, the more the pointer will turn to the right.

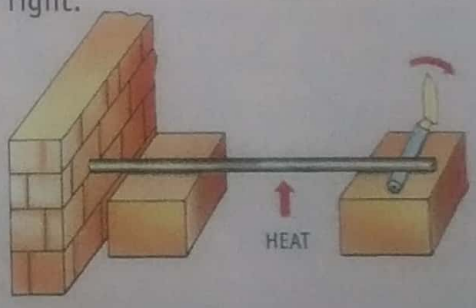


FIG. 5.2 Solids expand on heating.

The turning of the pencil shows that it has been rolled. This is possible only when the rod expands on heating. This shows that solids expand on heating.

Measurements of expansion made on different solids show that different solids expand by different amounts for the same increase in temperature.

Expansion in liquids

You know that the molecules of a liquid are not so firmly bound to each other as in a solid. Therefore, on heating, their vibrations increase more than the vibrations of molecules of solids. The result is that liquids expand more than solids on heating.

If the experiment is conducted using different liquids such as kerosene and oil, it is found that the amount of expansion is different in different liquids for the same increase in temperature.

Expansion in gases

On heating a gas the vibrations of its molecules increases. Since the molecules are not bound to each other at all, the average distance between the molecules increases considerably. Hence, the expansion will be more in case of gases than in liquids or solids. Thus, gases expand more than liquids and solids on being heated.

ACTIVITY 3 (Experimental investigation)

Fill a flask up to the brim with water. Take a rubber cork with a hole in it and insert a narrow tube into the hole. Fix the cork firmly in the mouth of the flask. The liquid will rise a little in the tube. Note the level of the liquid (Fig. 5.3a).

Heat the liquid. You will notice that the level of the liquid in the tube goes down a little and then starts rising (Fig. 5.3b). It goes down initially as the flask gets heated first and expands. When the heat reaches the liquid, it expands, and its level in the tube goes up. Cool the liquid to normal temperature. The level will go down again.

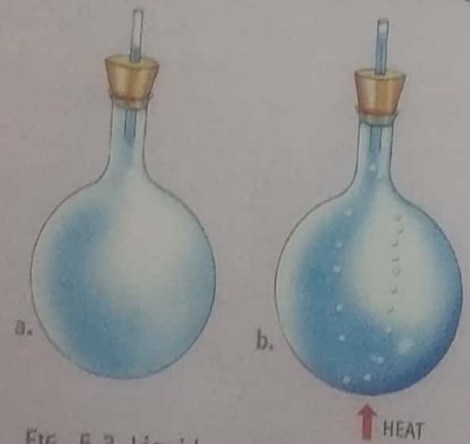


FIG. 5.3 Liquid expands on heating.

ACTIVITY 4 (Experimental investigation)

Empty the flask you used in the previous activity. Fix the flask to a stand in an upside-down position over a beaker of water, so that the glass tube dips inside the water. Heat the flask at the top. As the air in the flask expands, it escapes out of the flask through the tube into the beaker containing water. Bubbles of air can be seen in the water (Fig. 5.4a). Cool the flask. As the air inside the flask contracts, the water rises up the tube (Fig. 5.4b). This shows that gas like air expands on heating and contracts on cooling.

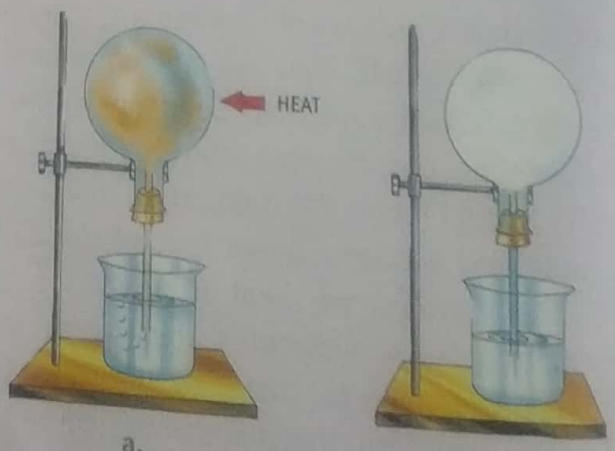
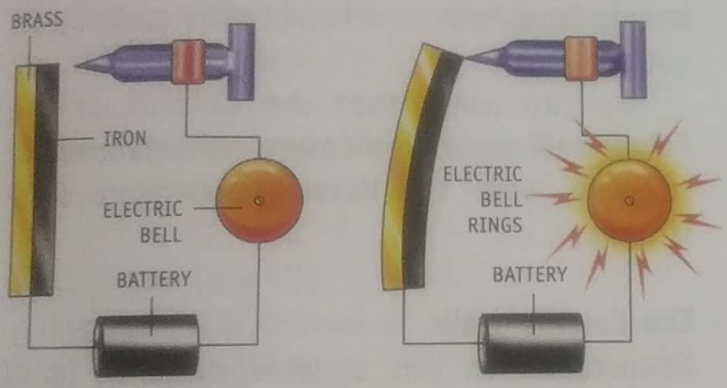


FIG. 5.4 Gases expand on heating.

Expansion around us

The expansion of solids can be put to use.

- The **automatic fire alarm** system uses the fact that different solids expand by different amounts on heating. The alarm contains two metal strips, one of iron and the other of brass, firmly bolted together (Fig. 5.5a). Brass expands more than iron on heating. Therefore, when this **bimetallic strip** gets heated because of fire, it bends on the side of iron. As it bends, the circuit of the electric bell is completed. The bell starts ringing to give the alarm (Fig. 5.5b). As the fire is put out, the strip gets cooled and straightens again. This causes the circuit to break, thus switching off the alarm.



a. At normal temperature b. When heated by fire

FIG. 5.5 An automatic fire alarm

- The metal caps on glass bottles can be loosened by pouring hot water over the metal cap. The metal cap expands on heating and loosens.

However, at many places expansion causes problems.

- In summer, electric cables between two poles expand and sag. In winter, they contract and become taut. If cables are laid in summer, they must be left a little loose to allow for contraction during winter. If this is not done, they may break on contraction in winter.
- The railway tracks over which trains run are made of iron. During summer, the iron expands. To allow this expansion, space has to be left between two sections of the rail tracks (Fig. 5.6). If this is not done, expansion of the tracks can cause them to bend. This can cause serious accidents.

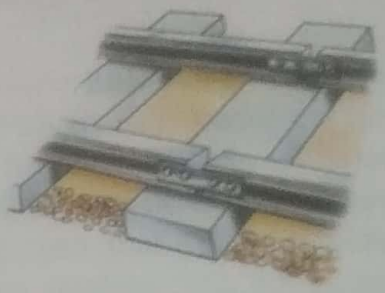


FIG. 5.6 Gaps for expansion between two sections of rail tracks

- In a similar way, in steel bridges one end is made to rest on rollers with enough space provided for expansion during summer (Fig. 5.7).

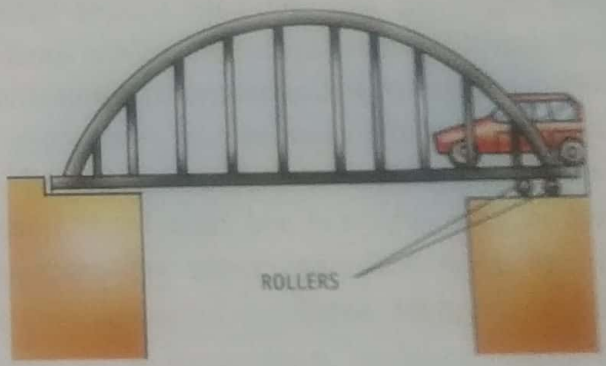


FIG. 5.7 Rollers for expansion in a steel bridge

- When very hot liquid is poured in a glass tumbler, the tumbler sometimes cracks. This happens because the inner wall gets heated first and expands but the outer wall remains unchanged. The resulting strain cracks the glass. These days, however, special types of glass, which expand very little when heated, are available. Due to their low expansion, they do not crack even if very hot liquid is poured in them. One such glass is pyrex glass.

ORAL QUESTIONS FOR FORMATIVE ASSESSMENT

1. Heat is a form of energy. What kind of energy is it?
2. When you heat a substance, several changes can be observed. Talk about three of these changes.
3. The expansion in all solids of equal size when their temperature is increased by the same amount is the same. Do you agree? Give reasons.
4. Arrange in order of increasing expansion on heating: liquids, solids, gases.

TEMPERATURE

Water in your tap is cool whereas ice is cold. If water is heated for about a minute it becomes warm. However, if it is heated to boiling it becomes hot.

ACTIVITY 5 (Experimental investigation)

Take three vessels. Fill one of them with ice-cold water, the second with tap water, and the third with water that has been heated for 1–2 minutes (be careful that the water does not become too hot, otherwise it will burn your hand). Dip your left hand in cold water and your right hand in hot water, for about half a minute. Now take out both hands and simultaneously dip them in tap water.

Is there a difference in the sensation of heat in your left hand and right hand? Does the tap water feel warm to the left hand and cold to the right hand?

The activity shows that the words cold, cool, warm and hot are relative terms. We cannot use these terms to describe how hot or cold an object is.

If you touch a hot object and a cold object with your hand, you can feel the difference. However, you can only say that one object is hotter than the other. You cannot say by how much. We, therefore, need to know the degree of the hotness or the coldness of a body. Thus the degree of hotness or coldness of a body is called its temperature. **Temperature** can also be defined as the quantity by which we can compare the hotness or coldness of bodies. The hotter a substance is, the higher is its temperature.

When you touch a hot object (say hot water), you feel hot. If you touch a cold object (say ice) you feel cold. You feel hot in the first case because heat energy flows from the hot object to your hand. In the second case as heat energy flows from your hand to the cold object, you feel cold.

We can use either the **Celsius** or the **Fahrenheit** scale to measure temperature. For scientific work, the **Kelvin** temperature scale is used.

The Celsius scale

Temperature on this scale is measured in °C (read as degree Celsius). On this scale, we take the temperature at which pure water freezes at sea level to be 0 °C. This is called the **lower fixed point**. The temperature at which pure water boils at sea level is called the **upper fixed point**. It is taken as 100 °C (Fig. 5.8a).

We say at sea level, because the temperature at which water freezes or boils, changes as we go to higher altitude. You will learn the reason for this in higher classes.

The Fahrenheit scale

Temperature is also measured in °F (read as degree Fahrenheit). Its lower fixed point is taken as 32 °F and the upper fixed point as 212 °F (Fig. 5.8b).

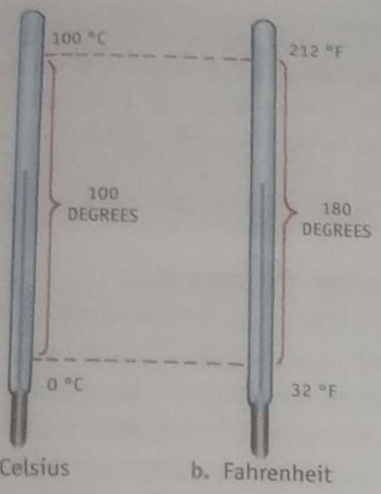


FIG. 5.8 Two commonly used temperature scales

In our country and in most other countries, the Celsius scale is more commonly used. Can you think of a reason for this?

Conversion from one scale to another

We know that

$$0\ °C = 32\ °F$$
$$100\ °C = 212\ °F$$

Therefore, the interval of 100 in °C is equal to an interval of 180 in °F. That is, the ratio of °C to °F is 100 : 180 or 5 : 9.

TO CONVERT	FORMULA USED
1. °C to °F	$F = (\frac{9}{5} \times C) + 32$
2. °F to °C	$C = (\frac{5}{9})(F - 32)$

EXAMPLE 1: Convert 10 °C to °F.

SOLUTION:
$$F = (\tfrac{9}{5} \times C) + 32$$
$$= (\tfrac{9}{5}) \times 10 + 32$$
$$= 50\ °F$$

EXAMPLE 2: Convert 95 °F to °C.

SOLUTION:
$$C = (\tfrac{5}{9})(F - 32)$$
$$= (\tfrac{5}{9})(95 - 32)$$
$$= (\tfrac{5}{9}) \times 63 = 35\ °C$$

EXAMPLE 3: At what temperature are the readings on the Celsius and the Fahrenheit scales the same?

SOLUTION: Let x be the common reading.
Then $C = F = x$
Using the formula: $C = (\frac{5}{9})(F - 32)$, and substituting x for C and F, we get

$$x = (\tfrac{5}{9})(x - 32)$$
$$x = (\tfrac{5}{9})x - (\tfrac{5}{9}) \times 32$$
$$x - (\tfrac{5}{9})x = -\frac{(5 \times 32)}{9}$$
$$(\tfrac{4}{9})x = -\frac{(5 \times 32)}{9}$$
or
$$x = -40$$

∴ The common temperature is −40 degrees, i.e. −40 °C = −40 °F.

Measuring temperature

You have seen that solids, liquids and gases expand on heating. The hotter an object is, the more it expands. Therefore, one of the ways of measuring temperature is to measure the expansion of solids, liquids or gases.

However, solids expand very little, while in gases the expansion is very high. Therefore, in order to measure temperature, we usually measure expansion in liquids.

The instrument used to measure temperature is called **thermometer**. The principle used in thermometers is the same as that of the apparatus used to observe expansion in liquids.

The laboratory thermometer

The thermometers available in the laboratory consist of a long, thin, uniform glass tube sealed at one end, with a bulb filled with a liquid at the other end. The most commonly used liquid is mercury. A shining thread of mercury can be seen from outside the thermometer.

As the temperature rises, the mercury in the bulb expands and rises into the thin tube called the **stem** of the thermometer. The stem is marked in °C or °F. The height of the liquid in the stem gives the reading of temperature. Laboratory thermometers with various ranges are available. The commonly used laboratory thermometers have a range from −10 °C to 110 °C. The bigger marks

normally read 1 °C. If there are 5 divisions between the bigger marks, each small division reads $\frac{1}{5}$ of a degree or 0.2 °C.

While measuring temperature with a laboratory thermometer, the following precautions should be observed.

- The thermometer should be washed before and after use.
- A thermometer is delicate and should be handled with care to avoid breakage.
- It should not be held by the bulb while reading the temperature.
- It should be kept upright and not tilted.
- The bulb should be completely surrounded by the substance whose temperature is being measured, and the bulb should not touch the sides of the container.
- While reading the thermometer, the level of mercury should be at the same level as the eye.

ACTIVITY 6 (Experimental investigation): To measure the temperature of hot water

Take some hot water in a beaker. Dip the bulb of a laboratory thermometer in the water, keeping it away from the sides of the beaker. Wait till the mercury thread becomes steady. Read the thermometer while it is still dipping inside the water. Take the thermometer out of the water and observe the level of mercury in the stem. Does it go down? Why?

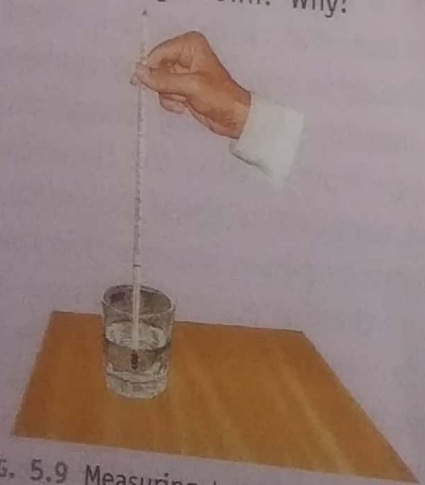


FIG. 5.9 Measuring temperature of hot water with a laboratory thermometer

ACTIVITY 7 (Collecting information and deducing)

Mercury cannot be used to measure very low temperatures. Instead, alcohol is used. Find out why. Since alcohol is colourless, it is coloured so that it can be seen in the stem.

The clinical thermometer

To check the body temperature, a thermometer is placed in your mouth or in your armpit. The temperature recorded in a laboratory thermometer will fall as soon as it is taken out of your mouth. To get a correct reading, therefore, a **clinical thermometer** is used (Fig. 5.10).

This thermometer has a slight bend or kink in the stem just above the bulb. When the thermometer is taken out of your mouth, the liquid in the bulb contracts and the mercury column breaks at the kink. Therefore, the level of mercury in the stem remains the same.

If the thermometer is to be used again, it is first given a jerk to bring the mercury in the stem back into the bulb.

The normal body temperature of a healthy person is 37 °C or 98.6 °F. It goes up if the person has fever. However, it does not go below 35 °C or above 42 °C. Therefore, a clinical thermometer has a range of 35 °C to 42 °C. In

IT'S A FACT!

Digital clinical thermometers are now fast replacing mercury clinical thermometers. Digital thermometers do not use mercury. This is a relief as mercury is a toxic substance, very difficult to dispose off if a thermometer breaks. In a digital thermometer, the temperature is displayed in a numerical form.

Liquid crystals are crystals with special properties. Some of them change colour according to temperature. They are used in making strip thermometers used to measure the body temperature of small babies.

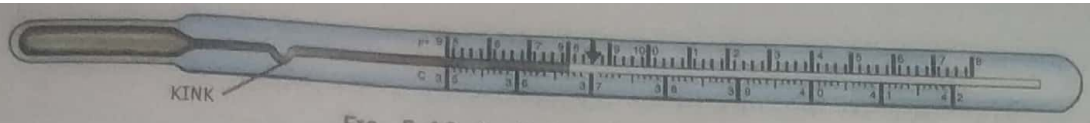


FIG. 5.10 A clinical thermometer

the Fahrenheit clinical thermometer, which is commonly used, the temperature range is from 94 °F to 108 °F.

ACTIVITY 8 (Experimental investigation): To measure body temperature using a clinical thermometer

Wash the clinical thermometer before use, preferably with an antiseptic solution. Hold it with the stem and give it a few jerks, to ensure that the level of mercury falls below 35 °C. Place the bulb of the thermometer below your tongue and close your mouth. Do not press your teeth on the glass of the thermometer. Let the thermometer stay in the mouth for a minute. Take it out and note its reading. The reading gives your body temperature.

Take the body temperature of 10 of your friends. Remember to wash the thermometer and jerk it before each measurement. Record your observations in a table. What do you find? Do all of them have a normal body temperature of 37 °C? You will find that there are slight differences between the normal body temperatures of different people.

Take the body temperature of someone who has fever. What do you find?

ACTIVITY 9 (Collecting information)

How does a veterinary doctor (a doctor who treats animals) find out the body temperature of domestic animals and birds? Go to the nearest veterinary clinic and find out.

ORAL QUESTIONS FOR FORMATIVE ASSESSMENT

1. What measure do we use to compare the hotness or coldness of a body?
2. Between Celsius and Fahrenheit scales which one is more convenient to use? Why?
3. Which temperature scale is used for scientific work?
4. Which property of matter is used to measure temperature? Matter in which state is more commonly used?
5. Name the instrument used to measure temperature. What is the special name given to the instrument used to measure body temperature?

NOW YOU KNOW

- Heat is a form of energy.
- Heat causes change in temperature, expansion, change of state and chemical changes. It also affects living organisms.
- Heat causes expansion. Solids expand the least. Gases expand the most.
- Expansion can be put to use. It can also cause problems.
- Temperature is a measure of hotness or coldness of a body. Temperature is usually measured in the Celsius scale or Fahrenheit scale. For scientific work, Kelvin temperature scale is used.
- Thermometers use the principle of expansion of liquids on heating to measure temperature. Generally a liquid such as mercury is used.
- A clinical thermometer is used to measure body temperature.

NEW WORDS

HEAT—energy due to movement of molecules in a substance
TEMPERATURE—the measure of hotness or coldness of a body
THERMOMETER—an instrument used to measure temperature

FOR FORMATIVE AND SUMMATIVE ASSESSMENT

A. MULTIPLE-CHOICE QUESTIONS: Choose the most appropriate answer.

1. Heat causes
   a. change of state.
   b. change of temperature.
   c. expansion.
   d. all of these

2. Heat causes expansion because
   a. heat occupies space.
   b. of increase in the movement of molecules.
   c. matter tries to escape from the heat.
   d. none of the above is true—it is not yet known why heat causes expansion.

3. Which of these will expand the most on heating?
   a. gold b. water c. mercury d. air

4. 0 °C is the same temperature as
   a. 0 °F. b. 212 °F. c. 32 °F. d. 100 °F.

5. A bimetallic strip is made of metals M_1 and M_2. On cooling through the same temperature, M_1 contracts more than M_2. When the strip is heated, it will
   a. bend towards M_1.
   b. bend towards M_2.
   c. not bend at all.
   d. direction of bending cannot be predicted.

6. A 10 °C fall in temperature is equal to
   a. 10 °F fall in temperature.
   b. 18 °F fall in temperature.
   c. 10 °F rise in temperature.
   d. 18 °F rise in temperature.

7. Temperature is measured by measuring expansion on heating. Expansion in which of these is most commonly used?
   a. solid b. liquid c. gas d. none of these

8. When you touch a cold object
   a. heat flows from your body to the object.
   b. heat flows from the object to your body.
   c. temperature flows from your body to the object.
   d. temperature flows from the object to your body.

B. VERY SHORT-ANSWER QUESTIONS: Give one-word answers.

1. Heat is a form of _____.
2. For scientific work, the _____ temperature scale is used.
3. The apparatus commonly used in the laboratory to show expansion on heating is the ring and _____ apparatus.

4. A solid is heated from 0 °C to 100 °C. Its volume increases from V_1 to V_2. It is now cooled to 0 °C. Will its volume at 0 °C be V_1 or V_2?
5. Which of these expand the most on heating—solids, liquids or gases?
6. All solids expand by the same amount when heated through the same temperature increase. True or false?
7. If overhead electric cables are being laid in summers, should they be tightened up, or left a little loose?
8. Which is the correct formula: $F = (\frac{9}{5})C + 32$ or $C = (\frac{9}{5})F + 32$?
9. Temperature is usually measured by measuring expansion in gases since gases expand the most. True or false?
10. What are the upper fixed points of the Celsius and the Fahrenheit scales?
11. A _____ thermometer is used to record body temperature.

C. SHORT-ANSWER QUESTIONS: Answer in a sentence or two.

1. List four effects that heat produces.
2. What does a bimetallic strip consist of?
3. A steel bridge expands in summer. What precautions are taken to make sure this expansion does not damage the bridge?
4. How are temperature and hotness of a body related?
5. What do you mean by 'upper fixed point'?
6. Why does a clinical thermometer have a kink in its stem?

D. LONG-ANSWER QUESTIONS: Answer in about 50 words.

1. Explain why a substance expands on heating.
2. Give one example where expansion on heating is put to good use. Explain the working with the help of a labelled diagram.
3. Explain why gases expand more than liquids and solids.
4. Explain with the help of a labelled diagram an experiment to show that liquids expand when heated.
5. Expansion on heating can be a nuisance. Explain giving two examples.
6. Convert: 25 °C to °F and 86 °F to °C
7. Calculate the temperature at which the reading on the Fahrenheit scale is double the reading on the Celsius scale.
8. What precautions will you take while measuring temperature with a laboratory thermometer? What extra precaution will you take while measuring body temperature with a clinical thermometer?

HOTS QUESTIONS: Think and answer.

1. You are planning to go to a very cold place where the night temperature drops to –50 °C. Which thermometer will you take with you—mercury or alcohol? Why?

2. Which is greater—a 1° rise in the Celsius scale or a 1° rise in the Fahrenheit scale?
3. Can a clinical thermometer be used to measure the temperature of boiling water? Why?
4. Why is a laboratory thermometer not used to measure body temperature?
5. You have seen that an ordinary glass tumbler can crack if very hot or very cold water is poured into it. You have two glass tumblers made of ordinary glass—one with thick walls a the other with very thin walls. Which one is more likely to crack when very hot or very co water is poured into them?

FOR FORMATIVE ASSESSMENT*

In the Library—Research Project

You have seen that heat energy of a substance is the energy of its moving molecules. The molecules say, ice are still moving at 0 °C. Below 0 °C their movement reduces but does not stop. Ice still has heat energy at this temperature. At some temperature below zero, the molecules of all substances should stop moving altogether. A body at this temperature will have no heat energy at all. Find out how much below 0 °C is this temperature. Find out what it is called. Find out if anyone has been a to cool a body to this temperature.

My Virtual Library—Research/Activities on the Internet

- ❒ Visit rsgr.in/lsc-cce-7 and click on LINK 11 to see a complete tutorial on heat and temperature with activities and experiments.
- ❒ Visit rsgr.in/lsc-cce-7 and click on LINK 12 to see how to make your own thermometer.
- ❒ Visit rsgr.in/lsc-cce-7 and click on LINK 13 to find more on temperature including experiments.

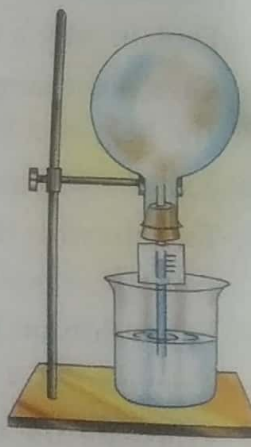
In the Laboratory—Making a Model

Making a gas thermometer Gases expand more than liquids or solids. You can convert the apparatus used in Activity 4 into a very sensitive thermometer.

You will need ◆ water with a little colour added to it ◆ white card

Procedure:

- ◆ Cut two slits in the white card. Slide the card over the glass tube so that it stays firmly at one place. You may use adhesive tape to fix it in place.
- ◆ Now invert the flask over water in a beaker and carry out the experiment. Let the flask cool to room temperature. Mark the level of water on the card. Take the room temperature reading on a standard thermometer kept nearby. Write the reading beside the mark on the card. As the room temperature changes during the day, keep marking the water level on the card, and the temperature beside each mark. You have now calibrated your thermometer, i.e. you have marked the readings on it.
- ◆ You can use the thermometer to measure room temperature over a narrow range only. If it becom too warm or too cold, the water level may go below or above the level of the card fixed by you.



*For more tasks see Page 55