UNIT 6

TEMPERATURE AND HEAT

Unit outcomes: **After completing this unit you should be able to:**

- ✓ **understand concepts related to temperature and heat.**
- ✓ **develop skill of manipulating numerical problems related to temperature.**
- ✓ **appreciate the interrelatedness of all things.**
- ✓ **use a wide range of possibilities for developing knowledge of the major concepts within physics.**

Introduction

So far, you studied three basic physical quantities mass, length and time. In this unit you will learn the fourth basic physical quantity called **temperature.**

This unit introduces the concept of temperature and discusses the differences between temperature and heat. The unit also presents temperature measuring instruments (scales), conversion of temperature scales, sources of heat and effects of heating.

6.1. Definition of Temperature

Activity 6.1: *Questions for Discussion*

i. What is a temperature?
ii. How do people express temperature in their daily life?
iii. Is there a difference between temperature and heat? Explain it.

People usually use the word hot, warm, cool and cold to express the temperature of an object. Do you feel the differences between hot and warm, cold and cool? These words are not very accurate to tell the temperature of an object. Most people are confused and they use the words heat and temperature interchangeably. But heat and temperature are two different physical quantities.

Activity 6.2: *Discuss the following questions*

iv. Consider you have three cups of tea filled with hot, lukewarm and cold water.
Step i. immerse your left hand finger in hot water and the right hand finger in cold water.
Step ii. Take out your hands from the hot and cold water.
Step iii. Quickly, put both your fingers in the lukewarm water.
What do you feel on your left and right fingers? Is there any difference?
v. What is the difference between heat and temperature?

As you withdraw your finger from the hot water and put it in the lukewarm water, you feel cold. When you withdraw your hand from the cold water and put it into the lukewarm water, you feel warm. **Can you tell which is hot and which is cold**?

From this activity you will learn that testing the hotness or coldness of a body by feeling is not reliable, because the lukewarm water is cold for one finger and hot for the other. So you can not conclude that the lukewarm water is hot or cold.

Temperature is a fundamental concept as the three fundamental quantities: mass, length, and time.

Substances are made up of small particles called atoms and molecules. These small particles are symbolized by small circles, like marbles, (Revise your chemistry lessons). The particles in a solid are fixed in a position, but vibrate back and forth about the fixed point. The particles in liquids and gases are always in motion. These particles have energy due to their motion called kinetic energy. (See Fig 6.1)

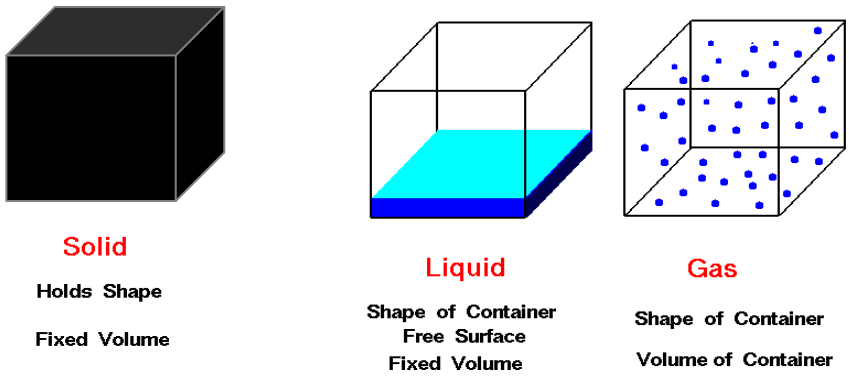


Fig 6.1 Three states of a substance

When a substance is made hotter, the speed of these particles increases, and gain kinetic energy. In science, heat is a form of energy. Heat is the total kinetic energy of all the particles in the substance. While 'temperature' is the measure of the average kinetic energy of the particles in the substance.

Thus temperature can be defined as the hotness or coldness of a body or as the average kinetic energy of the particles of a body.

A body having particles with small kinetic energy has low temperature.

Temperature is a measure of the average kinetic energy of the particles in a substance. It does not depend on the size of the body. For example, the temperature of a small cup of boiling water is the same as the temperature of a large pot of boiling water. But these two bodies have different heat.

Temperature is an intensive property of a body. That means, it does not depend on the system size, the amount or type of particles in the system. Temperature is intensive as pressure and density. For example, the density of a substance remains the same as the mass and the volume change. Density is an intensive quantity. By contrast, mass and volume are extensive properties and depend on the amount of material in the system. Similarly heat is an extensive quantity. That is, it depends on the amount or size of the particles in the substance. For example 100 liters of boiling water has different heat, but the same temperature to 1 liter of boiling water. If they are poured on ice the 100 liter water will melt more ice than the 1 liter of boiling water.

Check point 6.1

1. Explain the term 'temperature'.
2. Describe the difference between temperature and heat.
3. How can we relate the temperature of a body with the kinetic energy of its particle?
4. Temperature is an intensive property of a body, while heat is an extensive quantity. Explain it.

6.2. Measuring Temperature

Activity 6.3

i. Explain the local methods of measuring (estimating) temperature in every day life.
ii. What is the drawback of using our sense organs for knowing the temperature of a body?
iii. Have you seen a clinical thermometer used by medical personnel? What is there in the thermometer?
iv. How do we measure temperature?

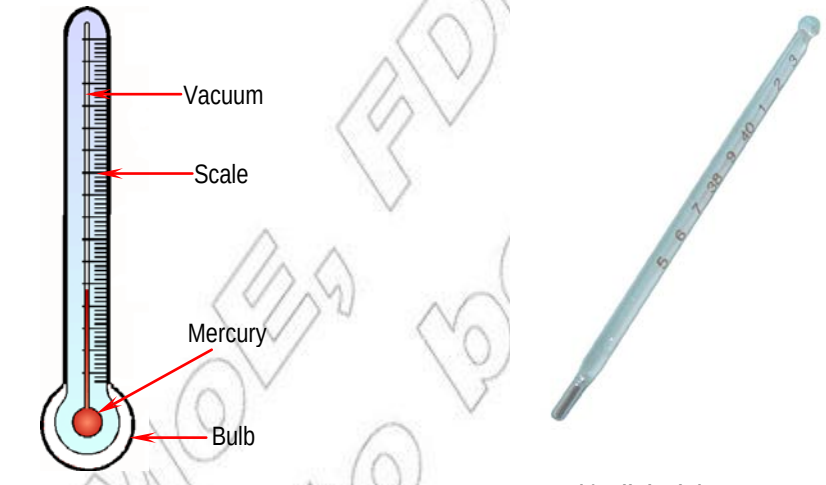
In everyday life, people use their hands to check the temperature of another body. For example, consider a soft drink which is taken out from a refrigerator. By holding the surface of the bottle, you can say that "it is too cold" lukewarm or "warm". Similarly for hot bodies, people use their hands. For example, mothers use their hands to check whether the water is hot or lukewarm for their babies. But it is impossible to measure the temperature of a body accurately by touching or using our sense perceptions.

To measure the temperature of a body accurately we need a special instrument called thermometer.

Thermometer is a device used to measure the temperature of a body. It measures temperature in degrees (°).

The first thermometer was made in 1592, by the Italian scientist called Galileo.

A thermometer consists of a tube of uniform thin bore with a small bulb at its bottom. The tube is commonly filled with mercury or alcohol to a certain height. It operates by contraction and expansion of the mercury or alcohol in the bulb. There are different types of thermometers, having different ranges and different substances in it. Some of them are:



a) Mercury Thermometer b) Clinical thermometer

Fig 6.2 Different types of thermometers

i) **Mercury Thermometer**: It operates based on the expansion of mercury with increase of temperature. Clinical thermometer and laboratory thermometer are made of mercury. The clinical thermometer is used by health officers in hospitals and in clinics. The laboratory thermometer is used by scientist for research purposes.

ii) **Alcohol thermometer**: It is used to measure very low temperature. It ranges from -80°C to 100°C

Check point 6.2

1. How can you measure accurately the temperature of a body?
2. Describe different types of thermometers.
3. Explain how a mercury thermometer functions. Draw a thermometer and label it.

6.3. Temperature Scales

Activity 6.4

i. What temperature scales do you know? Describe them.
ii. In what tempreature scales, do medical personnels and meteorologist read the temperature of bodies?

These days different temperature scales are in use. But at this level, you will only study the three most common temperature scales; namely the

1. Centigrade (Celsius) scale
2. Fahrenheit, scale
3. Kelvin scale

In making a thermometer, two temperatures of a body are marked on it as fixed points.

These are the **lower fixed point** (melting point of ice) and the **upper fixed point** (boiling point of water) at sea level.

I. The Celsius scale

The Celsius scale or centigrade scale was devised by the Swedish astronomer, Anders Celsius (1701-1744), He assigned the value 0 to the ice point and 100 to

the boiling point. By dividing the space between the two fixed points into 100 equal parts (divisions) a Celsius scale is obtained. Each division or unit is called **Degree** (°).

Temperature in Celsius scale is denoted as ^{o}C. It is read as degree Celsius. (Fig 6.3)

Challenge question

Do you know how much is the normal human body temperature in degree Celsius?

II. The Fahrenheit scale

The Fahrenheit scale was devised by the German scientist Daniel Fahrenheit. He assigned the value 32 to the ice point and 212 to the boiling point.

Since the difference between the ice point and boiling point is 180; one can obtain the Fahrenheit scale by dividing the space between the two fixed points into 180 equal parts. Temperature in Fahrenheit scale is denoted by ^{0}F, read as degree Fahrenheit (see Fig. 6.3.)

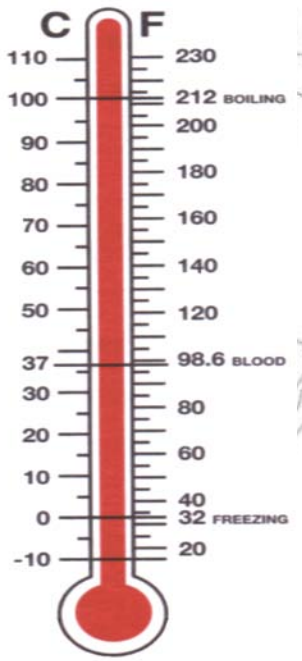


Fig. 6.3 Comparison of Celsius and Fahrenheit thermometers

This temperature scale is sometimes used in connection with reporting on the weather but is not commonly used in everyday life in one country and for scientific works in a laboratory.

III. The Kelvin Scale

A new type of temperature scale called **Kelvin** scale is devised by Lord Kelvin. He assigned 273 to ice point and 373 to boiling point. By dividing the space between the two fixed points into 100 equal parts Kelvin scale is obtained. This scale is used commonly for scientific works.

Temperature exists much colder than the freezing point of ice, 0 °C on Celsius scale. Experiments suggest that there is a limit to how cold things can get.

At a temperature of - 273°C or 0 K all the heat energy will be removed from a substance and the particles in the substance stop to move. We call this lowest possible temperature **Absolute Zero.**

The SI unit of temperature is Kelvin, symbolized by K. It does not have degree symbol on it.

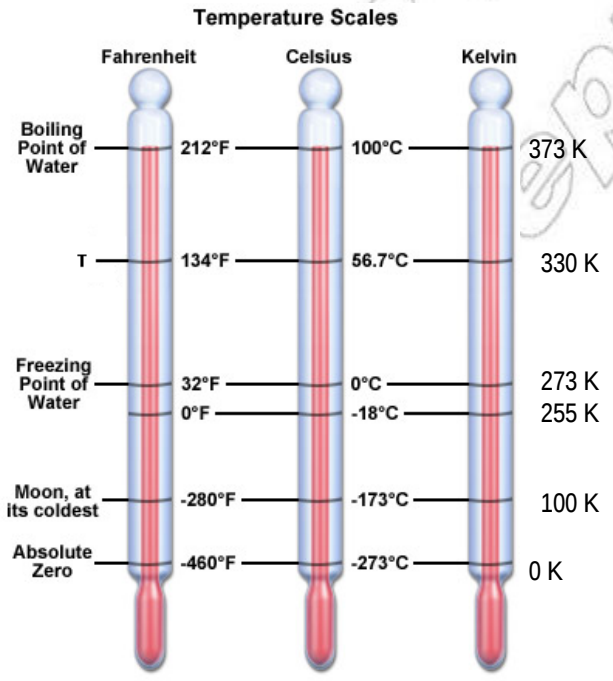


Fig. 6.4 Thermometer reading from different scales

Reading a thermometer

When the temperature of the surrounding air rises, the volume of the mercury will expand, causing the mercury inside the tube rise, so that one can read out of the marked scale on the tube and know the temperature. Contrary to this, when the temperature of the air falls, the mercury inside the tube will contract. This will cause the level of the mercury inside the tube to drop. The temperature can thus be read from the corresponding scale on the tube.

Activity 6.5: Measuring temperature of a bodies

Materials you need: water at different temperature, thermometer.

i. Try to measure the temperature of water in different containers and your body temperature using a thermometer.
ii. Record the measured values in a table with proper units.
iii. Compare the temperatures of different bodies. Which are hotter, hottest, coldest?

Check point 6.3

1. What are the different temperature scales? What are the fixed points in each scale?
2. Explain what it means by lowest and upper fixed points.
3. What is the SI unit of temperature?
4. How many divisions are there between the lowest and upper fixed points, in each scale?

6.4. Conversion of Temperature Scales

To change the reading of one temperature scale to another, we use, the following relationships. Ratio of interval between boiling point and ice point= Ratio of differences between the lower and unknown point.

i.e.

$$\frac{\text{intervals in Celsius}}{\text{interval in Fahrenheit}} = \frac{T_C - \text{ice point in Celsius}}{T_F - \text{ice point in Fahrenheit}}$$

$$\frac{100}{180} = \frac{T_C - 0}{T_F - 32}$$

a) To convert Celsius scale to Fahrenheit or vise-versal, we use the relationship:

$$T_F = \frac{9}{5} T_C + 32°$$

$$T_C = \frac{5}{9} (T_F - 32)$$

b) To convert Celsius scale to Kelvin or vise-versal, we use the relationship:

$$T_K = T_c + 273°$$

$$T_C = T_K - 273°$$

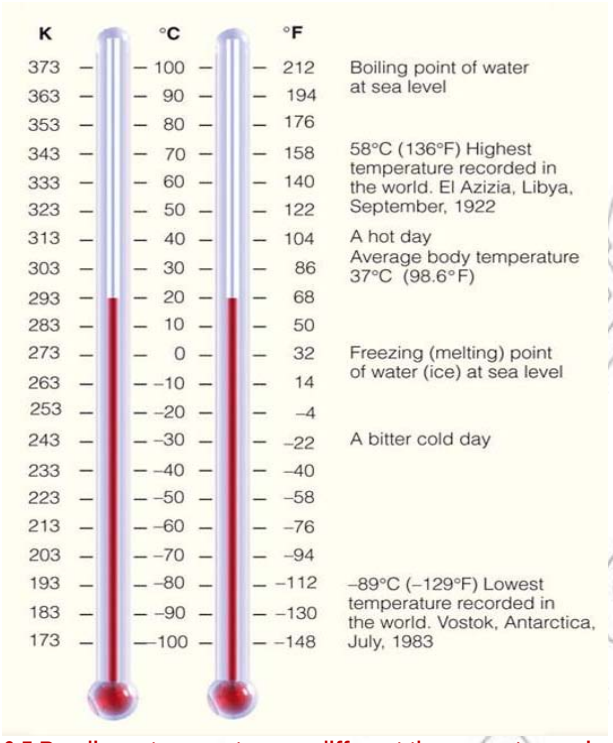


Fig. 6.5 Reading a temperature on different thermometer scale

Worked examples

1. The temperature of a room is 20°C. What is the temperature of the room in:
   a) Fahrenheit scale? b) Kelvin scale?

Given	Required
$T_C = 20°C$	a) $T_F = ?$
	b) $T_k = ?$

Solution

a) $\frac{9}{5}T_C + 32° = \frac{9}{5} \times 20° + 32°$

$= 36° + 32°$

$= 68°F$

b) $T_k = T_c + 273°$

$20° + 273°$

$= 293k$

2. What will be the temperature reading in Celsius scale when the reading in Fahrenheit scale is zero?

Given	Required	Solution
$T_F = 0$	$T_C = ?$	$T_C = \frac{5}{9}(T_F - 32°)$
		$= \frac{5}{9}(0 - 32°)$
		$= \frac{5}{9}(-32°) = \frac{-160°}{9}$
		$= -17.8°C$

Check point 6.4

1. Write the mathematical relations between Celsius and Fahrenheit scales.
2. Convert 56 °C to °F and K.
3. Convert 210 °F to °C and K.

6.5. Sources of Heat

Activity 6.6- Discuss

i. What is heat?
ii. Why do we need heat?
iii. Mention some soures of heat in your daily life.
iv. What is the difference between heat and temperature?

What is heat?

Heat was thought to be a substance called calorie. People thought that a hotter body contained more "calorie" than a cold body. But, series of experiments have showed that heat is not a substance. Heat is produced by energy changes. And heat is a form of energy. Do you know how ancient people were producing heat for cooking? Discuss with your friends and parents.

The sources of heat energy in our country are: fire wood, the sun, charcoal, petroleum fuel, electric heater, etc. You can add to these some sources of heat used in your locality.

a) The sun b) Electric stove c) Charcoal

Fig 6.6 some sources of heat

The most plentiful source of heat is the sun. The sun energy is important for life. Plants, animals and human beings need the sun energy for living on the earth.

Fig.6.6 shows some sources of heat. For what purposes do people use heat?

Temperature is the measure of the hotness and coldness of an object where as heat is a form of energy that can be transferred from a hotter body to a colder body.

The SI unit of heat energy is Joule.

In our country, majority of the people use fire wood and kerosene as sources of heat energy to cook their food and for other purposes.

Since both fire wood and kerosene are non renewable energy suppliers we must use them wisely. Or we need to use renewable energy suppliers such as solar energy, wind energy and water energy.

So as a citizen you are expected to use these energy sources wisely and you are also responsible to tell this idea for your family or friends.

Check point 6.5

1. List some every days sources of heat.
2. Explain the direction of heat flow from one body to another.

6.6. Effects of Heating

Activity 6.7

Discuss with your friends

i) What happens to a body, when you heat it? Make a list of these effects.

ii) Classify these effects into three groups.

When we heat a body, different effects may happen. When you heat a body it either burns, or melts, expands, rises in temperature, glows into red, or glass breaks, etc. These effects of heating can be grouped into the following three categories.

a) temperature rise,

b) expansion,

c) change of state.

a) Heating causes temperature rise

Activity 6.8 *Heating body causes temperature rise*

i. Materials required : a beaker, water, a source of heat, thermometer and a stand

ii. Assemble the apparatuses as shown is Fig 6.7

iii. Take the temperature of the water before heating it

iv. Now start heating the water and measure its temperature after every one minute.

v. Record the measured temperature with respect to time taken.

- interpret the recorded data
- What do you conclude?

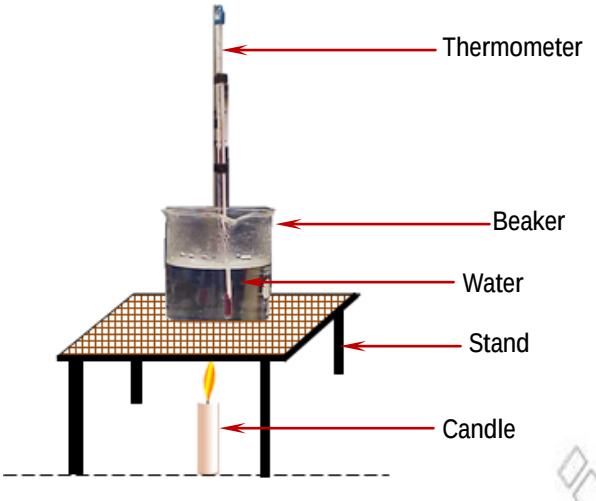


Fig 6.7 Heating water

t	Min	0	1	2	3	4	
T	(°c)						

As heating increases, the kinetic energy of the particles increases. This causes an increase in the temperature of the substance. Generally, as a body receives heat, its temperature rises.

b) Heating causes expansion

Since heating increases the kinetic energy of molecules, the molecules move faster and farther apart. This results in an overall increase in the size of the substance. Expansion is an increase in size of the body.

Gases, liquids and solids generally expand when heated and shrink when cooled.

To observe the effect of heating on the size of solids you can do the following activity.

a) both cold *b) ball heated* *c) both heated*

Fig 6.8. Expansion of solids

Activity 6.9 (Ball and ring experiment)

Materials required: metal ball with handle or string, metal ring with handle, source of heat.

Procedure:

1. At room temperature, the ball will just get through the ring. (see Fig 6.8 (a)
2. Heat only the ball and try to pass it through the ring. (Fig 6.8 (b)
3. Heat both the ball and the ring simultaneously but separately and then try to pass the ball through the heated ring as in Fig.6.8 (c).
   i) What do you observe from this activity?
   ii) Why didn't the ball pass through the ring after being heated?
   iii) Why did the heated ball pass through the heated ring?

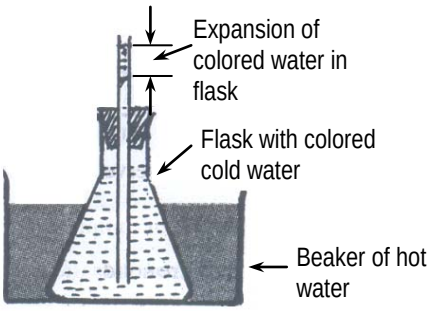


Fig 6.9 Water in a tube expands by heating

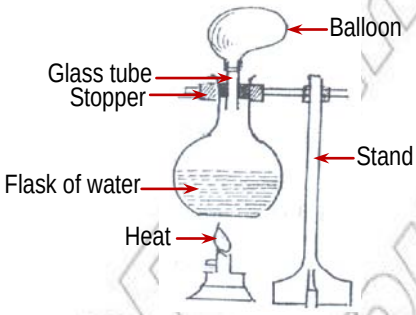


Fig 6.10 Air expands

Fig 6.9 and Fig 6.10 illustrate the expansion of liquid water and air in a bottle respectively.

c) Heating causes changes of state

Activity 6.10

i. What are the three states of matter?

ii. What are the three state of water called?

A substance exists in three states. They are solid, liquid and gaseous states. In solids the particles are closer together in a fixed pattern where the separating distance of adjacent particles is constant. The particles of liquids are not usually

as close together as in solid and are not held in any fixed pattern. In a gas or vapor the average separation of the particle is comparatively large.

Water is the most commonly found liquid substance on earth. It can exist as solid, liquid and gaseous states.

- Solid water (ice) exists below 0 ^{o}c.
- Liquid water (water) exists between 0 ^{o}c – 100 ^{o}c.
- Gaseous water (Vapor) exists from 100 ^{o}C and above.

The change of solid water (ice) to water and change of water to vapor are called changes of state.

Melting: solid ⟶ liquid

Boiling: liquid ⟶ gas (vapor)

Challenge question

1. Have you noticed the cooling effect when your arm is cleaned by alcohol during injection?
2. Do you know how your body removes unwanted heat?

Melting

When a solid is heated sufficiently it changes its state of solid to liquid. The process of changing a solid to a liquid state is called **melting**.

A definite temperature at which the solid body starts to melt is called the **melting point** of the solid. Different solid substances have different melting points. For example, solid water (ice) melts into liquid water at 0 ^{o}C and solid iron melts into liquid iron at 1536 ^{o}C.

Boiling

When water is heated, bubbles of water vapor are first formed at the bottom and sides of the container. As the water is continuously heated, its temperature rises, and its molecular bonds break and move farther apart. The process of changing a liquid into gaseous state is called **boiling**.

The definite temperature at which liquid starts to boil is called the **boiling point** of the liquid. For example, water boils at 100^{o}c and mercury boils at 357^{o}C.

Evaporation

Evaporation is the change of liquid to vapor at the surface of a body at any temperature. During heating the molecules near the surface of the liquid escape into the air; but not all molecules have enough energy to escape.

For example, water in a pond, lake or ocean, wet clothes, bottle covered with sacks evaporates as it is heated by the sun. (Fig. 6.11).

Discuss what things fasten evaporation?

Evaporation is fastened by exposing a body to a) source of heat, b) wind and c) when the body has wide surface area. For example, a pond of water evaporates quicker in a sunny, windy day and when it has wide surface area. On the opposite, evaporation is slower in rainy day, in still air, and when the surface area is narrow.

When the liquid molecules evaporate, they cool the surface from which they escape because they absorb heat. Thus, evaporation causes cooling of a body.

Table 6.2 Difference between boiling and evaporation

Boiling	Evaporation
• Happens at boiling point.	• Happens at any temperature
• Happens throughout the liquid body.	• Happens on the surface of a body- solid or liquid
• Has no cooling effect.	• Has a cooling effect on a body.
• Does not depend on wind & surface area.	• Is fastened in hot and windy day and where the body surface is wide.

Fig 6.11 Evaporation in different bodies

Activity 6.11

To observe cooling effect of evaporation

i. Put your fingers into alcohol and immediately expose your fingers to the air. What do you feel?

ii. Explain what happens to the alcohol and to your fingers.

Cooling effect of evaporation has some uses. For example refrigerators, freezers and air conditioning system use cooling by evaporation on a large scale. Evaporation is also important in water cycle for making rain on the earth's surface.

Activity 6.12

To measure melting point of ice and the boiling point of water.

Measure the temperature of solid ice, melt the ice and heat the resulting water until it vaporizes and record the boiling point of the water. What do you observe on the boiling point of water? Does it boil at 100 ^{0}C in your area?

Check point 6.6

1. Describe the three major effects of heating.
2. Explain the differences between 'evaporation' and 'boiling'.
3. What are the factors that affect the rate of evaporation?

Summary

In this unit you learnt that:

- temperature is the measure of hotness or coldness of a body. Or it is the measure of the average molecular kinetic energy of a body. An instrument which is used to measure temperature of a body is called thermometer.
- a given thermometer can read temperature of a body in one of the following three scales. These are Celsius scale (^oc), Fahrenheit scale (^oF), and Kelvin scale (K).
- the following formulae are useful in converting out temperature scale in to another scale.
- $T_C = \frac{5}{9}(T_F - 32°)$

  $T_F = \frac{9}{5} T_C + 32°$

  $T_K = T_C + 273°$
- heat is a form of energy. We can get heat from the sun, the food we eat, electric energy, kerosene and firewood.
- some of the effects of heating a body are expansion temperature rise and change of states. Gases expand much more than liquids and solids. Liquids expand more than solids.
- the change from solid to liquid is called melting. The change from liquid to vapor is called boiling. The rate of evaporation depends on) the heat supplied, surface area of the body (liquid) and the wind around the surface.

Review Questions and Problems

I. Write true if the statement is correct and false if the statement is wrong.

1. When air is warmed, it expands.
2. Heat and temperature are the same.
3. Electrical energy can be used as the source of heat.
4. Friction produces heat energy.
5. Many substances expand when cooled.
6. Heating speeds up the movement of molecules.

II. Match the word or words in the column A with correct explanations in column B

Column A	Column B
1. Expansion	a) the measure of hotness or coldness.
2. Temperature	b) 100 divisions between freezing and boiling point of water
3. Centigrade scale	c) decrease in size
4. Contraction	d) increase in size
5. Thermometer	e) substance that can produce heat
6. Fuels	f) instrument for measuring temperature
7. Sun	g) the source of radiant energy
8. Boiling	h) is a cooling process
9. Evaporation	i) takes place throughout the entire liquid

III. Short answer questions.

1. What device do you use to measure temperature?
2. What are the boiling and melting point of water?
3. What happens to a body when it is heated?
4. Name the three different temperature scales.
5. What is the difference between boiling and melting?
6. What is meant by expansion effect of heating?
7. What is the difference between boiling and evaporation?
8. What are the three factors affecting the rate of evaporation?

IV. Fill in the blank spaces with appropriate word.

1. **Almost all materials _____when their temperature is raised and shrink when their temperature is lowered (cold).**
2. **_____ is the measure of average kinetic energy of the particles of a substance.**
3. **The SI unit of temperature is _____.**
4. **The SI unit of heat is _____ .**
5. **The hotness or coldness of a body is measured by a quantity called _____.**
6. **_____ is the change of liquid into vapor from the surfaces of a body.**

V. Problem

1. **What is the temperature reading in Kelvin scale if the reading in Celsius scale is 50 °C.**
2. **The temperature of an object is 40 °C. What is this temperature in Fahrenheit scale?**
3. **What will be the temperature reading in Fahrenheit scale when the reading is 310 K?**