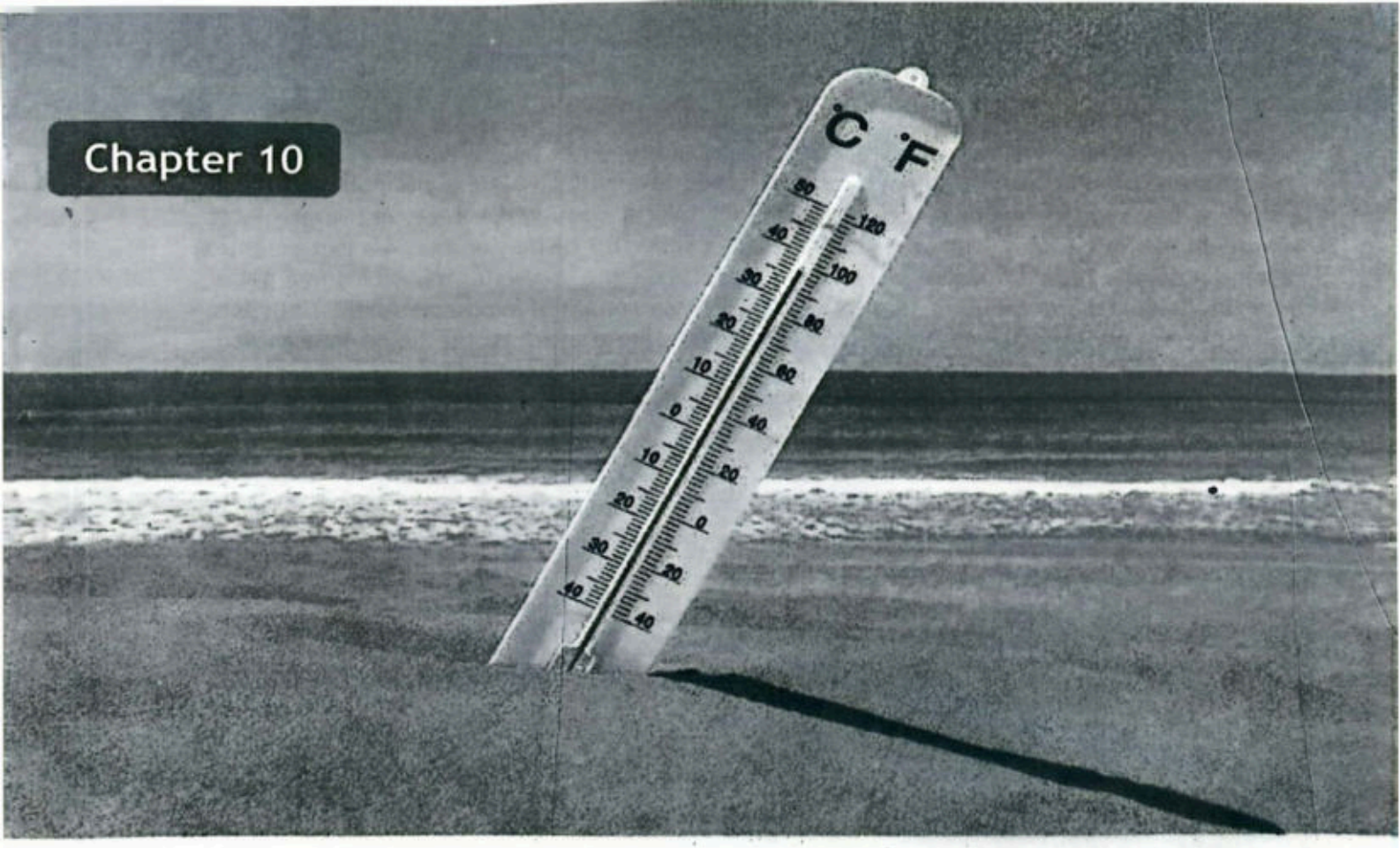

HEAT

SLOs: After completing this lesson, the student will be able to:

1. Differentiate between heat and temperature.
2. Describe thermal expansion and its consequences in daily life.
3. State the melting and boiling temperatures of water.
4. Differentiate between conduction, convection and radiation.
5. Differentiate between heat conductors and insulators.

The concept of heat and temperature are often mixed together by the human even from the early times. The concept of temperature is rooted in qualitative ideas of 'hot' and 'cold' based on observation of our sense of touch. We take a body which feels hot is at higher temperature than a body which feels cold. Many properties of matter that we can measure depend upon the temperature of the substance. For example the water molecules in a pot at very low temperature are solid (ice) but the same matter when exposed to heat turns into liquid (water) at higher temperature and further heating transforms the liquid into gaseous state (vapours) at very high temperature. This example shows that at different temperatures the same material shows different state and hence different properties.

10.1 HEAT AND TEMPERATURE

In liquid state at ordinary temperature the molecules of water in a pot move constantly but we cannot observe the motion of water molecules with the help of naked eye. However, we observe water currents, or water molecules in motion at higher temperature, when we place the pot on a stove which is burning, as shown in figure 10.1.

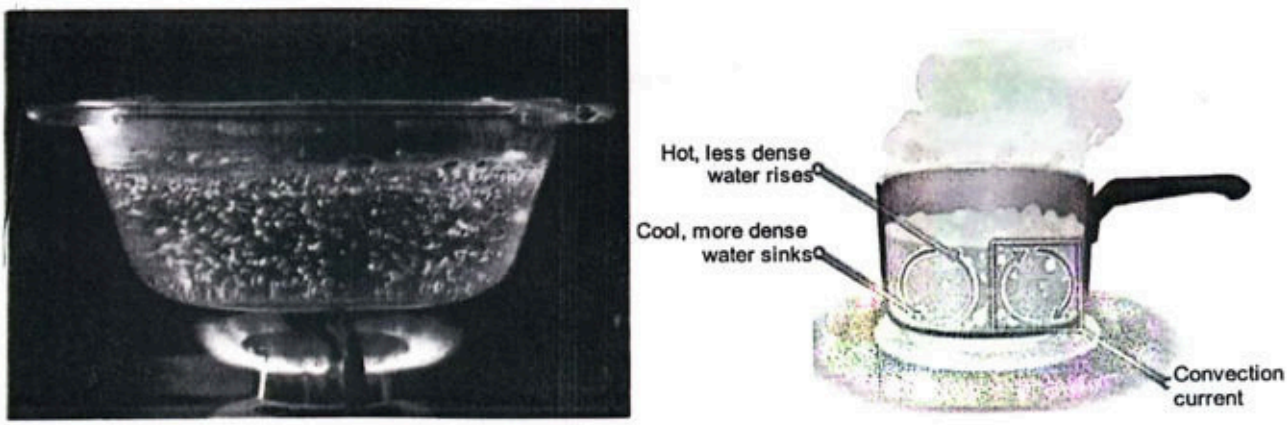

Fig. 10.1: Motion of molecules in hot water

This activity shows that there is a certain relationship between the motion of molecules of a material and its temperature.

When a material is heated, one of the two things happen, firstly the strength of attractive forces between the molecules decreases and bonds between the particles may break, secondly it can speed up the motion of the particles and hence increases the kinetic energy (K.E) of the particles. Heat and temperature are related concepts in physics but they refer to different properties. The temperature of a body can be defined as:

"The temperature of a substance is the measure of its hotness or coldness"

The temperature of a substance is directly proportional to the average kinetic energy (K.E) of its particles. Mathematically this relation can be given as:

$$T \propto \langle K.E \rangle$$

When we heat a substance the speed and hence the kinetic energy (K.E) of its particles (molecules) increases, that is why the temperature of the substance also increases. Conversely when we remove heat from a substance for example by placing water on ice or to keep it in refrigerator, the speed of the particle becomes slower and slower and the kinetic

energy (K.E) of the particles will decreases, therefore the temperature of the substance also decreases. With increase in temperature the increase in kinetic energy is shown in figure 10.2.

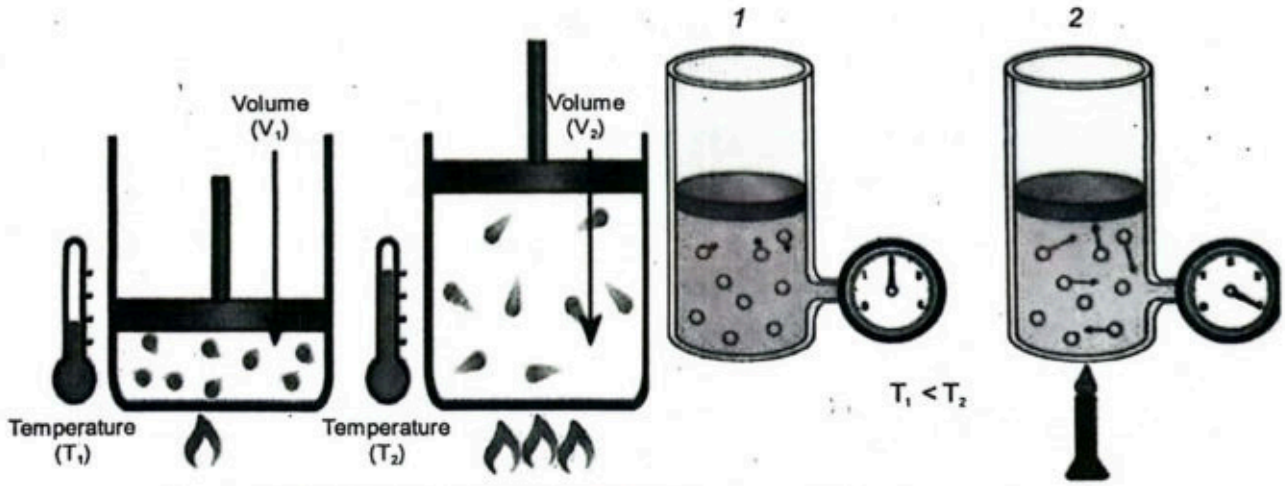

Fig. 10.2: Relation between temperature and K.E of molecules

Temperature can be measured in three units, kelvin (K), degree Celsius (°C) and Fahrenheit (°F), where kelvin is the SI unit of the temperature. These temperatures' units are related as:

The relation between kelvin (K) and degree Celsius (°C) is:

$$K = C + 273.16 \text{ --------- (10.1)}$$

The relation between degree Celsius (°C) and Fahrenheit (°F) is:

$$C = \frac{5}{9}(F - 32) \text{ --------- (10.2)}$$

The width of one unit of temperature scale is same for degree Celsius and kelvin scales while Fahrenheit scale has 1.8 units for each unit degree Celsius and kelvin scale.

Example 10.1 (Conversion in units of temperature) An average human body's temperature is 37°C. Convert it into degree Celsius and kelvin scale.

GIVEN

Temperature in degree celsius: $C = 37°C$

REQUIRED

Temperature in kelvin: $K = ?$

Temperature in Fahrenheit: $F = ?$

SOLUTION: To find the temperature in kelvin we use equation 10.1,

as: $K = C + 273.16$

Using values,

$$K = 37 + 273.16$$

$$K = 310.16$$

To find the temperature in Fahrenheit we use equation 10.2,

as:
$$C = \frac{5}{9}(F - 32)$$

Rearranging,

$$F = \frac{9}{5}C + 32$$

Using values,

$$F = \frac{9}{5}(37) + 32$$

$$F = 98.6\ ^{\circ}F$$

Assignment: 10.1: A body has temperature -12°F, convert this temperature into degree Calsius and kelvin scale.

Answer: -24.4°C, 248.7 K

Now we can define the heat as:

"Heat is the form of energy which produces sensation of warmth and flows when there is a temperature difference between the two bodies".

This is the energy which flows from hotter bodies to the colder bodies until both the bodies attain the same temperature. When both bodies gain the same temperature the flow of heat stops and the system is said to be in '*thermal equilibrium*'. Heat can be measured in the unit as joule (J) or calories (cal). The differences between heat and temperature are given in table 10.1.

Table 10.1: Difference between heat and temperature

Heat	Temperature
Heat is the form of energy it is called thermal energy.	Temperature is not energy it is the thermal state of a physical body or system. Temperature of a body indicates the average kinetic energy of all the molecules of the body.
Heat flow is a reason behind temperature change.	Temperature variation can be result of gain or loss of heat.
Two bodies having same temperature may not necessarily contain same quantity of heat.	Two bodies having same heat may not necessarily have same temperature.

Heat is exchangeable. It can flow from one body to another, so a particular body can release or gain certain amount of heat.	Temperature is not exchangeable. Only heat can be exchanged and the result of this exchange (heat transfer) can be the variation in temperature.
Total amount of heat present in a particular body cannot be measured. It can be measured only during flow or exchange. Thus only gain or loss of heat can be measured.	Temperature of a particular body can be measured. Moreover temperature does not flow like heat.
Amount of heat transferred between two bodies can be measured by calorimeter.	Temperature of a body can be measured by thermometer.
Unit of measurement of heat is joule (J) in SI system while it's commonly used unit is calories (cal).	Unit of measurement of temperature is degree centigrade (°C), Fahrenheit (°F) and kelvin (K).
Heat is not a fundamental property of matter.	Temperature is a fundamental property of the matter.

10.2 THERMAL EXPANSION

While boiling milk it is our common observation that milk expand in the pot and overflows due to this expansion if heat given to it is not removed, as shown in figure 10.3. This observation shows that liquids expand upon heating, but with more research on gasses and solids we come to know that all the three states of matter expand upon heating, hence this type of expansion is called the thermal expansion. Hence we can say that when the temperature acts on the body, it undergoes a change in length, width, height or volume of the material.

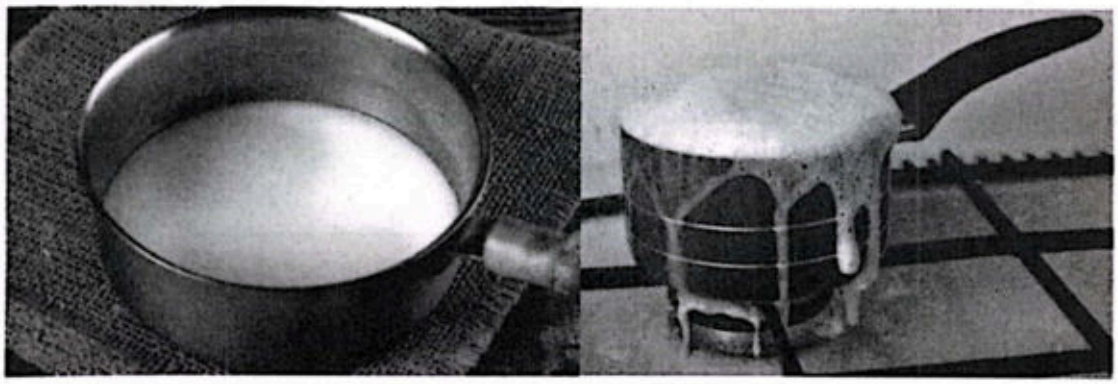

Fig. 10.3: Expansion of liquid upon heating

Since the atoms are tightly packed in solids, thermal expansion is seen evidently here. When a substance is heated it increases the kinetic energy of the molecules of the substance. Thermal expansion defines the tendency of an object to change its dimension either in length, area or volume, hence thermal expansion is of three types.

- **Linear expansion:** is the change in length due to heat, mathematically it can be given as:

$$\frac{\Delta L}{L_o} = \alpha_L \, \Delta T \text{ --------- (10.3)}$$

Here 'ΔL' is the change in length due to expansion, 'L_o' is the original length, 'ΔT' is the change in temperature and 'α_L' is the coefficient of linear expansion having units of K^{-1}. Linear expansion is shown in figure 10.4.

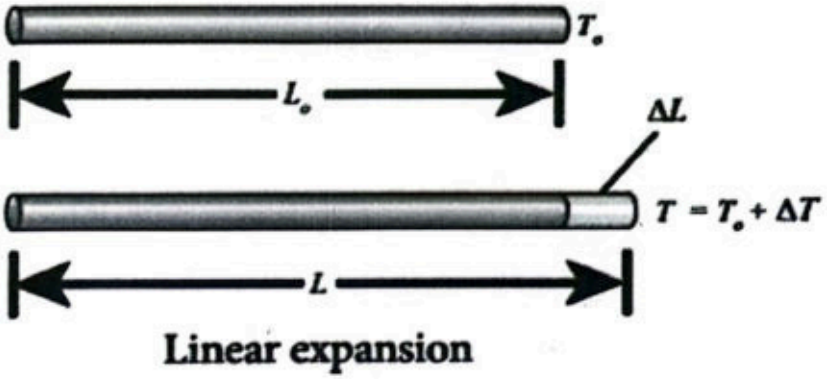

Fig. 10.4: Linear expansion

- **Area expansion:** is the change in area due to heat, mathematically it can be given as:

$$\frac{\Delta A}{A_o} = \alpha_A \, \Delta T \text{ --------- (10.4)}$$

Here 'ΔA' is the change in area due to expansion, 'A_o' is the original area, 'ΔT' is the change in temperature and 'α_A' is the coefficient of area expansion having units of K^{-1}. Area expansion is shown in figure 10.5.

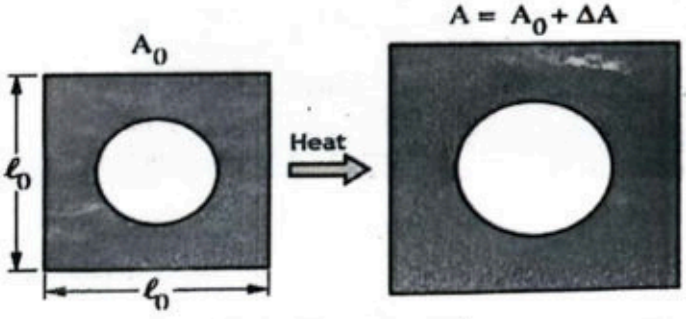

Fig. 10.5: Area expansion

- **Volume expansion:** is the change in volume due to Heat, mathematically it can be given as:

$$\frac{\Delta V}{V_o} = \alpha_V \, \Delta T \text{ --------- (10.5)}$$

Here 'ΔV' is the change in volume due to expansion, 'V_o' is the original volume, 'ΔT' is the change in temperature and 'α_V' is the coefficient of volume expansion having units of K^{-1}. Volume expansion is shown in figure 10.6.

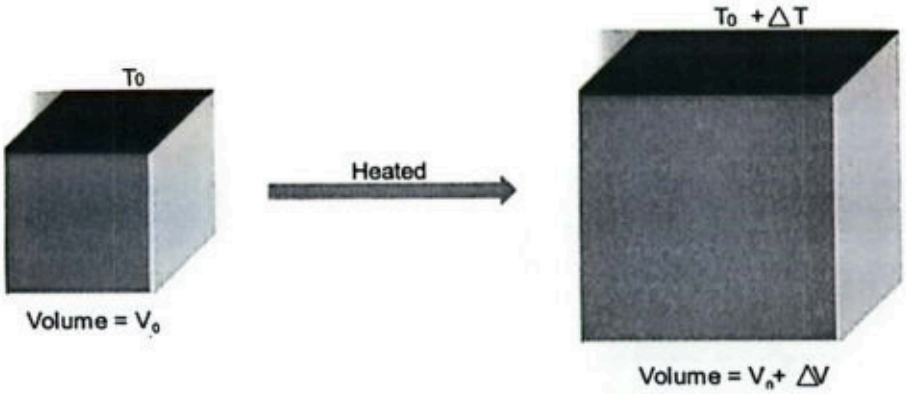

Fig. 10.6: Volume expansion

Example 10.2 (Linear expansion) A rod of length 5 m is heated to 40°C. If the length increases to 7 m after some time, find the expansion coefficient. Take room temperature as 20°C.

GIVEN

Initial length: $L_o = 5\ m$

Expanded length: $L = 7\ m$

Change in length: $\Delta L = L - L_o = 2\ m$

Temperature difference: $\Delta T = 40°C - 20°C = 20°C$

Absolute temperature: $\Delta T = 20°C + 273 = 293\ K$

REQUIRED

Temperature coefficient of linear expansion: $\alpha_L = ?$

SOLUTION: To find the temperature coefficient of linear expansion we use equation 10.3,

as:
$$\frac{\Delta L}{L_o} = \alpha_L\ \Delta T$$

Rearranging,

$$\alpha_L = \frac{\Delta L}{L_o \Delta T}$$

Using values,

$$\alpha_L = \frac{2\ m}{(5\ m)\ (293\ K)}$$

$$\alpha_L = 0.0014\ K^{-1}$$

Assignment: 10.2: A box with initial volume 4 m^3 is heated to 80°C. If its new volume is 4.5 m^3, find the coefficient of volume expansion if room temperature is 25°C.

Answer: 0.00038 K^{-1}

Daily life examples of thermal expansion:

Thermal expansion is the tendency of materials to change its length, area or volume in response to change in temperature. This phenomenon has various consequences in daily life like:

Steam Activity 10.1

To do an activity to study the thermal expansion in water.

You have to do the following tasks:

1. Take a graduated pot which is used to measure the volume of a liquid.
2. Fill the pot with water not to its full.
3. Note the value at the surface of water this shows the original volume 'V_o' of water at room temperature.
4. Note the room temperature with the help of thermometer 't_o'.
5. Now lit the burner under the pot to heat the water up to t=70°C.
6. You can note the temperature of water by dipping a thermometer in it.
7. Now take the reading of water level at this elevated temperature, this is your final value of volume 'V'.
8. Now by calculating the change in volume and change in temperature we will find all the terms.
9. Put all these values in equation 10.5 to find the coefficient of volume expansion of water.

- **Construction Material:** In buildings, bridges, dams etc. the construction material is used which can expand in the summer, so the structures are designed to accommodate thermal expansion. For example concrete, steel and other materials expand and contract with change in temperature. If construction is done without taking into account the thermal expansion, there may be cracks and even collapse of the structure may happened. The expansion in construction is shown in figure 10.7.

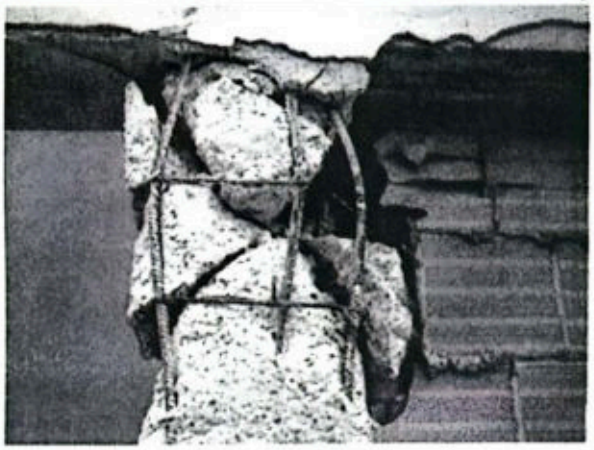

Fig. 10.7: Expansion in construction material

- **Railway tracks:** Are made up of iron. Iron also shows appreciable change in length corresponding to change in volume hence a gap is made between the railway tracks so

that after expansion they may not be bending. The expansion in railway track is shown in figure 10.8.

Fig. 10.8: Expansion in railway track

- **Pipelines:** Pipes which are used in very hot or very cold areas or transporting very hot liquids are made according to the requirements because they can significantly expand resulting burst or leakages in pipes. The expansion in pipelines is shown in figure 10.9.

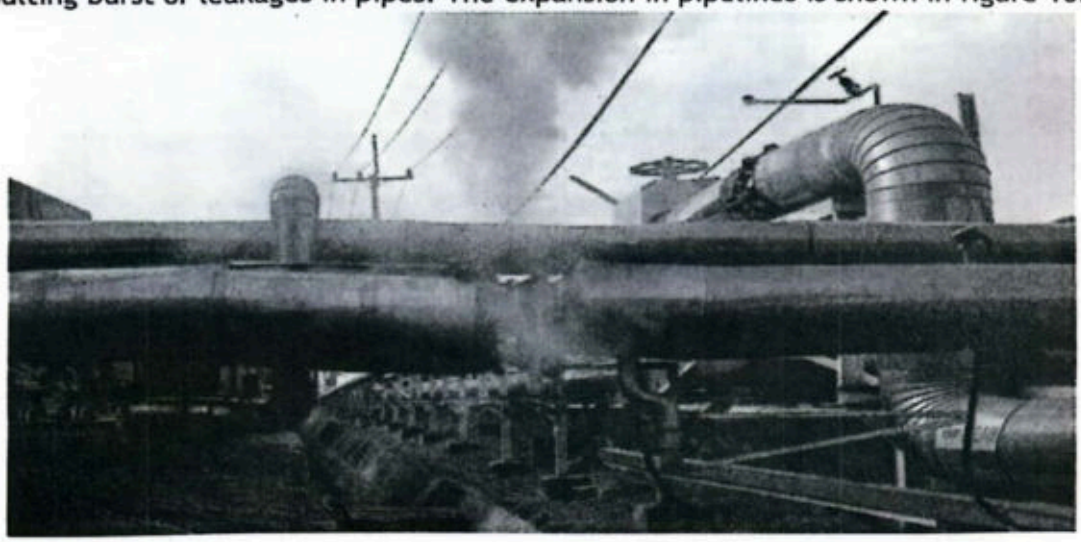

Fig. 10.9: Expansion in pipelines

- **Liquids:** Liquids also expand upon heating. This becomes important in functioning of thermometers and thermostats. Thermal expansions of liquids which have uniform expansion rate over a considerable temperature range are used in thermometers (devices used to measure temperature).

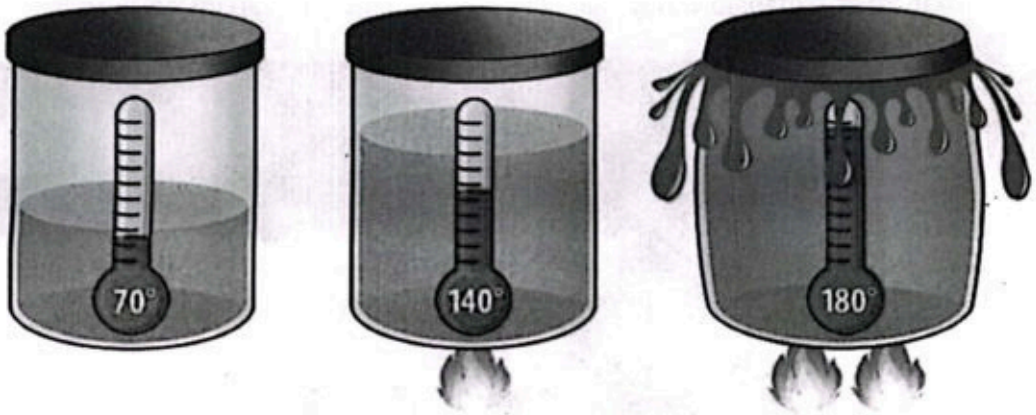

Fig.10.10: Expansion in liquids

- **Automobile's engines:** Metal parts in car engines like piston expand when the engine heats up during operation. This expansion is accounted for in the design of engine to ensure smooth operation of engine and to prevent damages due to expansions. The expansion in automobile's engine is shown in figure 10.11.

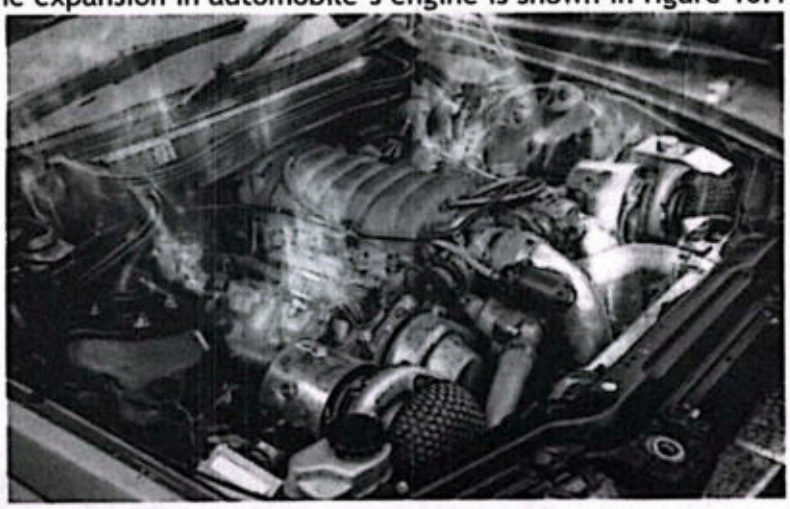

Fig. 10.11: Expansion in automobile's engine

- **Electronics:** Semiconductor materials used in electronics can also expand and contract in response to temperature change. To design the electronic components it is necessary to take into account this property of semiconductors to ensure reliability and prevent damages.

10.3 MELTING AND BOILING OF WATER

Water is one of the most important compounds we have in our life as well as in the world. Mostly we see water in liquid form but water exists in all three forms i.e. solid (ice), liquid and gas (vapours). With temperature variations phase changes in water take place. There are many terms related to phase changes in water but we will discuss only two i.e. melting point and boiling point.

Melting Point of Water:

- The melting point of water is the temperature at which water transforms from solid (ice) into liquid (water).
- The melting point of water is 0°C, 32°F or 273 K, below this temperature water converts into solid ice (this process is called freezing) in which molecules of water arrange themselves in a crystalline lattice structure and above this temperature water exists in liquid state.

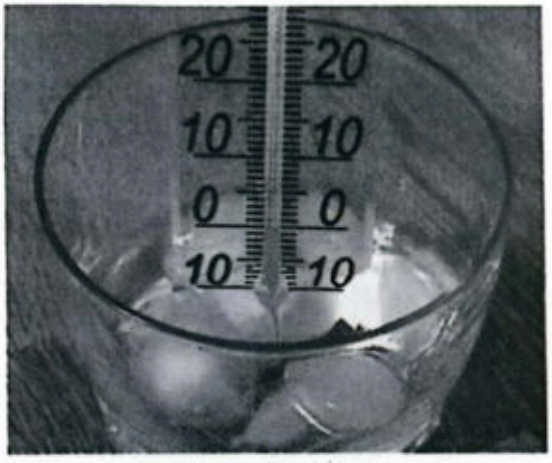

Fig. 10.12: Melting temperature of water

- It is to note that when the solid ice is melting the temperature of the system does not increases even you give more heat to the system as shown in figure 10.12. It would remain 0°C until all the solid ice melts. As the more heat is utilizes in breaking the bonds between the molecules to convert ice structure into liquid structure.
- When the temperature rises above the melting point the kinetic energy (K.E) of the water molecules increases and this energy becomes sufficient to overcome the intermolecular forces holding the molecules in the solid state causing the ice to melt and change its phase into liquid water as shown in figure 10.13.


Fig.10.13: Melting of ice

- As it is stated earlier that below melting point is solid ice and above melting point is the liquid water. Hence at melting point water can co-exists in both forms i.e. solid ice and liquid water. Infect at melting point there is dynamic equilibrium between the

two states means the number of molecules changing into liquid phase becomes equal to the number of molecules changing into solid phase. Rate of both the transitions becomes equal at equilibrium.

The melting and boiling points of water are shown in figure 10.14.

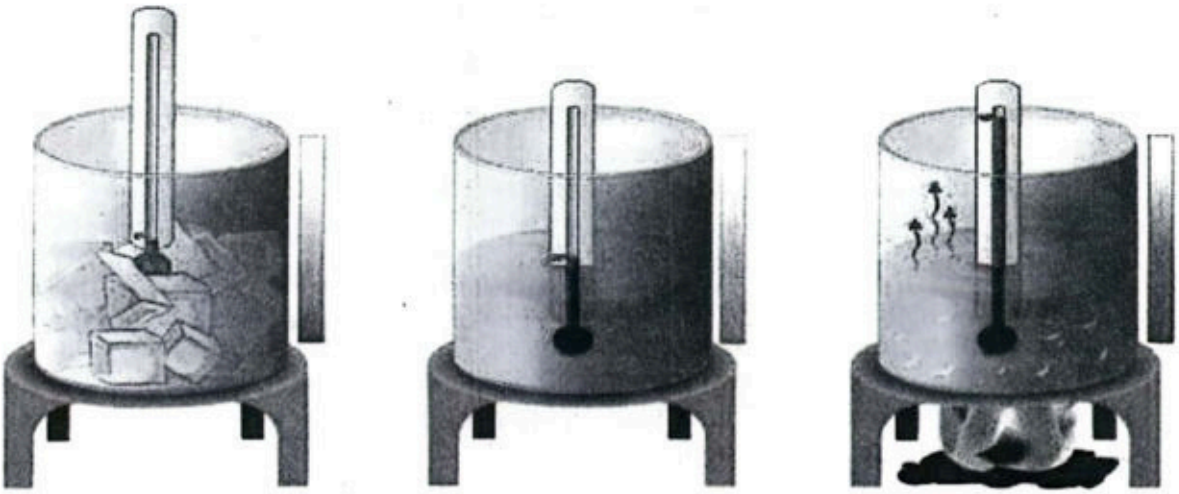

Fig. 10.14: Melting and boiling points of water

Boiling Point of Water:

- The boiling point of water is the temperature at which water transforms from liquid water into gaseous phase i.e. the water vapours.
- The boiling point of water is 100°C, 212°F or 373 K, above this temperature water converts into steam (gaseous form of water which contains water vapours) and below this temperature water exists in liquid state as shown in figure 10.15.

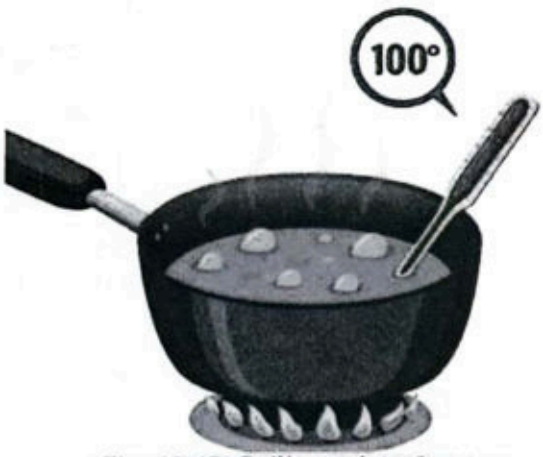

Fig. 10.15: Boiling point of water

- It is to note that when the liquid water is boiling the temperature of the system does not increases even you give more heat to the system. It would remain 100°C until all the liquid boils. As the more heat is utilized in breaking the bonds between the molecules to convert liquid structure which have stronger intermolecular attractions into a gaseous phase with negligible intermolecular attractions.
- When the temperature reaches the boiling point the kinetic energy (K.E) of the water molecules increases and this energy becomes sufficient to overcome the

intermolecular forces holding the molecules in the liquid state causing the liquid to evaporate and change its phase into gas (steam), by escaping the molecules from the surface of liquid water as shown in figure 10.16.

- At the boiling point the vapour pressure of the water becomes equal to the atmospheric pressure.
- As the boiling point is influenced by the atmospheric pressure, hence the boiling point of water can be altered with the atmospheric pressure. For example at higher altitudes where atmospheric pressure is low the boiling point of water is lower than 100°C, in contrary at high pressures like in cooker pressure the boiling point of water elevated at temperatures greater than 100°C. Boiling point of water at different altitudes is shown in figure 10.17.

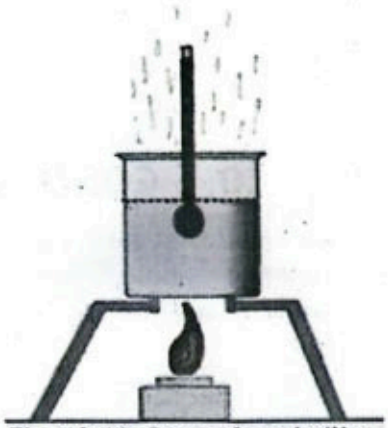

Fig. 10.16: Steam from boiling water

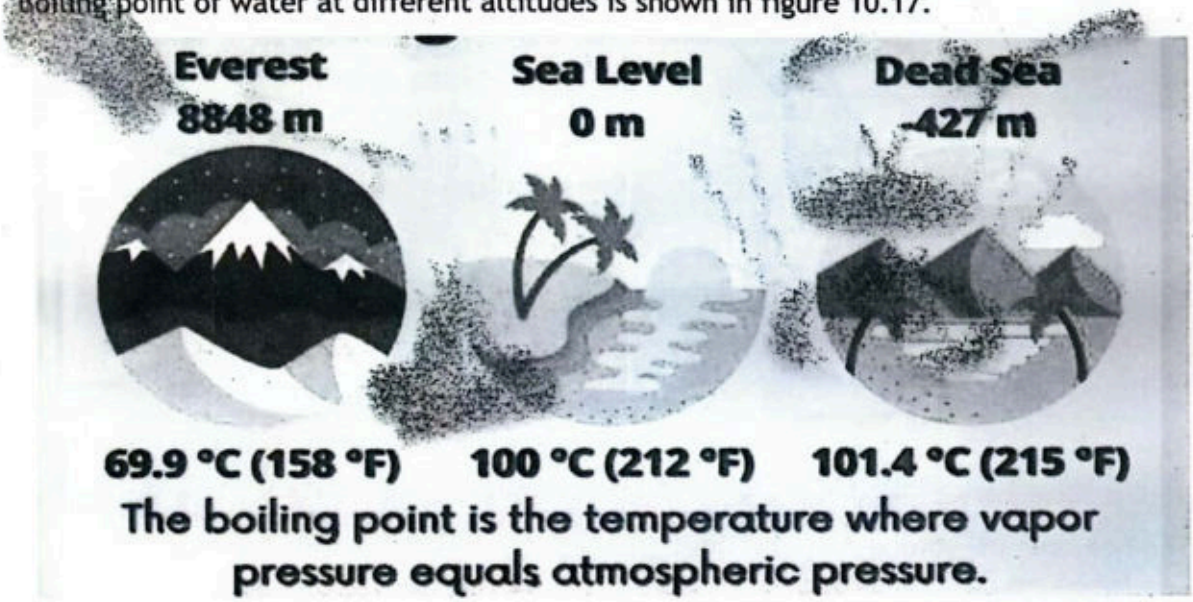

Fig. 10.17: Boiling point of water at different altitudes

Melting and boiling points of some common substances are given in the table 10.2.

Table 10.2: Melting and boiling points of some common substances

Material	Melting point (°C)	Boiling Point (°C)
Water	0	100
Oxygen	-219	-183
Nitrogen	-209.86	-195.8
Table salt	801	1465
copper	1083	2500

Iron	1200	2500
Gold	1063	2700

10.4 CONDUCTION, CONVECTION AND RADIATION

As we know that heat can be transfer from hotter bodies towards colder bodies but we are still unknown about the method of flow of heat. How heat flows from one object to another? To know about the modes of transfer of heat we would do an activity as shown in figure 10.18.

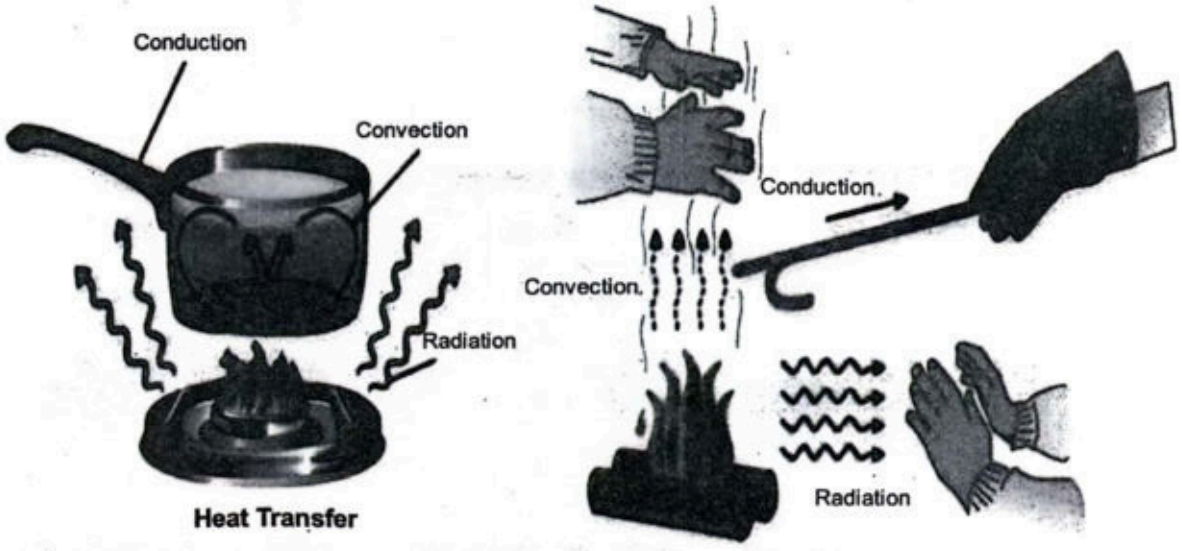

Fig. 10.18: Conduction, convection and radiation

The heat can be observed by the three methods by directly putting hands in hot liquid or gas i.e. by convection or through a medium like iron rod i.e. by conduction and the third one without making any physical contact with hot body i.e. by radiation. All the three methods of transferring the heat are given in details below.

Conduction

As in above diagram we see that the heat is transferred through metallic stick, the mode of heat transfer through a substance without the substance itself moving is called conduction. It happens within a stationary object or between two stationary objects that are in contact with each other.

'The transfer of heat by physical collision of particles of a system, occurs mainly in solids'

This process mainly occurs in solids as the molecules of the solids are closely packed hence they respond quickly by the collisions among them, because heat is conducted from the hotter region to the cooler region through molecular collisions. The process of conduction is shown in figure 10.19.

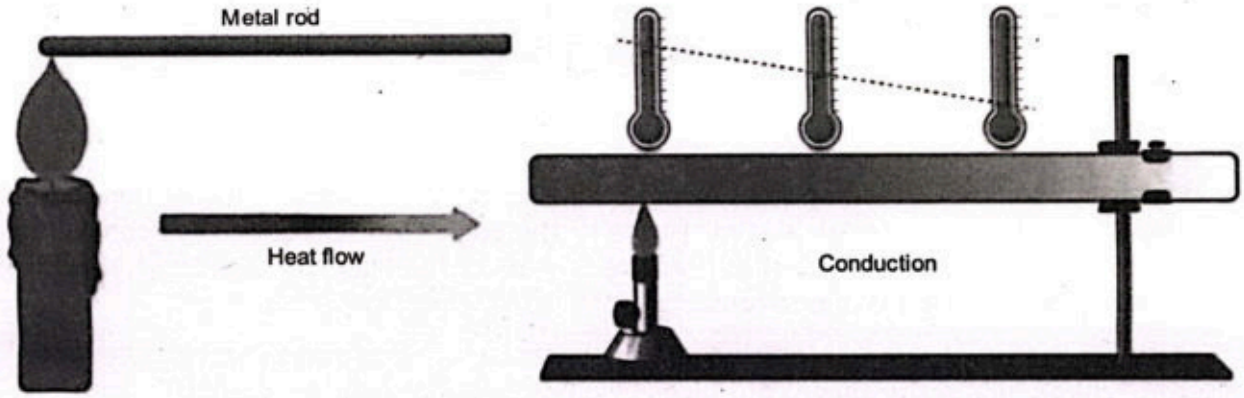

Fig. 10.19: Process of conduction

The rate of heat conduction depends on the material's thermal conductivity, cross-sectional area and the temperature difference between the two regions. Metals are good conductor of heat because they have free electrons moving within the body of metal while insulators like wood and plastic are poor conductors of heat.

Convection

The transfer of heat due to movement of liquids or gases is one other process used. It occurs when warmer regions of a fluid (a material which can flow like liquids and gases) become less dense and rise while cooler regions become denser and sink, this phenomenon creates a circular motion known as convection current. The convection currents in liquid and in gas (air) are shown in figure 10.20.

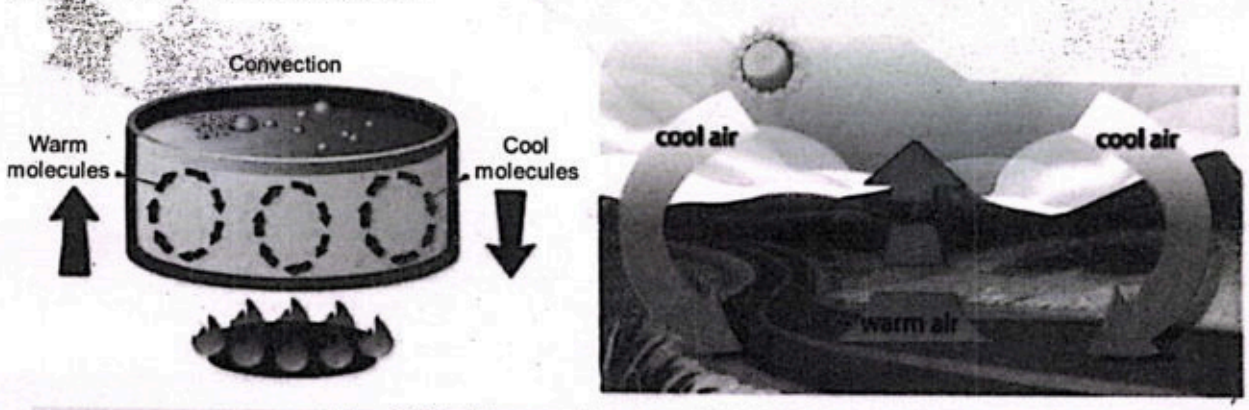

Fig. 10.20: Process of convection in liquid and gas

The process of convection plays a vital role in regulating the temperatures of our atmosphere by moving warm air above and cold air to low levels.

'The transfer of heat from one place to another due to the movement of the fluids is called convection'

Do You Know?

A hot body is kept in vacuum, after some time what change will occur in its temperature.

Convection can occur naturally as in the case of air currents in the atmosphere or water currents in the oceans or it can be forced like in the case of convection ovens or heating systems.

Radiation

The heat from the Sun is reaching to us even we have no physical contact with the sun like no solid, liquid or gaseous material is joining us with the Sun which is required for conduction and convection. Then how heat reaches from the Sun to us? The heat from the Sun is reaching on the surface of the Earth is due to radiations.

'The transfer of heat due to electromagnetic waves, which can move through both the medium and the space, produces by a hot body are called radiations'

Unlike conduction and convection, radiations require no medium to propagate, this phenomenon can occur in the space. All the bodies in the universe with temperature above 0 K (kelvin) emit radiations which depends upon the temperature of the body emitting radiation. Similarly objects absorb radiations, which depend upon the nature of surface and the colour of the surface. Common examples of this type of transfer of heat are the heat coming from the Sun and the heat from fire.

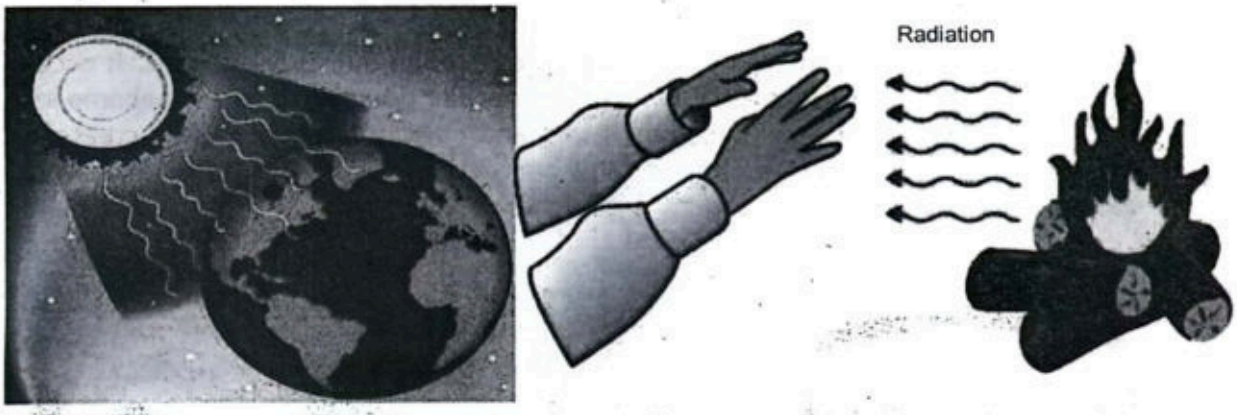

Fig. 10.21: Process of radiation

Table 10.3: Difference between conduction, convection and radiation

Conduction	Convection	Radiation
In this mode, heat transfer takes place due to difference of temperature	In this mode, heat transfer takes place due to difference of density	In this mode, heat transfer takes place due to temperature
Medium is necessary	Medium is required	Medium is not required
Heat transfer takes place from higher to lower temperature	Heat transfer from denser to rarer medium	Heat transfer takes place from higher to lower temperature

It takes place in solids	It take place in fluids	It take place in vacuum and in all substances
It is a slower process	It is a slow process	Heat transfer take place at faster rate
Constituent particle do not change their position	Constituent particles change their position	Particle of medium are not required at all
Path of heat transfer is irregular	Path of heat transfer is irregular	Path of heat transfer is linear

Materials are divided in to two types depending upon their response to the flow of heat i.e. heat conductors and heat insulators. Those materials which conduct heat are called heat conductors or thermal conductors for example metals like aluminium, iron, copper etc. are thermal conductors. On the other hand materials which do not allow heat to pass through them are called heat insulators or thermal insulators like rubber, plastic and wood. Thermal conductors are bonded by metallic bonds with plenty of free electrons while thermal insulators have strong covalent bonds. Materials which are good conductors of electric current are usually good conductor of heat too similarly those materials which are insulator to the electric current are also insulator of heat.

Table 10.4: Thermal conductors and insulators

Thermal conductors	Thermal insulators
Aluminum	Wood
Diamond	Concrete
Germanium	Asbestos
Silver	Glass wool
Gold	Graphite
Copper	Fiber
Tungsten	Thermoplastic

SUMMARY

1. Temperature of a substance is the degree of its hotness or coldness.
2. Temperature can be measured in three scales like kelvin, degree Celsius and degree Fahrenheit.
3. Temperature of a substance depends upon the average kinetic energy of the molecules of the substance.
4. Heat is the form of energy which can flow if the temperature of the two interacting bodies is different.
5. On heating substances use to expand while on cooling substances use to contract.
6. By heating the length of a substance can be increased such expansion is called linear expansion it is a type of one dimensional expansion.
7. By heating the area of a substance can be increased such expansion is called area expansion it is a type of two dimensional expansion.
8. By heating the volume of a substance can be increased such expansion is called volume expansion it is a type of three dimensional expansion.
9. In construction it is to take into account the expansions of the material, for this purposes we have to make voids in joints etc.
10. In railway tracks there should be some gaps between the iron made rails to accommodate linear expansion.
11. Pipelines are made to accomplish the liquid expansion through them.
12. Melting point of the water is the temperature at which water transforms from solid ice into liquid water.
13. Boiling point of the water is the temperature at which water transforms from liquid phase into gaseous phase (water vapours).
14. The transfer of heat by the collision of the molecules of a substance in solids is called conduction.
15. The transfer of heat from one place to another due to the movement of fluids is called convection.
16. The transfer of heat due to electromagnetic waves which move at very high speed through both medium and space are called thermal radiation.
17. Materials which can easily pass heat through them are called thermal conductors.
18. Materials which cannot pass heat through them are called thermal insulators.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

1. Heat is a form of:

   A) velocity
   B) mass
   C) force
   D) energy

2. The temperature of 15°C is equal to:

   A) $15^{\circ} F$
   B) $51^{\circ} F$
   C) $59^{\circ} F$
   D) $100^{\circ} F$

3. The Fahrenheit scale has _____ divisions between the freezing and boiling point of water:

   A) 32
   B) 100
   C) 180
   D) 212

4. Which of the following is not a unit of temperature?

   A) kelvin
   B) degree Fahrenheit
   C) degree Celsius
   D) calorie

5. The two dimensional thermal expansion in a material is called:

   A) linear expansion
   B) translational expansion
   C) area expansion
   D) volume expansion

6. Which material shows least expansion for a given increase in temperature?

   A) solid
   B) liquid
   C) gas
   D) air

7. The melting point of water is as that of:

   A) boiling point
   B) freezing point
   C) condensation
   D) sublimation

8. Melting point of oxygen is:

   A) -200
   B) -219
   C) -112
   D) -77

9. The fastest way of transferring heat is the process of:

   A) radiation
   B) evaporation
   C) condensation
   D) convection

10. Which of the following is the thermal insulator?

   A) gold
   B) tungsten
   C) germanium
   D) asbestos

Section II: Short Response Questions

1. Define heat? *Also give its unit.*
2. Describe a process in which heat is transferring but temperature remains constant.
3. Sound waves are produced due to vibrations of air molecules. Can sound waves produce heat?
4. When you sit by a campfire how does its hot air heats you? Explain.
5. What makes heat rise? Elaborate.
6. Do we feel the heat or the temperature? Explain.
7. Can human emit heat? If yes, what would be the process of emitting heat?
8. Why are cloudy nights generally warmer than clear nights? Explain.
9. Earth's core is a very hot place. What may be the process through which the inner heat comes out of the Earth?
10. On a cold winter morning, why does the metal of bike feels colder than the wooden handle of the door?
11. Why you use sealing in the house? Give your answer in terms of heat and temperature.

Section III: Extensive Response Questions

1. Compare the terms heat and the temperatures by explaining the similarities and differences between them.
2. Describe the inter conversion of different units of temperature.
3. What is thermal expansion? Also discuss its types like linear, area and volume expansion.
4. Can you give some daily life examples of thermal expansions?
5. What is melting point of the water? Also give its daily life examples.
6. How boiling point of the water has its applications in our daily life?
7. Heat can be transferred through the solids by conduction. Elaborate the statement.
8. Explain convection with examples.
9. Why transfer of heat through radiation does not require medium? Explain.
10. Differentiate between conducting and non-conducting substances.

Section IV: Numerical Response Questions

1. The temperature in the core of Earth is 5430°C. Convert it into kelvin and Fahrenheit scale. **(Answer: 5700 K, 9800 °F)**

Glossary

Acidification of water bodies: Process whereby bodies of water become more acidic due to the absorption of pollutants such as sulfur dioxide and nitrogen oxides from industrial and transportation sources.

Advantages of frictional force are many like we can walk on Earth due to friction.

Advantages of renewable sources of energy over non-renewable energy sources are due to their continuous supply and they are friendly to our environment.

Allotropic forms of carbon are three i.e. diamond, graphite and Bucky ball.

Altitude: is the distance above sea level, measured vertically. It affects various environmental factors such as temperature, atmospheric pressure, and oxygen levels.

Amorphous solid are the materials, whose constituent particles are arranged in a random manner without any order.

Analog stopwatch is a device which can measure the time between any two events with the help of rotating needles in fix duration.

Anion is a negatively charged ion formed when an atom gains electrons.

Area expansion is the process in which by heating the area of a substance can be increased it is a type of two dimensional expansion.

Atmospheric pressure is the force exerted by the weight of air molecules in the Earth's atmosphere.

Atom is the basic unit of a chemical element, consisting of a nucleus composed of protons and neutrons, surrounded by electrons in orbitals.

Atomic mass is also known as atomic weight, is the average mass of atoms of an element.

Atomic number of an element is the number of protons in the nucleus of its atoms. It determines an element's identity and its placement in the periodic table.

Atomic theory is a scientific theory that describes the nature of matter as composed of discrete units called atoms.

Base quantities are the seven quantities which are chosen randomly, all other quantities are derived from these base quantities.

Base units are seven units which are the units of seven base quantities all other units are derived from these base units.

Biodiversity: is the variety and variability of life on Earth.

Boiling point of a liquid is the temperature at which a liquid's vapour pressure becomes equal to the atmospheric pressure surrounding it.

Boiling point of the water is the temperature at which water transforms from liquid phase into gaseous phase (water vapours).

Bond is a force that holds atoms together in molecules or compounds.

Bucky ball is the allotropic form of carbon in which carbon atoms are joined together in a ball like structure.

Burning of fossil fuels Combustion of organic materials like coal, oil, and natural gas, releasing carbon dioxide and other pollutants into the atmosphere.

Camilo Golgi: Italian scientist who discovered Golgi apparatus Camilo in 1898.

Cardiac muscle: A kind of involuntary muscle that is found in heart.

Cathode rays: Streams of electrons observed in vacuum tube.

Cations: Positively charged ions formed by the loss of electrons from neutral atoms.

Cell membrane: The cell part that surrounds the cytoplasm and holds the cell together.

Cell wall: It is an outer protective membrane in many cells including plants, fungi, algae, and bacteria, its main functions are to provide structure, support, and protection for the cell.

Cell: It is the structural and functional unit of living things.

Centriole: Paired barrel-shaped organelles located in the cytoplasm of animal cells near the nuclear envelope. They help determine the locations of the nucleus and other organelles within the cell.

Chemical bonding: The attractive force that holds atoms together in compounds, forming molecules or ionic structures.

Chloroplast: is an organelle within the cells of plants and certain algae that is the site of photosynthesis,

Chromoplasts: Are colored plastids. They are ellipsoid, round, or needle-shaped structures. Their function is to give color to certain parts of plants such as flower petals, fruits, some roots, etc. so that insects are attracted for pollination.

Chromosomes: Are threadlike structures made of protein and a single molecule of DNA, located in the nucleus of cells.

Classification: *It involves putting things into a class or group according to particular characteristics* so it's easier to know about them.

Coal is the debris of dead plants underground which is a solid fossil fuel and produces large amount of pollution on burning.

Compressibility is the property of a gas which determines how much it can be compressed under a certain temperature, pressure and volume.

Concentrating sunlight: The process of focusing sunlight using mirrors or lenses to generate heat or produce electricity.

Condensation is the process in which a gas converts into a liquid phase.

Conduction is the process in which the transfer of heat occurs by the collision of the molecules of a substance in solids.

Conduction: The transfer of heat or electricity through a substance or material.

Connective tissue: Connect and support the body's various tissues and organs; include soft connective tissues as well as specialized forms such as cartilage, bone, adipose tissue, and blood. Cells in all connective tissues, excluding blood, secrete collagen or elastin fibers.

Conservation of biodiversity: is the protection and management of biodiversity.

Convection is the process in which the transfer of heat from one place to another is done due to the movement of fluids.

Covalent bond: A type of chemical bond where atoms share pairs of electrons to achieve stability.

Crystalline solids are those solids which have a regular and three dimensional arrangements of constituent particles.

Cytoplasm: It is the gelatinous liquid that fills the inside of a cell; is responsible for holding the components of the cell and protects them from damage; stores the molecules required for cellular processes.

Cytoskeleton: Is a structure that helps cells maintain their shape and internal organization, and it also provides mechanical support.

Density of a substance is the mass per unit volume.

Depletion of ozone layer: Reduction in the concentration of ozone molecules primarily caused by human-made chemicals like chlorofluorocarbons (CFCs).

Derived quantities are derived from the base quantities by adding, multiplying or dividing them.

Derived units which are derived from the base units by adding, multiplying or dividing the same or different base quantities.

Diamond is the crystalline allotropic form of carbon.

Diffusion of gases is the property in which due to random movement gas molecules transfer from high concentration region to low concentration region.

Digital stopwatch is a device which can measure the time between any two events digitally with perfect accuracy.

Dipole-dipole forces exist between the polar molecules.

Dipole-induced dipole forces exist between polar and non-polar molecules.

Disadvantages of frictional force are many like the wear and tear of machinery parts.

Duplet: A pair of electrons in the outermost shell of an atom, typically found in hydrogen and helium.

Earth science: includes all fields of natural science related to the planet Earth.

Efficiency of a machine is the ratio of output power to the input power.

Effusion is the process in which due to pressure difference the escape of gas molecules from tiny hole takes place.

Electromagnetic force is the force which binds the atoms and molecules which is due to attraction and repulsion between electric charges.

Electron microscope: Is a microscope that uses a beam of electrons as a source of illumination; used for obtaining high resolution images of biological and non-biological specimens.

Electron: A subatomic particle with a negative charge. Electronegativity: The measure of an atom's ability to attract electrons in a chemical bond.

Element: A pure substance composed of atoms which cannot be further divided.

Emissions: Release of pollutants or substances into the environment, often from industrial processes, vehicles, or natural sources.

Endoplasmic reticulum: a continuous membrane system that forms a series of flattened sacs within the cytoplasm of eukaryotic; is important in the synthesis, folding, modification, and transport of proteins.

Energy level: The specific energy state of an electron within an atom.

Energy resources are mainly of two types, i.e. renewable energy resources and non-renewable energy resources.

Energy resources: Natural sources such as fossil fuels, sunlight, wind, and water used to produce energy.

Epidermal tissue: Is the outer layer of cells covering an organism, in particular, the skin of an animal, overlying the dermis and the outer layer of tissue in a plant; protect the underlying cells.

Evaporation is the property of liquids in which a liquid turns into a gas or vapour state at temperature below the boiling point of the liquid.

Five kingdom classification: It was proposed by Whittaker. The five kingdoms are- *Monera, Protista, Fungi, Plantae and Animalia*.

Fluid is a substance which can flow.

Formal sciences: use formal systems to produce knowledge. It explores the nature of different disciplines.

Freezing point is the temperature, at which a liquid becomes a solid at normal atmospheric pressure.

Friction is the force that resists the motion when the surface of one object comes in contact with the surface of the other.

Fundamental forces In nature are only four all other macroscopic forces are due to these four forces.

Gaps between the iron made rails in railway tracks are there to accommodate linear expansion.

Gases are those substances which have neither fix shape nor fix volume.

Glazing: The process of applying a transparent or translucent coating to surfaces, often used in windows.

Golgi apparatus: also known as the Golgi complex, Golgi body, or simply the Golgi, is an organelle found in most eukaryotic cells; packages proteins into membrane-bound vesicles inside the cell before the vesicles are sent to their destination.

Graphite is the amorphous allotropic form of carbon.

Gravitational field is the region of space around any massive object where it can apply a force of attraction on a unit mass within this region.

Gravitational field strength is a vector with magnitude 'g' pointing in the direction of gravitational force i.e. towards the centre of the Earth.

Gravitational force is the force which holds us on the Earth, planets, stars and galaxies it is due to point masses or due to curvature of space and time.

Gravitational force is the force with which the Earth attracts everybody towards its centre.

Greener skill: practices focused on environmental sustainability and reducing ecological footprint.

Greenhouse effect: The trapping of heat in the Earth's atmosphere due to the presence of greenhouse gases like carbon dioxide and methane, leading to global warming.

Greening Education: Incorporating environmental education practices into academic curricula.

Groups: Columns in the periodic table representing elements with similar chemical properties due to the same number of electrons in their outermost shell.

Hazardous effects: Adverse impacts or risks posed by substances, activities, or phenomena on human health.

Heat is the form of energy which can flow if the temperature of the two interacting bodies is different.

Hydro-electric energy is a renewable source of energy in which we use the potential energy of water to produce electric energy.

Hydrogen bonding is the strongest intermolecular forces which exist between hydrogen and one of oxygen, nitrogen or fluorine.

Hydropower: Electricity generated by flowing or falling water, typically through dams or turbines in rivers or reservoirs.

Intermolecular forces are the forces of attraction between the molecules of a substance.

Ion dipole forces exist between molecules and the free ions.

Ionic bond: A type of chemical bond formed between ions with opposite charges, typically between a metal and a non-metal.

Kinetic energy and temperature are related as the temperature of a substance depends upon the average kinetic energy of the molecules of the substance.

Landfill: Area for the disposal of waste materials, typically buried underground or piled up in layers.

Less efficiency means that efficiency of any real machine can never be 100% due to losses.

Leucoplast: Are a type of plastids that are composed of colorless organelles; the basic function is the storage of essential compounds such as starch, lipids, and proteins.

Life science: is the study of life and living organisms.

Light microscope: It is used to visualize objects flattened onto glass slides in great detail. It typically has a magnification power of up to 1000x; might be used when examining individual cells within living tissue.

Linear expansion is the process in which by heating the length of a substance can be increased it is a type of one dimensional expansion.

Liquids are those substances which have fix volume but not fix shape.

London dispersion forces are weak forces which exist between non-polar molecules.

Lysosomes: are membrane-enclosed organelles that contain enzymes capable of breaking down proteins, nucleic acids, carbohydrates, and lipids.

Measurement is to assess the magnitude of a physical quantity by means of some instrument and by comparing it with some reference.

Measuring tape is a length measuring instrument which can measure as small value as 1mm. it can measure up to several meters.

Melting point of a solid is the temperature, at which the solid turns into liquid state at atmospheric pressure.

Melting point of the water is the temperature at which water transforms from solid ice into liquid water.

Meter rule is a length measuring instrument which can measure up to 1 meter and minimum value of 1 mm.

Methods to reduce friction are the ways by using them we can reduce friction between two contact surfaces like polishing the surfaces, using ball bearings and by applying lubricants.

Mitochondria: Are membrane-bound cell organelles (mitochondrion, singular) that generate most of the chemical energy needed to power the cell's biochemical reactions.

Molecule: A group of atoms bonded together, representing the smallest fundamental unit of a chemical compound.

Muscular tissue: Is a specialized tissue in animals which applies forces to different parts of the body by contraction; made up of thin and elongated cells called muscle fibers; controls the movement of an organism; cytoplasm in the muscle fibers is called sarcoplasm.

Natural gas is the gaseous fossil fuel which is used in cooking and industries.

Natural Science: is the study the nature of our physical world and the universe.

Nervous tissue: It is found in the brain, spinal cord, and nerves. It is responsible for coordinating and controlling many body activities. It stimulates muscle contraction, creates an awareness of the environment, and plays a major role in emotions, memory, and reasoning.

Neutron: A subatomic particle found within the nucleus of an atom, with no net electric charge.

Noble gas: A group of chemical elements with complete electron shells, making them chemically inert and stable.

Non-contact force is a force which does not require any physical contact between the objects for its application.

Non-physical quantities are those quantities which cannot be measured.

Non-renewable energy resources are those which cannot be re used if once utilized.

Non-renewable energy sources: Energy sources derived from finite resources such as fossil fuels (coal, oil, natural gas) and nuclear fuels.

Nuclear energy: Energy released during nuclear reactions.

Nuclear fuel is an example of non-renewable source of energy.

Nucleolus: It is a spherical structure found in the cell's nucleus whose primary function is to produce and assemble the cell's ribosomes.

Nucleus: It is a small, round and membrane-bound structure found in cells. The fluid inside the nucleus surrounded by the nuclear membrane is called nucleoplasm. It controls cell's growth and reproduction as it contains cell's hereditary information. It's covered by dual layer called a nuclear membrane.

Nucleus: The central part of an atom, containing protons and neutrons, and possessing most of the atom's mass.

Octet: The stable arrangement of eight valence electrons in the outer shell of an atom, fulfilling the octet rule.

Orbit: The path followed by an electron around the nucleus of an atom.

Organelles: An organelle is a subcellular structure that has one or more specific functions to perform in the cell, much like an organ does in the body. Among the more important cell organelles are the nuclei, which store genetic information; mitochondria, which produce chemical energy; and ribosomes, which assemble proteins.

Ozone: A molecule consisting of three oxygen atoms bonded together, forming a protective layer in the Earth's atmosphere.

Periodic table: Arrangement of chemical elements based on their atomic number.

Periods: Horizontal rows in the periodic table, indicating the number of electron shells an atom of an element possesses.

Petroleum oil is the liquid fossil fuel which is used in transportation and in industries.

Physical quantities are those quantities which can be measured.

Physical science: is the study of the universe.

Pipelines are made to accomplish the liquid expansion through them.

Plastids: Are double-membrane organelles which are found in the cells of plants and algae.

Point absorber is the device use to convert the kinetic energy of waves into electric energy.

Precision is the closeness of the estimated value to the actual value in any measurement.

Proton: A subatomic particle found within the nucleus of an atom, with a positive electric charge.

Radiation is the transfer of heat due to electromagnetic waves which move at very high speed through both medium and space.

Radiation: The emission and propagation of energy in the form of electromagnetic waves or particles.

Reflector: A surface or object that reflects light, sound, heat, or other energy.

Renewable energy resources are those resources which are cycled by the nature and can be used again and again.

Renewable energy sources: Energy sources derived from replenish able resources such as sunlight, wind, water, and biomass.

Ribosomes: Is an intercellular structure made of both RNA and protein, and it is the site of protein synthesis in the cell.

Robert Hooke: He invented of the compound microscope, the wheel barometer and the hydrometer. In 1665 he observed that the cork was made of tiny empty spaces with walls , named them as 'cells'.

Rolling friction has very small value than the sliding friction.

Round off is the process in which if the result of any measurement is quite large we round off the result up to the significant figure.

Salter's duck is the device use to convert the kinetic energy of waves into electric energy.

Science: It means knowledge or learning.

Scientific collaboration: When two or more scientists work together to achieve a common goal.

Shell: A group of atomic orbitals representing the energy levels where electrons are found.

Significant figures are the figures which include accurately known digits and the first doubtful digit in any measurement.

Smog: A type of air pollution resulting from the interaction of pollutants with sunlight.

Smooth muscle: It is an involuntary, non-striated muscle; consists of thick and thin filaments. On microscopic examination, it will appear homogenous. ; is present throughout the body; It is in the stomach, intestines, urinary system.

Social sciences: study human societies from across the globe as well as the relationship of human beings with their social environment.

Solar energy is a renewable source of energy in which we use the sunlight into electricity which is a safe source of producing electricity.

Solar Oven: A device that uses sunlight as a source of energy to cook food or heat substances.

Solids are those substances which have fix volume and fix shape.

Specular reflection: The type of reflection where light rays are reflected in a single direction, producing a clear image.

Sterilization: The process of killing or removing all forms of microbial life, including bacteria, viruses, and fungi.

Stopwatch is a time measuring device.

Striated muscle: Are muscles in our bodies that have a striped appearance. This striped appearance is due to these muscles' light and dark bands which appear in an alternate fashion; are voluntary in nature; they help the body in balance, posture and movement.

Strong nuclear force is the force which binds the nucleus.

Sublimation is the process of the transformation, in which a solid substance transforms into vapours directly without melting first.

Subshell: is field of a shell where electros pass.

Sustainable: Capable of being maintained or continued over the long term.

System international is the system of units which is internationally recognized.

Systematics: scientific study of diversity of organisms and their evolutionary relationship.

Taxonomy: is concerned with identification, naming and classification of organisms.

Temperature of a substance is the degree of its hotness or coldness.

The compressibility of a solid determines their ability to undergo change in volume under the changed pressure.

The weight of an object is the product of its mass and the value of gravitational field strength.

Thermal conductors are those materials which can easily pass heat through them.

Thermal contraction is the process in which on removing heat from the substances they use to contract.

Thermal expansion is the process in which on heating substances use to expand.

Thermal insulators are those materials which cannot easily pass heat through them.

Three-kingdom system of classification: in the 1860s, the German biologist Ernst Haeckel proposed it. · Haeckel's three kingdoms were Animalia, Plantae, and Protista.

Tidal barrages are constructed on sea shores to produce electric energy by using the tidal energy.

Time is the duration between two events.

Tissue: Are a group of cells with similar structure and specific functions

Triple point of water is the temperature at which water can be found in all the three states at the same time at 0°C.

Two-kingdom classification system: it was given by Carolus Linnaeus in 1758. Linnaeus. The two major kingdoms are Kingdom Plantae for plants and Kingdom Animalia for animals.

Units of temperature can be divided in three different scales like kelvin, degree Celsius and degree Fahrenheit.

Vacuole: Is a membrane-bound cell organelle. In animal cells, vacuoles are generally small and help give out waste products. In plant cells, vacuoles help maintain water balance.

Valence electron: An electron located in the outermost shell of an atom, involved in chemical bonding.

Vapour pressure is the measure of the tendency of a material to change into the gaseous or vapour state.

Voids and joints are made in construction for the purpose of taking into account the thermal expansion and contraction during different weather conditions.

Volume expansion is the process in which by heating the volume of a substance can be increased it is a type of three dimensional expansion.

Weak nuclear force is the force which is responsible for decay of nuclei and conversion of neutron and protons into each other.

Weight of any object is the force with which the Earth attracts an object towards its centre.

Wind energy is a renewable source of energy in which we use the kinetic energy of wind to produce electric energy.

ABOUT THE AUTHORS

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Prof. Jawaid Mohsin was born on 12th February in 1945 in the province of Bihar. Malik is the title given to his ancestor Syed Ibrahim by the king Tughlaq. Syed Ibrahim was a saint, the commander in chief of the army and conqueror of Bihar. Syed Ibrahim is the descendent of Hazrat Ghos-e-Azam, Syed Abdul Qadir Jilani (رحمۃ اللہ علیہ) at the seventh generation. The ancestors of Syed Ibrahim migrated from Iraq to Afghanistan and settled in the village "Bunt Nagar" near Ghazni. Prof.Jawaid is a former head for the department of Zoology, Federal Government Postgraduate College, H-8 Islamabad where he served for more than twenty-five years. He is also a former Principal, Federal Government College, H-9, F-10/4 Islamabad and Director Colleges and Director and Director Administration, Federal Directorate of Education, Islamabad. He has contributed his services to FBISE in various capacities such as paper setter, head examiner etc. He developed the modern question paper of FBISE which consists of three parts i.e., MCQ's, short answer question and extensive answer questions is now used all over Pakistan. In 1968 he did his post-graduation in zoology with specialization in Entomology, from Dhaka University, East Pakistan (former). He taught in Muhammadpur College, Quaid-e-Azam College and the prestigious Notre Dame College of Dhaka. He taught various classes for more than forty-five years in various capacities. He has also worked as Education Officer, in Nigeria for four years. He has successfully completed the 61st advance course in administration and development held in 1996 at National Institute of Public Administration (NIPA), Karachi. In 1995. He was awarded a shield by the honourable Mr. Rafiq Tarar, the then President of Pakistan, for his services to humanity. He has published four research papers in Science Journals of Pakistan on Butterflies of Pakistan. He has contributed articles on science and sports in Urdu and English dailies of Islamabad. He is co-author and managing author of more than fifty textbooks on General Science and Biology as well as Biology Practical Notebooks. He has travelled to Singapore, Thailand, Indonesia, India, Bangladesh, UAE, Saudi Arabia, Egypt, Italy, Holland, UK, Qatar, USA and Nigeria. He has also served as a National Consultant, Science Education, JICA sponsored project for the promotion of Student centered and Inquiry based SCIB) learning, National Institute of Science and Technical Education, Ministry of Education, Islamabad, He retired from survive on 12th November 2005. He has published four literary books in Urdu on which a student has obtained M.Phil., Degree from a university in Islamabad. He has served as book reviewer at National curriculum Council (NCC) and member interview committee of FPSC for selection of faculty for a number of years.

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