UNIT 4

HEAT

Learning Objectives

I8X5R1

After the completion of this lesson students will be able to:

- understand the effects of heat.
- explain the transfer of heat.
- know about calorimetry.
- calculate heat capacity and specific heat capacity of substances.
- list out the functions of thermostat.
- know about the working of thermos flask.

Introduction

All the substances in our surrounding are made up of atoms and molecules. These atoms and molecules are always at vibratory motion. Due to this motion, substances have an energy known as heat energy. This energy flows from hot substances to cold substances or from hot region to cold region of a substance. When heat energy is supplied to any substance it increases the energy of the atoms and molecules in it and so they start to vibrate. These atoms and molecules which vibrate make other atoms and molecules to vibrate. Thus, heat energy is transferred from one part of the substance to other part. We can see this heat energy transfer in our daily life also. Heat energy brings about lot of changes. You will learn about them in this lesson. You will also study about transfer of heat and measurement of heat change.

4.1 Effects of Heat

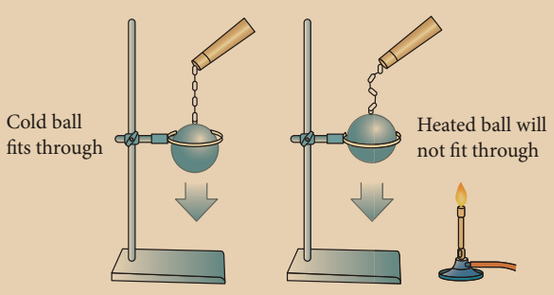
When heat energy is supplied to any substance, it brings about many changes. There are three important changes that we can see in our daily life. They are:

- Expansion
- Increase in temperature
- Change in state

4.1.1 Expansion

Activity 1

Take a metal ball and a metal ring of suitable diameter. Pass the metal ball through the ring. You can observe that the metal ball can easily go through it. Now heat the metal ball and then try to pass it through the ring. It will not pass through the ring. Keep the metal ball on the ring for some time. In few minutes, it will fall through the ring.



Why didn't the ball go through the ring initially but went through it after some time? When the ball is heated the atoms in the ball gain heat energy. They start vibrating and force each other apart. As a result an expansion takes place. That's why the ball did not go through the ring. After some time, as the ball lost the heat energy to the surrounding it came back to its original size and it went through the ring. This shows that heat energy causes expansion in solids. This expansion takes place in liquids and gases also. It is maximum in gases.

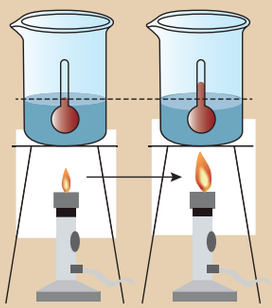
DO YOU KNOW?

Electric wires used for long distance transmission of electricity will expand during day time and contract at night. That is why they will not be set very tightly. If they are set very tightly they will break when they cool at night.

4.1.2 Rise in Temperature

Activity 2

Take a cup of water and note its temperature. Heat the water for few minutes and note the temperature again. Do you find any increase in the temperature? What caused the temperature change?



When the water is heated, water molecules receive heat energy. This heat energy increases the kinetic energy of the molecules.When the molecules receive more energy, the temperature of the water increases. This shows that heat energy causes increase in temperature.

4.1.3 Change of State

Activity 3

Take few ice cubes in a container and heat them for some time. What happens? The ice cubes melt and become water. Now heat the water for some time. What do you observe? The volume of water in the vessel decreases. What do you understand from this activity?

In ice cubes the force of attraction between the water molecules is more. So they are close together. When we heat them the force of attraction between the molecules decreases and the ice cubes become water. When we heat the water, the force of attraction decreases further. Hence they move away from one another and become vapour. Since water vapour escape to the surrounding, water level decreases further. From this we understand that heat energy causes change in the state of the substances. When heat energy is removed, changes take place in reverse direction.

If heat energy is supplied to or taken out from a substance, it will undergo a change from one state of matter to another.

One of the following transformations may take place due to heat energy.

- Solid to Liquid (Melting)
- Liquid to Gas (Vapourisation)
- Solid to Gas (Sublimation)
- Gas to Liquid (Condensation)
- Liquid to Solid (Freezing)
- Gas to Solid (Deposition)

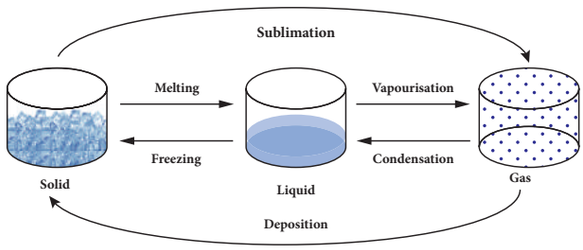


Figure 4.1 Change of state in Water

Water is the only matter on the Earth that can be found naturally in all three states - Solid, Liquid and Gas.

4.2 Transfer of Heat

If heat energy is supplied to any substance, it will be transferred from one part of the substance to another part. It takes place in different ways depending on the state of the substance. Three ways of heat transfer are:

- Conduction
- Convection
- Radiation

4.2.1 Conduction

Activity 4

Take some hot water in a cup and put a silver spoon in it. Leave the spoon inside the water for some time. Now touch the other end of the spoon. Do you feel the heat?

How did the other end of the spoon become hot? It is because heat in the hot water is transferred from one end to other end of the spoon. In solid substances such as silver spoon, atoms are arranged very closely. Hot water molecules which are vibrating transfer the heat energy to the atoms in the spoon and make them vibrate. Those atoms make other atoms to vibrate and thus heat is transferred to the other end of the spoon.

In conduction heat transfer takes place between two ends of the same solid or through two solid substances that are at different temperatures but in contact with one another. Thus, we can define conduction as the process of heat transfer in solids from the region of higher temperature to the region of lower temperature without the actual movement of atoms or molecules.

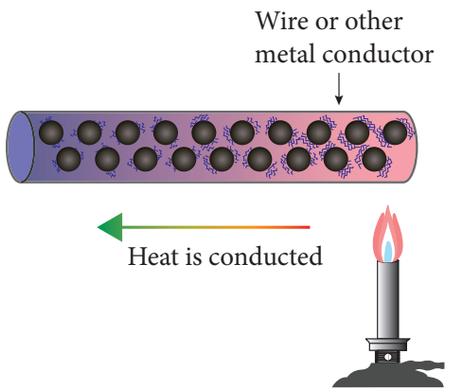


Figure 4.2 Conduction in Solids

All metals are **good conductors** of heat. The substances which does not conduct heat easily are called **bad conductors or insulators**. Wood, cork, cotton, wool, glass, rubber, etc are insulators.

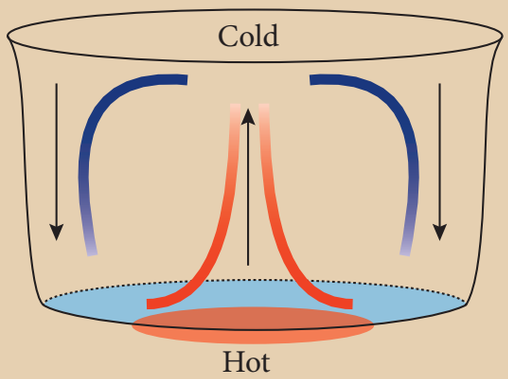
Conduction in daily life

- We cook food in vessels made up of metals. When the vessel is heated, heat is transferred from the metal to the food.
- When we iron dresses, heat is transferred from the iron to the cloth.
- Handles of cooking utensils are made up of plastic or wood because they are poor conductors of heat.
- The temperature inside igloo (snow house) is warm because snow is a poor conductor of heat.

4.2.2 Convection

Activity 5

Take some water in a vessel and heat it on a stove. Touch the surface of the water. It will be cold. Touch it after some time. It will be hot now. How did the heat which was supplied at the bottom reach the top?



When water in the vessel is heated, water molecules at the bottom receive heat energy and move upward. Then the molecules at the top comes down and get heated. This kind of heat transfer is known as convection. This is how air in the atmosphere is also heated. Thus, the form of heat transfer from places of high temperature to places of low temperature by the actual movement of molecules is called convection. Convection takes place in liquids and gases.

Convection in daily life

- Formation of land breeze and sea breeze is due to convection of air.
- Wind flows from one region to another region by convection.
- In hot air balloons heat is transferred by convection and so the balloon raises.
- In refrigirators, cool air moves downward and replaces the hot air because of convection.

4.2.3 Radiation

Radiation is the third form of heat transfer. By conduction, heat is transferred through solids, by convection heat is transferred through liquids and gases, but by radiation heat can be transferred through empty space even through vacuum. Heat energy from the Sun reaches the Earth by this form of heat transfer. Radiation is defined as the way of heat transfer from one place to another in the form of electromagnetic waves.

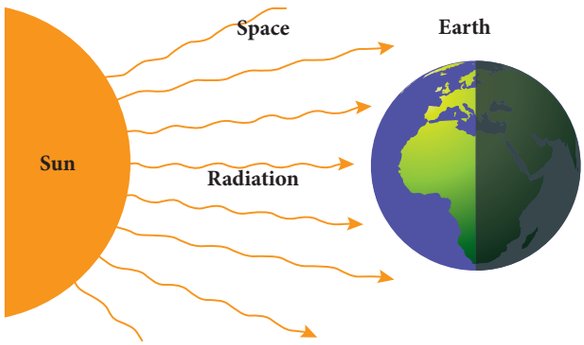


Figure 4.3 Heat transfer by radiation

Radiation in daily life

- Heat energy from the Sun reaches the Earth by radiation.
- While standing near fire we feel the heat which is transferred as radiation.
- Black surfaces absorb heat radiation. So that the bottom of the cooking vessels are painted black.
- White colour reflects heat radiation. That's why we are advised to wear white cloth during summer.

Heat transfer by radiation is visible to our eyes. When a substance is heated to 500°C the radiation begins to become visible to the eye as a dull red glow, and it is sensed as warmth by the skin. Further heating rapidly increases the amount of radiation, and its perceived colour becomes orange, yellow and finally white.

4.3 Calorimetry

We studied about the effects of heat energy. When heat energy is supplied to substances, physical changes take place in them. Solid form of water (ice) is changed to liquid form, and liquid form of water is changed to gaseous form. These are all the physical changes due to heat energy. Similarly, heat energy produces chemical changes also. To know more about the physical and chemical changes that take place in substances, we need to measure the amount of heat involved. The technique used to measure the amount of heat involved in a physical or a chemical process is known as calorimetry.

4.3.1 Temperature

Temperature is a physical quantity which expresses whether an object is hot or cold. It is measured with the help of thermometer. There are three scales to measure the temperature. They are:

- Celcius scale
- Fahrenheit scale
- Kelvin scale

Among these three scales, Kelvin scale is the most commonly used one. You will study about this elaborately in Standard IX.

4.3.2 Unit of Heat

We know that heat is a form of energy. The unit of energy in SI system is joule. So, heat is also measured in joule. It is expressed by the symbol J. The most commonly used unit of heat is calorie. One calorie is the amount of heat energy required to raise the temperature of 1 gram of water through 1°C. The relation between calorie and joule is given as, 1 calorie = 4.186 J.

DO YOU KNOW?

The amount of energy in food items is measured by the unit kilo calorie.

1 kilo calorie = 4200 J (Approximately).

4.3.3 Heat capacity

Activity 6

Take some amount of water and cooking oil in two separate vessels. Heat them till they reach a particular temperature (Caution: Heat the oil under the supervision of your teacher). Which one is heated first? Water will take more time to get heated. Why?

In general, the amount of heat energy gained or lost by a substance is determined by three factors. They are:

- Mass of the substance
- Change in temperature of the substance
- Nature of the material of the substance

Different substances require different amount of heat energy to reach a particular temperature. This nature is known as heat capacity of a substance. Heat capacity is defined as the amount of heat energy required by a substance to raise its temperature by 1°C or 1 K. It is denoted by the symbol C'.

Heat capacity

$$= \frac{\text{Amount of heat energy required (Q)}}{\text{Raise in temperature } (\Delta T)}$$

$\therefore C' = Q / \Delta T$

The unit of heat capacity is cal / °C. In SI system, it is measured in JK^{-1}.

DO YOU KNOW?

Water has higher heat capacity than most other substances. This accounts for the use of water as common coolant. 100 g of water can take away more heat than 100 g of oil.

Problem 1

The temperature of a metal ball is 30° C. When an energy of 3000 J is supplied, its temperature raises by 40° C. Calculate its heat capacity.

Solution

Heat capacity, $C' = Q / \Delta T$

Here, $Q = 3000$ J

$\Delta T = 40°C - 30°C = 10°C$ or 10 K

$C' = 3000 / 10 = 300\ JK^{-1}$

The heat capacity of the metal ball is 300 JK^{-1}.

Problem 2

The energy required to raise the temperature of an iron ball by 1 K is 500 JK^{-1}. Calculate the amount of energy required to raise its temperature by 20 K.

Solution

Heat capacity, $C' = Q / \Delta T$

$Q = C' \times \Delta T$

Here, $C' = 500\ JK^{-1}$

$\Delta T = 20$ K

$\therefore Q = 500 \times 20 = 10000$ J.

The amount of heat energy required is 10000 J.

4.3.4 Specific heat capacity

When the heat capacity of a substance is expressed for unit mass, it is called specific heat capacity. Specific heat capacity of a substance is defined as the amount of heat energy required to raise the temperature of 1 kilogram of a substance by 1°C or 1 K. It is denoted by the symbol C.

Specific heat capacity

$$= \frac{\text{Amount of heat energy required (Q)}}{\text{Mass} \times \text{Raise in temperature } (\Delta T)}$$

$\therefore C = Q / m \times \Delta T$

The SI unit of specific heat capacity is J kg^{-1} K^{-1}.

Problem 3

An energy of 84000 J is required to raise the temperature of 2 kg of water from 60° C to 70° C. Calculate the specific heat capacity of water.

Solution

Specific heat capacity, $C = Q / m \times \Delta T$

Here, $Q = 84000$ J

$m = 2$ kg

$\Delta T = 70° C - 60° C = 10° C$ or 10 K

$C = 84000 / 2 \times 10 = 4200\ J\,kg^{-1}\,K^{-1}$

The Specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

Problem 4

The specific heat capacity of a metal is 160 $J\,kg^{-1}K^{-1}$. Calculate the amount of heat energy required to raise the temperature of 500 gram of the metal from 125° C to 325° C.

Solution

Specific heat capacity, $C = Q / m \times \Delta T$

$Q = C \times m \times \Delta T$

Here, $C = 160$ J kg K^{-1}

$m = 500\ g = 0.5$ kg

$\Delta T = 325° C - 125° C = 200° C$ or 200 K

$= 160 \times 0.5 \times 200 = 16000$ J.

The amount of heat energy required is 16000 J.

4.4 Calorimeter

A calorimeter is a device used to measure the amount of heat gained or lost by a substance. It consists of a vessel made up of metals like copper or aluminium which are good conductors of heat and electricity.

Q9C5H3

The metallic vessel is kept in an insulating jacket to prevent heat loss to the environment. There are two holes in it. Through one hole a thermometer is inserted to measure the

temperature of the contents. A stirrer is inserted through another hole for stirring the content in the vessel. The vessel is filled with liquid which is heated by passing current through the heating element. Using this device we can measure the heat capacity of the liquid in the container.

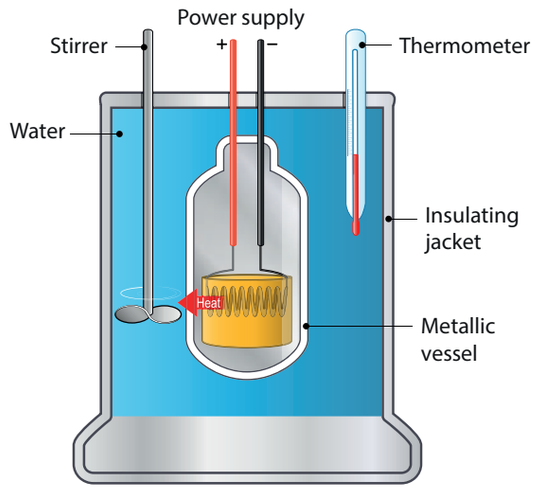


Figure 4.4 Calorimeter

DO YOU KNOW?

The world's first ice-calorimeter was used in the year 1782 by Antoine Lavoisier and Pierre-Simon Laplace, to determine the heat generated by various chemical changes.

4.5 Thermostat

A thermostat is a device which maintains the temperature of a place or an object constant. The word thermostat is derived from two Greek words, 'thermo' meaning heat and 'static' meaning staying the same. Thermostats are used in any device or system that gets heated or cools down to a pre-set temperature. It turns an appliance or a circuit on or off when a particular temperature is reached. Devices which use thermostat include building heater, central heater in a room, air conditioner, water heater, as well as kitchen equipments including oven and refrigerators. Sometimes, a thermostat functions both as the sensor and the controller of a thermal system.

Figure 4.5 Thermostat

4.6 Thermos flask (Vacuum flask)

The thermos flask (Vacuum flask) is an insulating storage vessel that keeps its content hotter or cooler than the surroundings for a longer time. It is primarily meant to enhance the storage period of a liquid by maintaining a uniform temperature and avoiding the possibilities of getting a bad taste.

DO YOU KNOW?

The vacuum flask was invented by Scottish scientist Sir James Dewar in 1892. In his honour it is called as Dewar flask. It's also known as Dewar bottle.

Working of Thermos flask

A thermos flask has double walls, which are evacuated. It is silvered on the inside. The vacuum between the two walls prevents heat being transferred from the inside to the outside by conduction and convection.

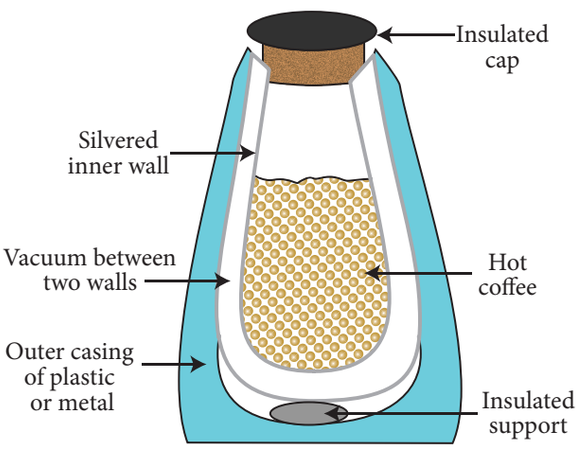


Figure 4.6 Thermos flask

With very little air between the walls, there is almost no transfer of heat from the inner wall to the outer wall or vice versa. Conduction can only occur at the points where the two walls meet, at the top of the bottle and through an insulated support at the bottom. The silvered walls reflect radiated heat back to the liquid in the bottle.

Points to Remember

- Heat is a form of energy which is transferred from one part to another part of a substance.
- Heat transfer causes expansion, increases temperature and changes the state of the substance.
- When thermal energy is supplied to a solid, the atoms or molecules present in it gain energy and vibrate more vigorously about their fixed positions, forcing each other further apart.
- Melting, vapourisation, sublimation, condensation, freezing and deposition are the change of states that take place due to heat energy.
- Heat transfer takes place in three ways: conduction, convection and radiation.
- Conduction occurs in solids, convection in liquids and gases, and radiation takes place in vaccum.
- Capacity of substances to gain or loose heat energy is determined by three factors: mass of the substance, change in temperature and nature of the substance.
- There are three scales to measure temperature: Celcius scale, Fahrenheit scale and Kelvin scale.
- Calorimeter measures the heat capacity of water.

A-Z GLOSSARY

Calorimeter	A device which measures the heat capacity of liquids.
Calorimetry	The technique used to measure the amount of heat involved in a physical or a chemical process.
Conduction	The process of heat transfer in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules.
Convection	The form of heat transfer from places of high temperature to places of low temperature by the actual movement of liquid or gas molecules.
Heat capacity	Amount of heat energy required to raise the temperature of a substance by 1° C or 1 K.
Radiation	The form of heat transfer from one place to another place in the form of electromagnetic waves.
Specific heat capacity	Amount of heat energy required to raise the temperature of 1 kilogram of a substance by 1° C or 1 K.
Temperature	Physical quantity which expresses whether an object is hot or cold.
Thermos flask	An insulating storage vessel that keeps its content hotter or cooler than the surroundings for a longer time.
Thermostat	A temperature sensing device that turns an appliance or circuit on or off when a particular temperature is reached in it.

TEXTBOOK EXERCISES

L6I2M4

I. Choose the best answer.

1. Heat is a form of _____.
   a) electrical energy
   b) gravitational energy
   c) thermal energy
   d) None of these
2. If you apply some heat energy to a substance, which of the following can take place in it?
   a) Expansion
   b) Increase in temperature
   c) Change of state
   d) All the above.
3. Which of the following substances will absorb more heat energy?
   a) Solid b) Liquid
   c) Gas d) All the above
4. If you apply equal amount of heat to a solid, liquid and gas individually, which of the following will have more expansion?
   a) Solid b) Liquid
   c) Gas d) All of them
5. The process of converting a liquid into a solid is called_____.
   a) sublimation b) condensation
   c) freezing d) deposition
6. Conduction is the way of heat transfer which takes place in a_____.
   a) solid b) liquid
   c) gas d) All of them

II. Fill in the blanks.

1. A calorimeter is a device used to measure the_____.
2. _____ is defined as the amount of heat required to raise the temperature of 1kg of a substance by 1°C.
3. A thermostat is a device which maintains _____.
4. The process of converting a substance from gaseous state to solid state is called _____.
5. If you apply heat energy, the temperature of a system will _____.
6. If the temperature of a liquid in a container is decreased, then the interatomic distance will _____.

III. State True or False. If false, correct the statement.

1. The applied heat energy can be realised as an increase in the average kinetic energy of the molecules.
2. The dimensions of a substance are increased if the temperature of the substance is decreased.
3. The process of converting a substance from solid state to gaseous state is called condensation.
4. Convection is the process by which the thermal energy flows in solids.
5. The amount of heat gained by a substance is equal to the product of its mass and latent heat.
6. In a thermos flask, the silvered walls reflect and radiate the heat outside.

IV. Match the following.

Conduction	Liquid
Convection	Gas to liquid
Radiation	Solid to gas
Sublimation	Vaccum
Condensation	Solid

V. Consider the statements given below and choose the correct option.

1. **Assertion:** Radiation is a form of heat transfer which takes place only in vacuum.

   Reason: The thermal energy is transferred from one part of a substance to another part without the actual movement of the atoms or molecules.

2. **Assertion:** A system can be converted from one state to another state.

   Reason: It takes place when the temperature of the system is constant.

a. Both assertion and reason are true and reason is the correct explanation of assertion.

b. Both assertion and reason are true, but reason is not the correct explanation of assertion.

c. Assertion is true, but the reason is false.

d. Assertion is false, but the reason is true.

VI. Answer briefly.

1. What are the applications of conduction in our daily life?
2. What are the effects of heat?
3. Name three types of heat transfer.
4. What is conduction?
5. Write a note on convection.
6. Define specific heat capacity.
7. Define one calorie.

VII. Answer in detail.

1. With the help of a neat diagram, explain the working of a calorimeter.
2. Write a note on thermostat.
3. Explain the working of thermos flask.

VIII. Higher Order Thinking Questions.

1. Why does the bottom of a lake not freeze in severe winter though the surface is all frozen?
2. Which one of the following statements about thermal conductivity is correct? Give reason.

   a) Steel > Wood > Water

   b) Steel > Water > Wood

   c) Water > Steel > Wood

   d) Water > Wood > Steel

IX. Numerical Problems.

1. An iron ball requires 1000 J of heat to raise its temperature by 20°C. Calculate the heat capacity of the ball.
2. The heat capacity of the vessel of mass 100 kg is 8000 J/°K. Find its specific heat capacity.

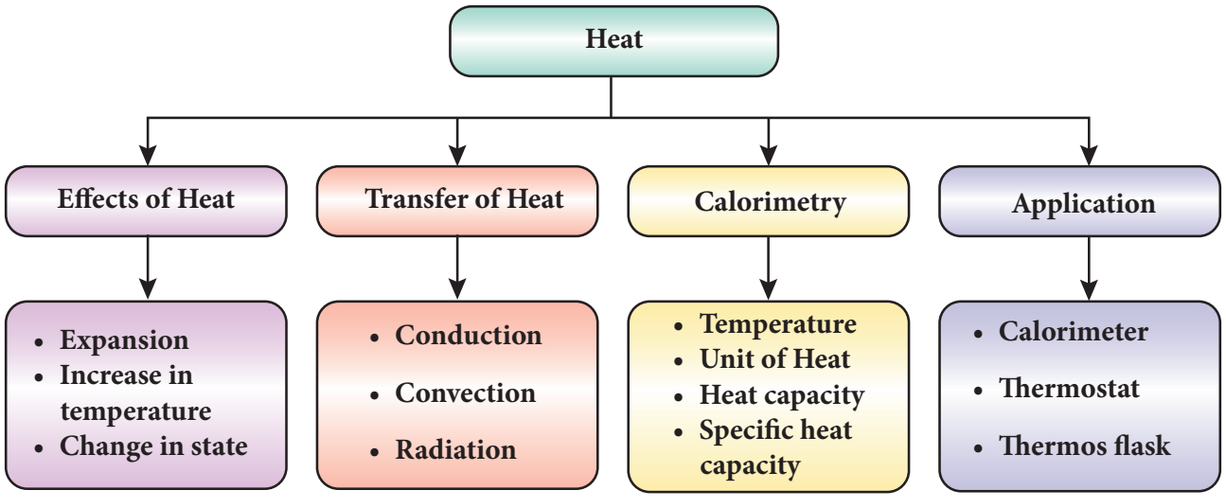
REFERENCE BOOKS

1. Fundamentals of Statistical and Thermal Physics - F.Reif
2. Statistical Thermodynamics and Microscale Thermo -physics - Carey
3. Heat, Thermodynamics and Statistical Physics - BrijLal and Dr. N. Subramaniyam
4. Thermodynamics and an Introduction to Thermos-statistics byHerbert Hallen
5. Fundamentals of Engineering Thermo dynamics by Michael Moran

INTERNET RESOURCES

1. https://www.explainthatstuff.com/thermostats.html
2. https://youtu.be/8-nLHWpgDsM
3. https://youtu.be/rYwgsF_haAg
4. https://youtu.be/EwzkYTfHFbo

Concept Map



ICT CORNER

Heat

Through this activity you will learn about heat energy through Interactive games.

Step 1 Open the Browser and type the URL given below

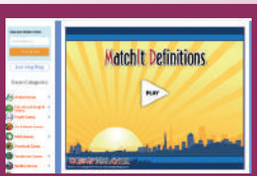
Step 2 You can see lot of games about heat energy.

Step 3 For example, click "Heat Energy match it" game. You will see the match words in the screen. Play and learn about heat energy.

Step 4 Likewise you can explore all the games.

Step1

Step2



Step3

Step4

Browse in the link:

https://www.learninggamesforkids.com/heat-energy-games.html

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