Heat

Heat and Temperature

On returning from school, when Ravi touched the iron gate of his house, he found it to be extremely hot. Later, he touched other things made of iron present inside his house and found that they were not hot. Then, he touched other substances (not made of iron) present in his house to determine whether they were hot or cold. He listed the various substances observed in the table given below.

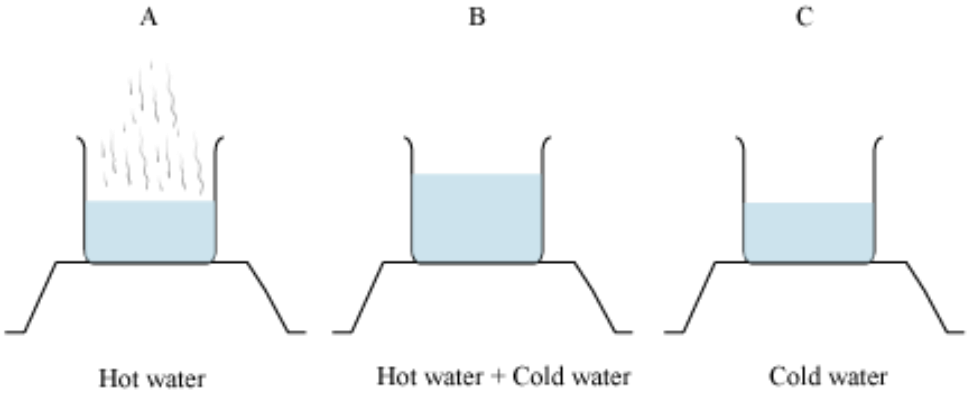
Substances	Hot/ Cold
Tea	Hot
Coffee	Hot
Ice	Cold
Ice cream	Cold
Cooked rice	Hot
Frozen meat	Cold

Try to make a table listing some other substances, which are present in your house and classify them as hot or cold. **But how do you decide whether a substance is hot or cold? Can you always tell whether a substance is hot or cold simply by touching it?** The following activity will help you understand better.

Measurement of Temperature

Activity:

Take three containers and label them as **A, B**, and **C**. Take hot water in container **A**, and cold water in container **C.** In container **B**, mix hot and cold water in equal amounts. Now, place your left hand in container **A** and right hand in container **C** for two minutes. Then, dip both your hands in container **B**.



What can you say about the water present in all three containers? Note your observations in the table given below.

Container	Hot/Cold
A	
B	
C	

What is your observation for container B? Is the water in container B hot or cold?

When you dip your hands in container **B**, your left hand will tell you that the water is cold, while your right hand will tell you that the water is hot. Thus, you will not be able to distinguish whether the water present in container **B** is hot or cold.

From this activity, we can conclude that we cannot decide whether a substance is hot or cold just by touching it. Thus, we need something more reliable than our sense of touch to decide whether a substance is hot or cold.

The measure that can be used to detect the degree of hotness and coldness of a substance is called temperature. More the temperature of a substance, the hotter it will be.

Thermometer

The device that is used to measure the temperature is called a **thermometer.**

The scales used to measure temperature can either be degree Celsius or degree Fahrenheit.

The thermometer in which liquid is used as a thermometric fluid is called a liquid thermometer. The two most commonly used liquids are mercury and alcohol.

Use of mercury in thermometers

1. Mercury has a very high boiling (357 ºC) and freezing point (-39 ºC). Thus it can be used over a wide range of temperature.
2. Mercury has a large expansion over a small change in temperature.
3. It does not stick to the glass of the capillary tube.
4. It is an opaque and shiny liquid and thus it can be easily seen through the glass tube.

Use of alcohol in thermometers

1. The freezing point of alcohol is very low (-100 ºC). Thus, it can be used to measure temperature in regions such as Arctic and Antarctic.
2. Alcohol expands more quickly than mercury.
3. Alcohol is brightly coloured. Hence, it can be easily seen in the capillary glass tube.

Types of thermometer

There are two types of thermometers: **clinical thermometers and laboratory thermometers**. The table given below tells us the difference between them.

Types of Thermometers	
Clinical thermometer	**Laboratory thermometer**
This thermometer is used in homes. It is basically used to measure the temperature of humans. A clinical thermometer has a temperature range of only 35 ºC to 42 °C. Can you tell the reason why? This is because our body temperature never goes below 35 °C or above 42 °C. 	This thermometer is used to measure the temperature of all things, except the human body. It is a complex device. A laboratory thermometer has a temperature range of -10 ºC to 110 ºC. 

Why can we not use a laboratory thermometer to measure the body temperature of humans? Let us perform a small activity to understand.

Activity:

Take a beaker full of water. Now, dip a laboratory thermometer in it. Make sure that it touches neither the bottom of the beaker, nor the walls of the beaker. You will see that the mercury line rises for some time, but then ceases to rise. Note the reading where the mercury stagnates. This is the temperature of water. Take out the thermometer.

What do you observe? The mercury starts falling rapidly. This means that with a laboratory thermometer, temperature has to be read when placed in water. On the other hand, to measure the body temperature, the thermometer has to taken out of the mouth to note the reading. Thus, it is not convenient to use a laboratory thermometer.

Do You Know?

Mercury is a very toxic substance. Hence, now-a-days digital thermometers have become more popular, which do not contain mercury.

There is another thermometer which is particulary used to measure maximum and minimum temperatures of a day. Thia thermometer is known as Maximum-minimum thermometer.

Temperature Scale

The three temperature scales that are in use are Celsius scale, Fahrenheit scale, and Kelvin scale. However, the SI unit of temperature is Kelvin (K).

0 K = -273 ^{o}C

273 K = 0 °C

373 K = 100 °C

Conversion of Temperature Scale

- Degree celsius to Kelvin scale

  Temperature in Kelvin = Temperature in °C + 273

For example 40°C = (40 + 273) K = 313 K

Conversely, 343 K = (343 − 273) K = 70 °C

- Degree celsius to Fehrenheit

  Temperature in Fehrenheit (°F) = °C × 9/5 + 32
  or, Temperature in degree celsius (°C) = (°F - 32) × 5/9
  For example human body temperature is 37 °C = 37 ×× 9/5 + 32 = 98.6 °F

  Precautions while using thermometer

- Thermometer used be washed well before and after every use with an antiseptic like alcohol.
- Washing should not be done in hot water.
- Keep the mercury level straight or along the line of sight while reading the thermometer.
- Do not hold the thermometer by its bulb while taking the readings.
- handle the thermometer with care as it is made up glass.

How is temperature a measure of heat?

In the SI system, the unit of temperature is Kelvin, whereas the unit of heat is joule (J). Still temperature measurement can tell us about the heat energy contained in a body.

$$Q = m \times C \times t$$

Other common units of heat are calorie (cal) and kilocalorie (kcal).
1 calorie is the amount of heat energy required to increase the temperature of 1 g of water by 1 ^{o}C.

1 kcal = 1000 cal
1 cal = 4.2 J

Thus, we can define heat and temperature as follows —

Heat − It is a form of energy which causes in us the sensation of hotness or coldness.

Temperature − It is measure of the degree of hotness or coldness.

Effects of Heat

Man is dependent on various sources of heat. The sun is the major source of heat on the earth. The heat received from the sun is the reason why life flourishes on the earth.

Here are many changes that take place around us because of the effects of heat.

Let us study the effects of heat in detail.

Rise of temperature

The temperature of a body increases on heating; however, the temperature falls on removing heat from a body or by cooling it.

When we heat water and oil in separate vessels, it takes more time to for change ing the temperature of the water by 1one degree Celsius than time taken to raise the temperature of the oil by 1one degree Celsius.

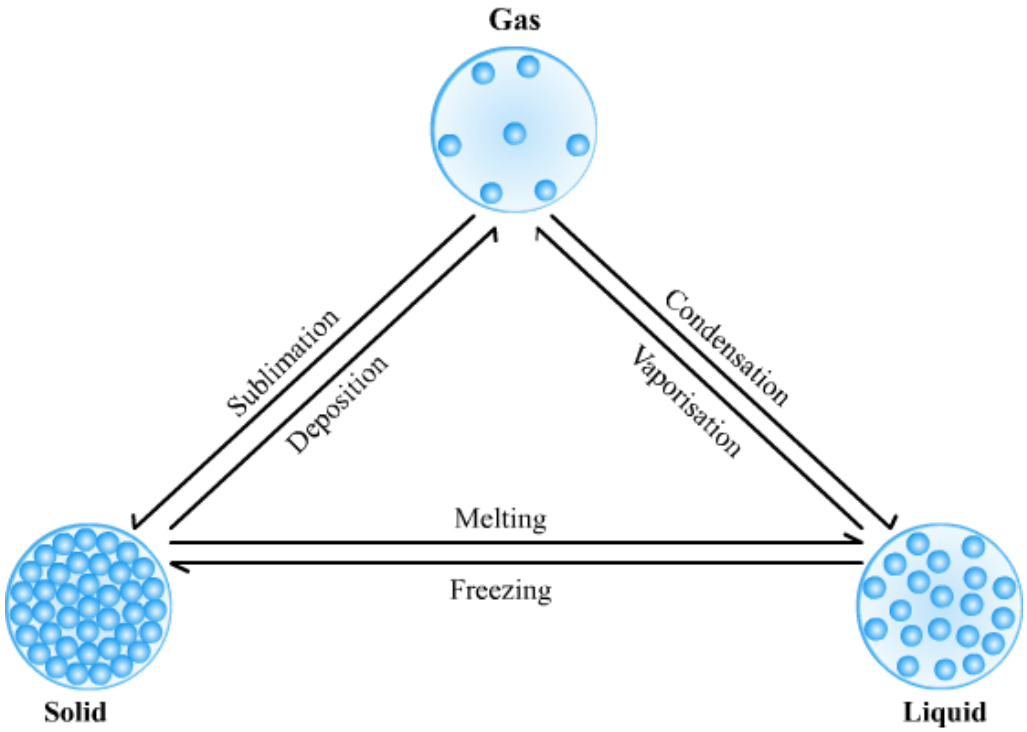
Do you know the reason behind this?

The amount of heat required to raise the temperature of a substance is dependent on the nature of the substance. Oil absorbs the heat faster than water, and this is the reason that it takes more time to increase the temperature of water by one degree Celsius.

Change in state

The addition of a sufficient amount of heat to a substance, or the removal of a sufficient amount of heat from it, can change the state of the substance. When a solid is heated up to a particular temperature, it starts melting and, after some time, changes into a liquid.

In the same way, when a liquid is heated to a certain temperature, it starts to boil and converts into a gas. On cooling, the gas is converted into its liquid state, and on further cooling, it is converted into its solid state.



For example, ice kept at room temperature absorbs heat from the surroundings and melts into water. Water, on strong heating, boils to form water vapour. If we cool the water vapour, it gets converted into water, and on cooling water, it is converted into ice.

Therefore, it can be concluded that when a substance is heated, it changes its state from solid to liquid to gas, and when it is cooled, the reverse happens.

Change in physical properties

The physical properties of substances are altered on heating. For example, iron, which is a hard metal at room temperature, becomes soft on strong heating and can be moulded into a desired shape.

The electric resistance of a conductor decreases at high temperatures. High temperature of a conductor is achieved on heating it.

Heating a magnet leads to loss of its magnetism.

Chemical changes

The application of heat can cause chemical changes to a substance. Some substances break down—for example, calcium carbonate decomposes into calcium oxide and carbon dioxide on heating. The speed of a chemical reaction may increase or decrease with heat. For example, food decays faster in summer than in winter. Reactions in which heat is released slow down if heat is added—for example, the rate of a neutralisation

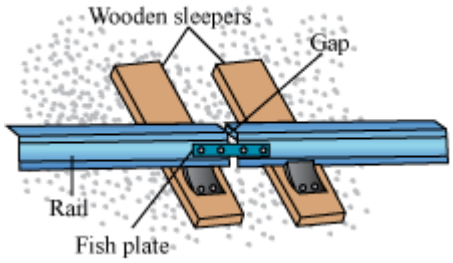
reaction decreases on adding heat.

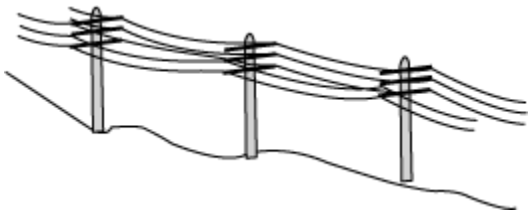
Expansion
You must have observed that in winter, it is difficult to open the lid of a jar. So, to open the jar, it is heated. Why do we do this? It is because **substances expand on heating and contract on cooling.** This property is exhibited by all the states of matter (solid, liquid and gas). The amount of expansion or contraction depends on the nature of the material and the amount of heat applied.

Thermal Expansion

Expansion of Solids

Rohit was travelling from Nasik to Mumbai. While waiting on the platform for the train to arrive, he noticed the rail track carefully. He observed that the rail tracks were joined by a metal plate and there was a small gap between the rail tracks. Can you explain the reason behind leaving a small gap between two rails at the joining?





Have you ever noticed the electric transmission wires connected to electric poles? Their lengths are always kept longer than the distance between the poles, so that they sag down. Do you know why?

The rail tracks and the electric wires are made up of metals. On heating, almost all metals expand. The expansions may be along the length, area or volume.

Let us perform an activity to prove this.

Now, can you answer why a gap is left between two rail tracks at the joining? During summers, the metals rail tracks expand because of heating. If the rail tracks are fitted end-to-end leaving no gap, then on expansion, the rail track would bend. To avoid this, rail tracks are joined by a fish plate, leaving some gap between the rail tracks.

The lengths of electric transmission wires are also kept longer to avoid any tension in the wires when they contract during winters.

Expansion of Gases and Liquids

Have you seen people gliding in the air in a basket tied to a balloon? This is called hot-air ballooning. How does the balloon move?

Situated just below the balloon and above the basket is a flame that heats up the air inside the balloon up to about 100ºC. This hot air expands as a result of heating.

When the air expands, its density reduces. The air inside the balloon thus becomes lighter and less dense than the air outside the balloon. This makes a hot-air balloon rise.

Thus, we know that air expands on heating.

Not only air, but **all gases expand on heating**.

Let us perform an activity to understand this principle

We know that hot air expands. How does hot air make a balloon move up?

Let us perform an activity to understand this phenomenon

Using a pump, inflate a balloon with cold air and another one with hot air. Hang them on a horizontal, wooden stick. Observe the motion of both the balloons.

You will find that the balloon filled with hot air rises more in comparison with the balloon filled with cold air. **Can you explain why this happens?**

Since air expands on heating and occupies more space, the hot-air balloon becomes lighter than the cold-air balloon.

Why does the smoke from a fire move upwards? This is because fire heats the air and causes the air to move upwards. The upward-moving air carries the smoke along with it.	

Like gases, liquids also expand on heating. Let us perform an experiment to see the expansion of liquids on heating.

Take three similar glass bottles. Fill the bottles with three different liquids, say kerosene oil, coloured water and milk. Now, insert a straw in each bottle with the help of a cork. Mark the liquid levels in the straws. Place the bottles in a big beaker and pour hot water in the beaker. What do you observe after 10 minutes?

You will see that the liquid levels in the straws increase, and the increases are different for all the three liquids. This happens because the liquids expand on heating, and they expand at different rates on the same amount heating.

Thermal Expansion and Its Applications

Expansion of Solids

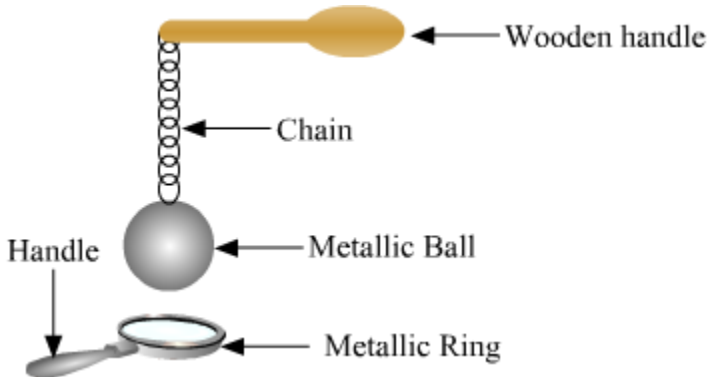
Heat not only raises the temperature of a substance, but it also has some additional effects.

Expansion of Solids on Heating

On heating, solids generally expand in all directions. Hence, it is also known as cubical expansion or volume expansion. But many a times, one of the dimensions of the solid object might be negligible as compared to others.

For example, the thickness of a plate is negligible in comparison to its surface area, or the cross section of a wire is negligible in comparison to its length.

Activity: Solids Expand on Heating



Take a ring and ball apparatus such that the metallic ball just passes through the ring, as shown in the figure. This is so because the internal diametre of the ring is same as the diametre of the metallic ball.

Now, heat the metallic ball over a burner for 5-10 minutes. Again, try to pass the ball through the ring. You will notice that the ball does not pass through the ring.

Why? This is because the metallic ball expands on heating, hence, its diameter also increases. So, the ball is unable to pass through the ring.

Now, let the ball cool and then try to pass it through the ring. What will you observe?

You will observe that the ball passes through the ring.

This activity shows that solids expand on heating and contract on cooling.

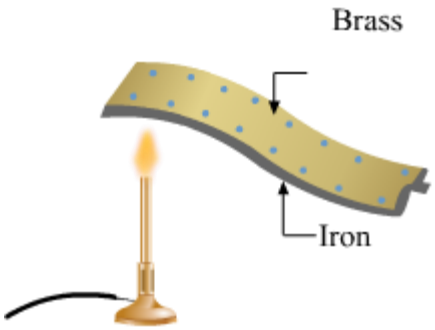
Advantages and Disadvantages of Expansion of Substances

The thermal expansion of solids has many advantages and disadvantages in our daily lives. Let us see some of them:

Advantages

1. Bimetallic strips are used as heat operated switches in circuits of some appliances such as iron box, fire alarms, microwave oven, etc.

Expansion in Bimetallic Strip



A bimetallic strip contains equal strips of brass and iron riveted together firmly on a wooden handle.

Let us heat one end of the strip using a burner. You will observe that the strip bends towards the iron strip. This bending of the strip is used in switches.

But why does the strip bend?

This is because brass expands more on heating than iron.

2. Many thermometers work on the principle of expansion of liquids.

3. Expansion of gases is useful in automobile engines.

Disadvantages

1. Breaking of a thick glass tumbler on pouring boiling water into it: When boiling water is poured into a thick glass tumbler, it cracks immediately due to the fact that glass is a poor conductor of heat. The heat from the boiling water expands the inner wall of the glass but it is not transferred to the outer wall. Thus, the outer wall fails to expand and this uneven expansion breaks the glass.

Similarly, a thick glass tumbler cracks when ice is placed in it.

The solution to this problem is that a very thin glass tumbler with low expansion capacity (like pyrex or borosilicate) should be chosen.

2. Narrow spaces are left between the small stretches of **cemented roads** so that they do not bend and cause problem to vehicles and people.

3. The **metal pipelines** used to transfer hot water or molten liquid in industries are provided with metal loops at regular intervals. This is because the expansion and contraction might bend or break the pipe. So, the expansion of pipeline causes the size of the loop to increase slightly and prevent the pipe from breakage.

Loop of metal pipe

4. The **iron tyres of cart wheels** are made a little smaller than their wooden wheels in order to prevent them from expanding in summers and loosening from the tyre.

5. Railway tracks are made up of steel, leaving small spaces in between them in order to prevent the tracks from bending and derailing the trains. The spaces get closer in summers and wider in winters and prevent the track from bending.

6. The **telegraph wires** between two poles are never strongly tightened as they sag in summers and get tighten in winters.

Conduction of Heat

You must have observed that each part of a frying pan becomes hot when kept on a flame. When the hot pan is removed from the flame, it cools down. **Do you know why this happens?**

This is because in the first case, transfer of heat takes place from the part of the pan which is directly in contact with the flame to the other parts. In the second case, transfer of heat takes place from the pan to its surroundings. Thus, in both cases, **heat flows from a hotter region to a cooler region. This process of heat transfer is called conduction.**

Conduction is a process in which heat is transferred from the hotter end of an object to its cooler end.

Let us understand the process of conduction with the help of the following animation.

In solids, heat is generally transferred by the process of **conduction.** Solid substances are classified on the basis of whether they conduct heat or not. Some materials allow heat to pass through them, while others do not. On this basis, materials are classified as **conductors** or **insulators**.

Conductors

The substances that allow heat to pass through them are called **conductors** of heat. Iron, copper and aluminium are examples of conductors. All metals are good conductors of heat.

Insulators

The substances that do not allow heat to pass through them are called **poor conductors** of heat or **insulators**. Plastic and wood are examples of insulators.

Applications of conductors and insulators

- The space between double walls of the oven are filled with wool and cork so as to prevent heat of the oven to escape. The wool and cork act as good insulators of heat in the oven.
- Cooking utensils are made up of metals as they are good conductors of heat. This enables them to cook the food rapidly.
- Woollen clothes worn by us in winters have air trapped in it. As air and wool both are insulators, thus they do not allow heat from our body to escape to the surroundings.
- Water pipes are covered with cotton in winters so as to prevent freezing of water in the pipes. Cotton has air trapped in its fine pores. The cotton as well as air are bad conductors of heat and thus they do not allow the heat from water in the pipes to escape to the surroundings.

Convection

We know that heat flows from a body of higher temperature to a body of lower temperature. However, can you tell how heat is transferred from one body to another, or within the same body? Or, how does heat get transferred when there is no medium between the bodies transferring heat?

There are three ways by which heat can flow from one object to another. They are: **conduction, convection,** and **radiation**. In this part, we will learn how transfer of heat takes place through convection.

Convection

The process of transference of heat through a fluid (liquid or gas) is called **convection**. Water and air are poor conductors of heat, and heat transfer in these mediums takes place by the process of convection.

The concept of convection can be understood with the help of the following activity.

Activity1:

Take a flask and fill it with water. Place it on a tripod stand (as shown in **figure 1)**. Now, using a straw, gently place a crystal of potassium permanganate in the centre of the flask. Place a burner below the crystal and heat the water.

Transfer of heat by convection in water

It can be observed that when water is heated, water near the flame gets hot and starts rising up. On the other hand, cold water moves down from the sides of the flask, towards the source of heat. Then, this water becomes hot and rises up. This process continues till all the water present in the flask gets heated. This process of heat transfer is called **convection**.

Similarly, when air is heated, the air present near the heat source gets heated and rises up. On the other hand, the air from the sides come towards the source, gets heated, and rises up. In this manner, air gets heated by the process of convection.

Convection Currents in Nature

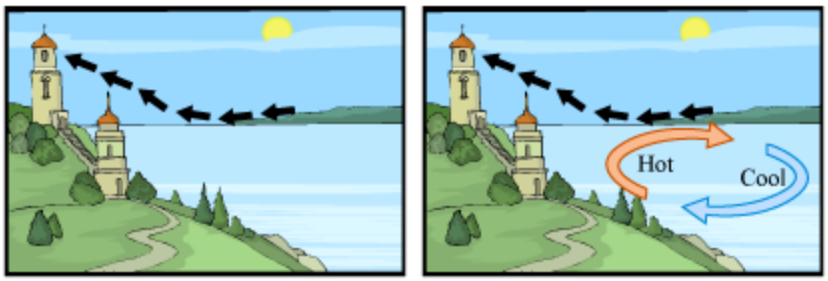
Do you know why winds blow near the coastal areas? Two types of winds are experienced near the coastal areas− **sea breeze and land breeze**.

Sea breeze

Sea breeze is the wind that blows from the sea towards the land. It develops during day time.

Let us understand the formation of sea breeze with the help of an animation.

Do you know that it is for this reason that the windows of houses in the coastal regions are built in such a way that they face towards the sea to receive the cool sea breeze.



Sea Breeze

What is land breeze?

Land breeze is the wind that blows from the land towards the sea or the oceans. It develops during night time.

Land cools down faster than water. Therefore, during night time, land is cooler than sea. Hence, cool air from the land blows towards the sea. This is called the **land breeze (**see **figure 3).**

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Land Breeze

Some other applications of convections are:

- Rooms are equipped with ventilators placed near the roof so as to have proper ventilation of air. This is because our breathing makes the surrounding air in the room warm and impure. This warm air, being less dense, rises up and escapes out of the ventilator. Then the cold fresh air, being denser, comes in through the ventilator and takes the place of the escaped warm-impure air. Thus, this continuous circulation of air keeps the air in the room clean and fresh.
- Room heaters and blowers are always placed on or near the floor of the room in winters. This allows the hot air near the heater or blower to rise up and warm the entire room.

Radiation of Heat

You know that heat flows from a body of higher temperature to a body of lower temperature. **But, do you know how the transference of heat takes place? How does heat travel through various mediums? And, how is it transferred in the absence of a medium?**

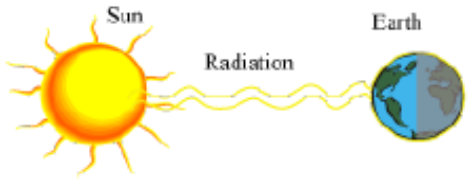
Transfer of heat can take place by three ways: **conduction, convection,** and **radiation.** In solids, the transfer of heat takes place by conduction. In liquids and gases, heat transfer takes place through convection. When no medium is present, heat transfer takes place by radiation.

Here, we will study about the transfer of heat through radiation.

Radiation

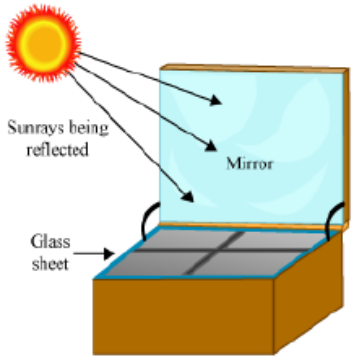
Radiation is a method of heat transfer which does not require a medium.

For example, the Earth receives heat energy from the sun by the process of radiation. We know that most of the space present between the Earth and the sun is nothing but vacuum. Hence, there is no medium existing between these two heavenly bodies. Therefore, the heat that the Earth receives from the sun is a result of the transference of heat through radiation.



Transfer of heat by radiation

A solar cooker also functions because of the heat energy obtained from the sun by the process of radiation.



Solar cooker obtains heat by the process of radiation

When we sit in front of a room heater, we feel hot. The heat that we obtain from the room heater is through both convection and radiation.

All hot bodies radiate heat.Our body also radiates heat to our surroundings. When heat falls on an object, a part of it gets reflected, another part is absorbed, and yet another may get transmitted. The temperature of an object increases because of the heat energy that is absorbed.

Do You Know?

It is advised to use an umbrella while going out in the sun. We know that the temperature of an object increases only when it absorbs heat. The fabrics used to make umbrellas are bad absorbers of heat. They reflect a large part of heat that falls on them. Hence, we are protected from the heat of the sun.

Applications of black and white surfaces

- White or light coloured clothes are preferred in summers whereas black or dark coloured clothes in winters. This is because white or light coloured clothes reflect most of the Sun's heat and absorb a little amount heat. Thus they keep our body cool in summers. Now, the black or dark coloured clothes absorbs most of the heat from the surroundings and keep us warm in winters.

- Utensils are painted black at the bottom to cook food very fast. This is because black colour absorbs more amount of heat and thus readily heats the cooking utensil and the food present in it.

Summary:

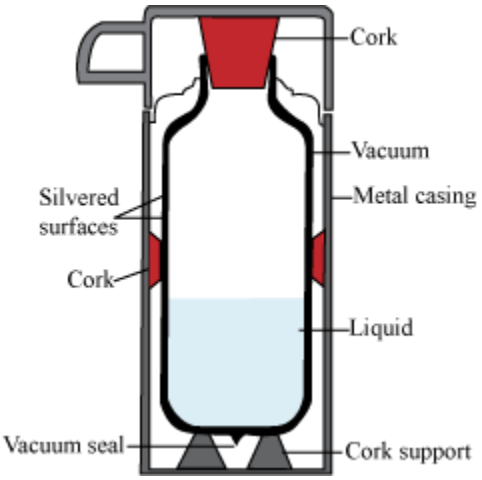
Conduction and convection require some material as a transport medium. These modes of heat cannot transfer heat between two bodies placed in vacuum. Radiation is the mechanism for heat transfer that requires no medium.

It is the manner of heat transfer to the earth from the sun through vacuum. Energy emitted by a body in the form of radiation by virtue of its temperature is called thermal radiation. Black bodies absorb and emit radiant energy better than bodies of lighter colours.

Thermos Flask

Reena goes for a picnic with her family. On reaching the picnic spot, she notices her mother pour out hot tea from a bottle. She wonders how the tea could remain warm in spite of the long journey they had made from their home to the picnic spot. Does the bottle have any special quality to keep things warm?

The bottle is a **thermos flask**. A thermos flask maintains the temperature of the materials kept inside it. Thus, it is used for keeping tea, coffee, milk, etc., warm.



A thermos flask is a double-walled glass vessel sealed at the top. Between the walls, there is a hollow, almost-vacuum space. The outer surface of the inner wall and the inner surface of the outer wall are silvered.

The flask is placed in a metal case, with a ring of rubber and a plastic cork at the top. This plastic cork is then covered with a cup.

Silver has a shiny surface and thus, is a bad radiator of heat. Therefore, the silver coating on the walls prevents the liquid kept inside from losing heat by radiation. The vacuum between the walls ensures that there is minimum heat loss due to conduction and convection.

The glass itself is a bad conductor of heat; cork and rubber are also not very good conductors. So, they also do not allow the heat of the liquid kept inside to escape.

Hence, the heat of the liquid cannot escape by conduction, convection or radiation. As a result, the temperature of the liquid in the flask remains almost unchanged.

Similarly, heat from the outside is also not allowed to enter the flask.