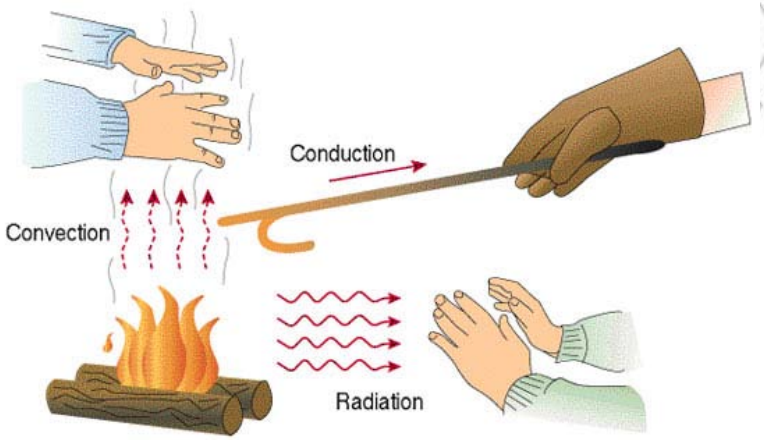
UNIT 4

HEAT ENERGY

Unit out comes: After completing this unit you should be able to:

- ✓ understand concepts related to heat energy.
- ✓ develop skill of manipulating problems related to heat energy.
- ✓ appreciate the interrelatedness of all things.
- ✓ use a wide range of possibilities for developing knowledge of the major concepts with in physics.



Introduction

In grade 7 physics, you learnt about temperature and heat. You learnt the differences between temperature and heat. Further more you studied about temperature scales, measuring temperature, types of thermometers and some effects of heating a body.

In this grade and this unit you will learn about heat transferring methods and the quantity of heat energy gained or lost by a substance.

Under heat transfer you will learn the three basic mechanisms of heat transfer namely **conduction**, **convection** and **radiation** and be introduced to different practical activities which help you to understand these heat transfer mechanisms.

The diagram on page 68 shows the different ways bodies get heat from a burning wood. Can you explain the different ways shown in the diagram?

When you deal with quantity of heat you will learn how to calculate heat lost or gained by a body. The relation between quantity of heat and change in temperature and nature of the substance will be your main focus. You will also be introduced to the concept of "Specific heat capacity".

Activity 4.1 Discuss with your friends on the following points.

i) What is temperature? And how is it related to heat?
ii) Explain the interrelationship between heat and molecular energy of a body.
iii) Is heat transferable? How do bodies get heat from different source?

4.1 Transfer of Heat

- Temperature is the measure of hotness or coldness of a body.
- It is the measure of the average molecular kinetic energy.
- It is an indication of the direction of heat flow.
- Kelvin is the SI uint of temperature.
- Thermometer is the instrument used to measure temperature

In grade 7 physics, you learnt about '*temperature*' and '*heat*'. Can you, explain them? The term temperature is one of the fundamental physical quantities. It is the measure of hotness or coldness of a body. Heat is a form of energy. Heat energy is directly related with the kinetic energy of molecules of a body. The kinetic energy of the atoms and molecules of matter gives rise to heat energy.

Heat transfer is the movement or flow of heat energy from a hotter body to a colder one.

Heat transfer occurs whenever there is a temperature difference between two bodies or between two parts of the same body. The movement of heat stops when the temperature of each object becomes the same. There are three ways by which heat moves from one body to another. These are Conduction, Convection and Radiation.

i. Conduction

Activity 4.2 Observing the transfer of heat by conduction

Material required: A metal rod, a source of heat (candle) wax, and paper pins.
Procedures: Fix the paper pins into wax around the metal rod.

i. Hold one end of the metal rod, and place its other end into a burning candle. (As shown in Fig 4.1)
ii. After a period of time, the wax near the candle melts and the pin falls.
iii. How did the heat move from the source to the metal rod?
iv. What do we call this method of heat transfer?

Heat energy can be transferred by conduction from one substance to another when they are in direct contact.

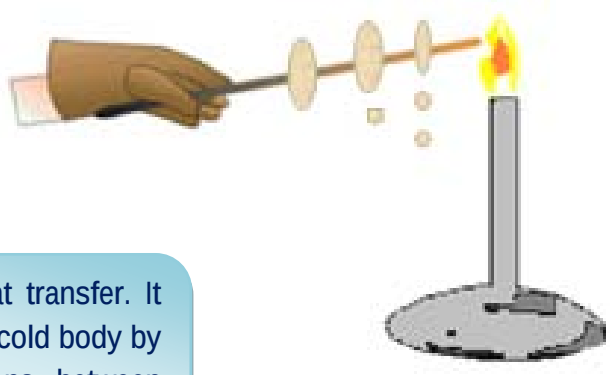


Fig 4.1Conduction of heat in a metal

Conduction is one way of heat transfer. It takes place from a hot body to cold body by means of successive collisions between neighboring particles.

Conduction is mainly seen with in solid objects; however it can happen when any material comes into contact with a source of heat. When you hold a cup of hot water, your hand gets heat by conduction from the hot water.

Activity 4.3 Classifying materials as conductors and insulators of heat

Materials required: The same materials as in Activity 4.2, and different materials like copper, steel, aluminum, wood, glass, plastic, etc.

Procedure: Use the procedure indicated in Activity 4.2 for different materials.

Fill in the table below

Materials	Good conductor	Poor conductor (insulator)
Copper		
Steel		
Wood		
Glass		

The degree with which heat flows within matter varies greatly.

Some materials are better conductors of heat than others. For example, metals are good conductors of heat, while a material like wood isn't. Metal heated on one end will soon be hot on the other end too, while this is not true with a piece of wood. Good conductors of electricity are often good conductors of heat.

Conduction is good in solid and it is poor within gases, because the atoms and molecules are not in close contact with each other.

Since the atoms in solid are closer to each other, solids conduct heat better than liquids or gasses. This means that two solid materials in contact would transfer heat from one to the other better than a solid in contact with a liquid.

Materials which allow heat to flow through them are called heat *conductors*. Iron, copper and other metals are examples of heat conductors.

Materials which do not allow heat to pass through them are called heat *Insulators*. Wool, wood, water glass, etc are examples of heat insulators.

What happens in conduction?

Heat flows from a hotter part of a body to colder part of a body. During heating, the molecules at the hot end of the material increase their vibrations since the temperature on the region is increased. As a result they collide with their slowly moving neighbors and their kinetic energy is transmitted successively from one particle to the next, until it reaches the colder region. Hence heat energy is transmitted from one end to the other while the particles are fixed in their original position except for their violent vibration about their original position.

Methods of controlling heat loss

Heat conduction is important in our daily lives. In cold weather, we wear clothes that stop the conduction of heat from our warm bodies to the cold air. For example, we wear head cap, hand gloves, cotton jacket, and wear socks to keep heat in our body.

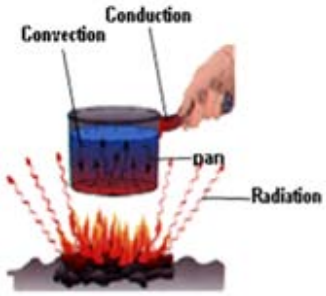


Fig 4.2 Heating a pan

Activity 4.4 Practical work

i. Put a pan on a hot stove. Can you touch the pan after some seconds? Why?
ii. Why do you think the handle of a pan is made of wood or plastic?
iii. Explain why people use carpets and rugs in their room.
iv. Stand on your bare feet on a ceramic tiled floor. What do you feel?

From Activity 4.4 and Fig. 4.2 you will notice that, when a pan is placed on hot stove, the bottom of the pan is in contact with a hot burner. The heat flows through the metal and soon raises the temperature of all parts of the pan.

Similarly, when you step on a carpets very little heat is transferred away from your feet, so you stay warm. But when you step bare feet on cement floor or ceramic tiled floor, more heat is transferred from your feet. So you feel cold.

Handles on metal pan are often made of wood or plastics to stop the conduction of heat from the burner to your hand as shown in Fig 4.3.

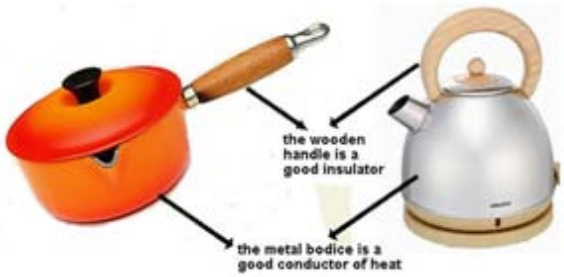


Fig 4.3 Examples of good conductors and poor conductors

Carpets and rugs are also used to reduce loss of heat by conduction.

Activity 4.5

How do your families keep heat in foods (drinks) at home? Discuss this question with your parents.

ii. Convection

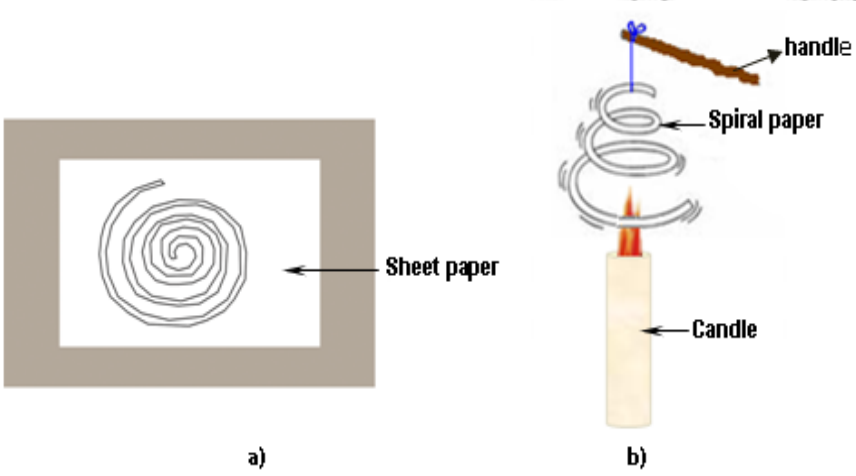


Fig 4.4 Observing the effect of heat transfer by convection

Activity 4.6 Observing heated air rises

Material: A sheet of paper, scissors, and thread.

Procedure: Cut the paper along the line spirally. (Fig. 4.4(a))

i. Hang the cut spiral paper by passing a string (thread) along it center.
ii. Put a burning candle under heating the spiral paper.(Fig. 4.4(b))
iii. Observe and explain what happens to the paper.
iv. Explain what causes it to rotate.

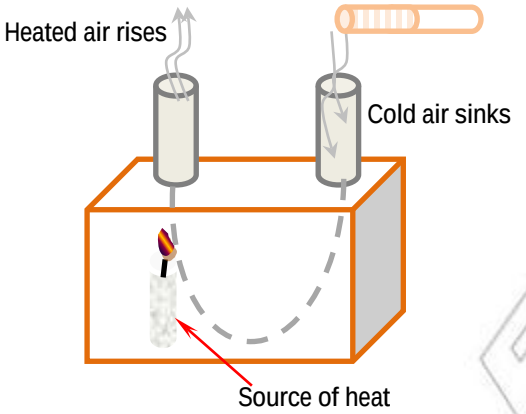


Fig 4.5 Convection in air (Smoke box)

Activity 4.7 Observing convection in air

Material required: A cardboard box with one side covered with transparent plastic sheet.

i. A source of heat
ii. Two tubes made from paper sheet.
iii. A smoking paper

Procedure: Assemble the materials as shown in Fig 4.5. Observe and explain what happens to the smoke.

- Explain the process of convection in this demonstration.

In Fig 4.4 and 4.5, the air gets heated by the burning candle. The heated air rises because it expands and become less dense than the air around it. Cooler air, which is heavier, goes down and replaces the hot air place. This cold air in turn is heated. Fig 4.4 and Fig 4.5 shows transfer of heat by convection in air.

The transfer of heat from one place to another by the actual movement of particles of the medium is called convection. Convection takes place primarily in fluids (gas and liquids). It is caused by the expansion of fluid particles when it is heated. As fluid particles expand, its density decreases. Thus the lighter portion of the fluid rises, and cold fluids takes its place and get heated. In convection, heat is carried by the moving medium. Convection can occur only in liquids and gases.

Transfer of heat by convection is applied in home, industry and in nature.

1. Air conditioner, chimney and boiling water in a dish use convection.
2. Land and sea breezes also work with convection. Wind blows from sea to land during the night, while wind blows from land to sea during the day because of temperature difference
3. The balloon shown in Fig 4.6 uses convection. A hot air balloon contains heated air having less density than the surrounding air. Thus the heated air rises up taking the balloon with it. For what purpose is a hot air balloon used?

Fig 4.6. Uses of convection in a balloon

iii. Radiation

Activity 4.8

Discuss: i) How does the heat from the sun reach our earth?
ii) How does the sunlight change into heat on the earth's surface?
iii) What do you call this type of heat transfer?

Heat transferred by radiation is also called **heat radiation**. Heat radiation is carried by an electromagnetic wave called **infra-red wave**. This wave is not visible to human eyes.

All objects emit heat radiation. For example, if an object is hotter than its surroundings, then it will give out heat radiation. In doing so, it will lose heat and cool down. Heat from electric heater and heat from a burning charcoal reaches its surrounding by radiation. For example, when we sit around a fire we feel warm. Conduction or convection is not responsible here. Since air is a poor conductor of heat and the warm air rises upwards. The heat reaches to our body from the fire by radiation. Heat can be transmitted by radiation through vacuum or a material medium.

Radiation is the transfer of heat from one place to another without a material medium. The heat of the sun reaches the earth by the process of radiation. Heat can be transferred by radiation in vacuum.

Types of surfaces will affect how quickly the object heats up. A rough and black surface is a good emitter and absorber of heat radiation while shiny and polished flat surface is a poor emitter and absorber of heat radiation.

Activity 4.9 Discuss the following with your friends.

- What do you know of the terms: absorber, reflector and emitter of heat? Describe them and give examples related to heat absorption, reflection and emission.

Activity 4.10 To observe which materials are good absorbers of heat radiation.

Material required: Two identical cans; one painted white and the other painted black, thermometer, the sunlight.

Procedure: Fill the two cans with equal volume of water

- Put a thermometer in each can and leave both cans in the sunlight.
- Measure the temperature of water in both cans, and record the reading data

at an interval of time, as shown in Fig 4.7.

- Draw the graph of temperature versus time taken for both cans.
- Which material (can) absorbed more heat radiation?

Heat radiation is controlled in house construction, in types of clothes worn, and thermos flask. For example, houses built in very cold climate use special materials for flooring, walls and roofing. The heat supplied to warm the house is absorbed by good absorbers and emitted back to warm the room (house). People living in hot areas wear white clothes to reflect the heat radiation because white clothes are poor heat absorbers.

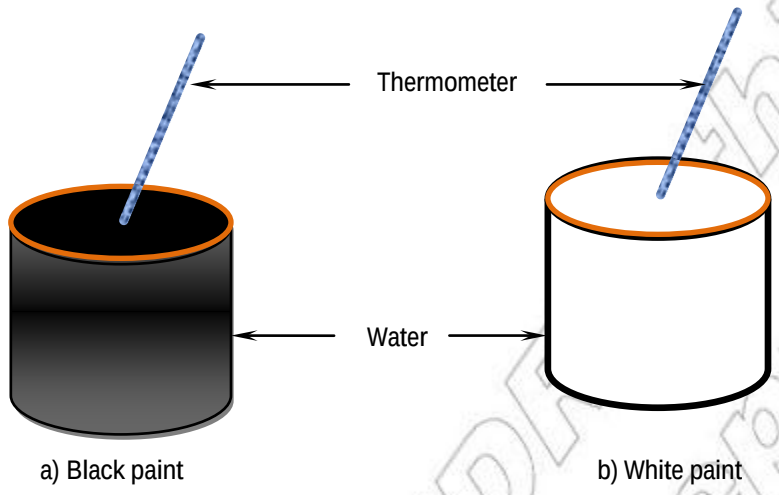


Fig 4.7 Observing good absorbers of heat radiation

Check point 4.1

1. **Under what condition, does heat flow from one body to another?**
2. **State the three ways of heat transfer.**
3. **Distinguish between conduction and convection of heat transfer methods.**
4. **Explain what good and poor conductors of heat are.**
5. **How does heat radiation from the sun reach the earth?**

4.2 Quantity of Heat

The important concepts you will learn under this section are the quantity of heat and the specific heat capacity of substances.

Activity 4.11 *Dependence of heat on the mass of a body.*

Material: Source of heat, two metallic balls (small and big) a tong, wax and vessel with water

i. Put the two metallic balls in water
ii. Heat the water with the balls until it boils
iii. Take large and very small pieces of metallic objects from boiling water and place them on a large piece of wax.
iv. Which metallic objects melted more wax?
v. Which object has more heat energy?
vi. What does this show?

When a substance cools, it loses heat energy. When a substance is heated it gains heat energy. A body can receive some heat from different sources.

We cannot actually measure the total amount of heat energy that a body contains. But, we can measure how much energy is gained or lost by a body. How do we measure the quantity of heat lost or gained by a body?

Specific heat capacity

The amount of heat energy needed to raise the temperature of 1kg mass of a substance by 1^0C is called the *specific heat capacity* of the substance.

Table 4.1 gives the values of specific heat capacity of some liquids and metals. The unit of specific heat capacity is Joule/kg °C. (Joule /kg K)

For example, 1kg of aluminum would need 900 J of heat to raise its temperature form 27 ^{0}C to 28 ^{0}C. If the temperature of the aluminum falls from 28 ^{0}C to

27 ^{0}C, it will give out 900 J of energy. So, the general formula for calculating heat energy transferred is:

Heat energy = mass × specific heat capacity × temperature change.

$Q = m \times c \times (T_2 - T_1)$

Where Q is the heat gained or lost

m is the mass of the body

c is the specific heat capacity

($\Delta T = T_2 - T_1$) is the temperature change.

Table 4.1 The specific heat capacity of some substances

Substances	c (in J/kg0c)
• Water	4200
• Brine (salty water)	3000
• Aluminum	900
• Iron	480
• Copper	385
• Lead	130

From Table 4.1 you notice that specific heat capacities of solids are much less than those of the liquids. For example, water needs nearly five times as much heat as the same mass of aluminum.

Example 4.2

1. How much heat is required to raise the temperature of 500g of iron from 50 °C to 250 °C? (c = 480J/kg °C)

Given	Required	Solution
m=500g = 1/2 kg	Q = ?	Q = mc ΔT
T_i = 50 °C		= 0.5kg × 480J/kg °C ×200
°C		
T_f = 250 °C		= 48,000J

c = 480J/kg °C = 48 kJ

2. How much heat is lost by a copper bar weighing 2000g when it cools from 100 °C to 40 °C? c = 385 J/kg °C?

Given	Required	Solution
m = 2000g=2kg T_i = 100 ^{0}C T_f = 40 ^{0}C C = 385 J/kg °C	Q = ?	Q = mc ΔT = 2kg ×385J/kg °C× −60^{0}C = - 46,200 J

Note: The negative sign indicates heat lost.

3. A 200 g of copper is cooled from 100 °C to 0 °C. How much heat is given off? (c = 385 J/kg °C)

Given	Required	Solution
m = 0.2kg T_i = 100 °C T_f = 0 °C c = 385 J/kg °C	Q = ?	Q = mc ΔT ΔT = T_f - T_i = 0 °C – 100 °C = – 100 °C Q = 0.2kg ×385J/kg °C×(-100 °C) = - 7700 J

Check point 4.2

1. What is heat?
2. When do we say a body has gained heat?
3. Name the factors on which heat gained or lost depends on?
4. Write the equation of specific heat capacity for a given substance.
5. Define specific heat capacity.

SUMMARY

In this unit you learnt that:

- heat is a form of energy and is expressed in unit of joules (J); while temperature is the measure of the hotness or coldness of a body.
- heat transfer is the transmission of heat energy from a body at higher temperature to a body at lower temperature. The three mechanisms (ways) of heat transfer are:
  - i) Conduction
  - ii) Convection
  - iii) Radiation
- heat conductors are materials which allow heat flow through them. Heat Insulators are materials which do not allow heat to pass through them.
- the quantity of heat which is lost or gained by a body is directly proportional to mass of the substance, temperature rise and nature of the substance. The quantity of heat is given as

  $Q = mc\Delta T$
- the specific heat capacity of a substance is the heat required to raise the temperature of 1 kg of it through 1 ^{0}C. The SI unit of specific heat capacity is J/ kg ^{0}C or J/kg K. Water has a highest specific heat capacity of all liquids.

Review Questions and Problems

I. Fill in the blanks with the proper term or phrase.

1. _____ is the measure of the average kinetic energy of particles in a body.
2. _____ is the SI unit of heat energy.
3. _____ is the transfer of heat between two bodies by contact.
4. Materials that do not allow heat to pass through them are called_____.
5. _____ is the heat required to raise the temperature of 1kg mass of a substance by (1°C)

II. Short answer questions.

1. Explain a conventional method of heat transfer.
2. Give practical examples (3 examples) where poor conductors (insulators) of heat are used in our daily life to protect heat lost.
3. State the three methods of heat transfer.
4. Define the term specific heat capacity of a substance and state its unit.
5. Explain the formula $Q= mc (T_2-T_1)$ in words.

III. Word problems

1. The temperature of a body of mass 0.5 kg is raised from 15 °C to 20 °C. What is the heat taken by the body if its specific heat capacity is 400 J/kg °C?
2. How much heat energy must be supplied to raise the temperature of 2 kg of water by 20 °C? (c of water =4200 J/kg °C).
3. If 5400 J of energy is supplied to 3 kg of aluminum, by how much will the temperature rise? (c of aluminum is 900 J/kg °C)