# 8 TRANSMISSION OF HEAT

# CONDUCTION

**OBJECTIVES**

At the end of the topic, students should be able to:

- explain conduction in terms of the kinetic molecular theory;
- explain thermal conductivities and show that different materials conduct heat at different rates;
- differentiate between good and bad conductors of heat;
- state some uses of good and bad conductors.

Heat is energy transferred due to temperature difference between two points. Heat transfer, from hot to cold region can occur in three different ways: **conduction, convection** and **radiation**.

**Conduction** is the mode of heat transfer through **solids, liquids** and **gases.** Heat transfer through a substance from the hot to the cold end takes place through vibration of molecules. Some materials conduct heat quickly; they are called **good conductors.** Metals are generally good conductors of heat. Materials, which do not conduct heat well, are **bad conductors** or insulators of heat. Wood, plastic, glass and rubber are examples of bad conductors of heat.

## Examples of conduction

- When you hold a hot cup of tea, the metal cup conducts heat quickly from the hot tea to your hand.
- If a flame heats one end of a copper rod, heat is transferred from the end of the rod in direct contact with flame to the other end by conduction.

## Using kinetic theory to explain heat transfer by conduction

Good conductors like metals, have free or mobile electrons moving at random in all directions inside the material. If one end of the material is heated, the mobile or free electrons near the flame gain more energy and move rapidly inside the conductor. These energetic mobile electrons sometimes collide with other mobile electrons with less energy and transfer their excess energy to them. The collision and transfer of energy from one free electron to another continue until heat is carried from the hot to the cold end of the material. This process of heat transfer by free or mobile electrons in a material is known as **conduction.** Conduction of heat through a material can be explained using its molecules. Molecules closest to the heat source gain energy and vibrate faster, excess energy is transferred to the neighbouring molecules until heat gets to the cold end.

***Conduction is the transfer of heat energy by mobile (free) electrons or vibrating molecules from the hot to the cold end of a substance without the bulk movement of the substance.***

## Thermal conductivity

Thermal conductivity is the ability of a material to conduct or transfer heat energy from one part of the substance to another. The rate of heat conduction through a material depends on:

- **Temperature difference between two points:** Heat is transferred through a substance fast if the temperature difference between the points on the material is high.
- **Length of the material or distance between the points:** The greater the distance between the two points on the material, the less the rate of heat transfer.
- **Area of the cross-section or the thickness of the material:** Heat is transferred better through a thick material than a thin material.
- **Nature of the material:** Some materials are better conductors of heat than others. Copper, for example, conducts heat better than wood.

The time rate of heat conduction through a material is proportional to the product of its area of cross-section and the **temperature gradient.** Temperature gradient is the rise in temperature per unit length.

$$\frac{Q}{t}=\frac{kA(T_1-T_2)}{L}$$

Q = Quantity of heat transferred

t = time during which the heat is transferred

A = Area of cross-section

$\frac{Q}{t}$ = rate of heat transfer or heat transferred per unit time.

$\frac{T_1-T_2}{L}$ = temperature gradient.

$T_1 - T_2$ = temperature difference between two points.

$L$ = length of the conductor or the distance between the points of the conductor under consideration.

$K$ = thermal conductivity of the material. The unit of thermal conductivity (k) is $Wm^1K^1$.

## Worked examples

1. The temperature difference between the ends of a conductor 38 cm long is 25 Â°C. Calculate the heat energy per second passing through the conductor given that the thermal conductivity is 380 $Wm^{-1}$ $K^{-1}$ and the area of the cross-section is 1.0 x $10^{-2}$ m.

### Solution

$$\text{Temperature gradient } \frac{T_1-T_2}{L}= \frac{25}{0.38}=65.79$$

$$\frac{Q}{t}=\frac{kA(T_1-T_2)}{L}$$

$$=380\times1.0\times10^{-2}\times65.79$$

$$=250\text{ W}$$

[the unit of rate of heat transfer is J/s or Watts (W)]

2. A thermal conductor of length 0.5 m loses 3000 J in 300 seconds when the temperatures at the ends are 100 Â°C and 80 Â°C respectively. Calculate the thermal conductivity if the area of the cross-section is 1.5 x $10^{-2}$ m.

### Solution

$$\text{Energy lost per second } \frac{Q}{t} = \frac{3000}{300} = 10\,W$$

$$\text{Temperature gradient } \frac{T_1 - T_2}{L} = \frac{20}{0.5} = 40$$

$$\frac{Q}{t} = \frac{kA(T_1 - T_2)}{L}$$

$$10 = k \times 1.5 \times 10^{-2} \times 40$$
$$k = 16.67\ Wm^{-1}\,K^{-1}$$

## Comparing thermal conductivity of different solids

The rate at which heat is transferred in a solid depends on certain factors. The factors are: the nature of the material if their length, thickness and temperature remain the same. Figure 9.1 is used to compare the thermal conductivity of different solids in the form of a rod.

- Rods of different materials having the same length and thickness are used.
- The rods are coated lightly with wax and placed in hot water tank.
- Hot water heats the rods to the same temperature. Each rod conducts heat along its length to melt the wax.
- Good conductors transfer heat faster to melt the wax along its length than bad conductors.
- The wax melts most for silver followed by copper and least for wood.

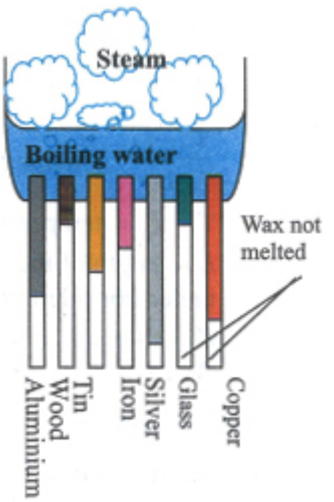



*Figure 8.1 Comparing conductivity of different solids*

The result of the experiment confirms that heat conduction through a material varies depending on their conductivity. Silver is the best conductor of heat quickly followed by copper. Wood and glass are bad conductors of heat. The thermal conductivity of good conductors is high because they have mobile or free electrons which help to transfer heat energy. The thermal conductivity is low for bad conductors or insulators because they do not permit free movement of electrons.

## Water as a bad conductor of heat

All liquids are bad conductors of heat apart from **mercury** and **molten metals**. Figure 9.2 is used to show that water is a bad conductor of heat.

- The tube is filled with cold water and wire gauze is used to trap ice at the bottom of the boiling tube.
- The water is heated from the top of the boiling tube to its boiling point. The water at the top boils but the ice at the bottom does not melt. The water could not conduct heat to the bottom of the boiling tube to melt the ice.
- If a good conductor of heat like iron or spoon is placed in the boiling tube to touch the ice at the bottom, heat is conducted through the spoon to melt the ice.
- Water is a bad conductor of heat because it does not conduct the heat to the bottom of the boiling tube to melt the ice.

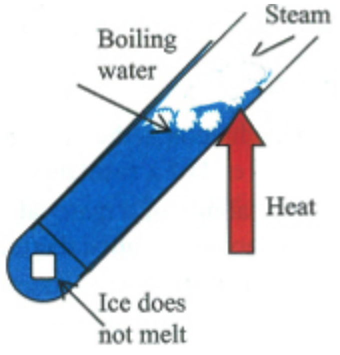



*Figure 8.2 Experiment to demonstrate that water is a bad conductor of heat*

## Air as a bad conductor of heat

We can demonstrate that air is bad conductor of heat as follows:

- Hold a stick of match a little distance from a flame, the match will not ignite because air is a bad conductor of heat.
- Hold the match on a very hot metal, the match ignites.

The match could not ignite when it is held near the flame because the air molecules between the flame and the match could not conduct heat to the match.

## Uses of good and bad conductors of heat

1. Good conductors of heat are used in making cooking pots, kettles, saucepans, radiators for cars and aeroplane engines. Metals like copper and aluminium are used to produce these things because

they transfer heat quickly to the food inside the pot or away from the radiators. The base of a pressing iron is made of a good conductor to help it transfer heat to the cloth being pressed.

2. Bad conductors of heat like plastic and wood are used to make the handles of cooking utensils and pressing iron because they conduct very small quantity of heat.
3. Air is a bad conductor of heat. When air is trapped by animalâ€™s wool (fur) or birdâ€™s feathers, they prevent loss of heat by conduction. This helps the animal or bird to keep warm during cold season.
4. Rug and carpet are bad conductors of heat; therefore, they do not conduct heat away from our feet. Concrete floor is a better conductor of heat and it conducts heat away from the foot very fast. This is why we feel cold when we step on concrete floor with bare feet.
5. Asbestos are used as ceiling boards to keep heat from the galvanised aluminium sheet from reaching the floor because they are good insulators. Roofs made from thatched leaves stop heat radiations from getting to the floor better than iron roofs without ceiling boards.

## Summary

- Conduction is the transfer of heat energy by mobile or free electrons from the hot to the cold end of a substance without the bulk movement of the substance.
- The ability of a material to conduct or transfer heat energy from one part of a substance to another is called thermal conductivity.
- Silver is the best conductor of heat quickly followed by copper.
- The thermal conductivity of good conductors is high because they have mobile or free electrons, which help to transfer heat energy.
- All liquids are bad conductors of heat apart from mercury and molten metals.

## Practice questions 8a

1. Explain the following observations.
   a) A carpet feels warmer to bare feet than a cement floor.
   b) The handles of cooking utensils are made of plastic.
   c) Birds spread their wings to trap air in cold season.

2. Define conduction and explain heat transfer by conduction using kinetic theory of matter.
3. (a) What do you understand by thermal conductivity of a material?
   (b) Outline the steps you will take to compare the thermal conductivity of different solids.
4. (a) What are the factors that determine the rate of heat conduction through a solid?
   (b) How long will it take 4800 J of heat to flow through a copper rod of length 100 cm and area of cross-section 5.0x$10^{-4}$ $m^2$, if the temperatures at the ends of the conductor are 250 Â°C and 50 Â°C respectively? {Thermal conductivity of copper is 380 $Wm^{-1}K^{-1}$}
5. Describe and explain one example each of the use of a good conductor and bad conductor of heat.
6. Explain why metals are good conductors of heat while insulators are not.
7. At what rate is heat conducted through a metal whose thermal conductivity is 240 $Wm^{-1}$ $K^{-1}$ if its cross-sectional area is 1.2Ã—$10^{-4}$$m^2$, the length is 0.2 m and the temperatures between the ends of the conductor are 300 Â°C and 100 Â°C respectively.

# CONVECTION

**OBJECTIVES**

At the end of this topic, students should be able to:

- explain convection in terms of the kinetic molecular theory;
- explain the convection process in liquids and gases;
- state some uses of convection.

**Convection** is the mode of heat transfer in **liquids** and **gases** (fluid). Heat is transferred as a result of movement of the fluid (liquid or gas) from the hot to the cold part of the fluid. Fluids flow (circulate) easily; therefore they carry the heat energy from one part of the fluid to another. The molecules of the fluid close to the source of heat absorb heat energy, expand and become less dense. The warm, less dense molecules rise to the top and are immediately replaced by the sinking denser molecules.

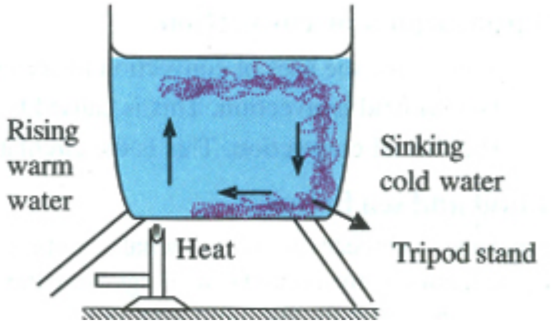


*Figure 8.3 Convection current in liquid*

***Convection is the transfer of heat energy by internal movement of fluid molecules from the hot to the cold part of the fluid.***

Heat transfer by convection is not possible in a solid because the solid molecules are not free to flow or circulate at ordinary temperature.

**To investigate heat transfer by convection:**

- Carefully drop a crystal of potassium permanganate at the bottom of beaker filled with cold water as shown in Figure 8.3.
- Heat the water where the crystal is placed and watch the purple coloured water rise to the top and the sinking cold water taking the place of the rising warm water.
- The rising of warm water and the sinking of cold water set up a circulation of water called **convection current.**

Convection is set up in the water because the warm water expands as it absorbs heat from the flame to become less dense. The less dense water rises to the top while the cold dense water sinks to replace the rising warm water. This process is repeated until the entire water boils.

## Convection in gases

Figure 8.4 is a glass box with two chimneys used to demonstrate the convection in gases.

- A burning candle is placed under one chimney and smoking paper is placed above the second chimney.
- Thick smoke sinks down from the smoking paper and is heated by the candleâ€™s flame.
- The heated air becomes less dense and rises through the chimney above the flame while cold air sinks again to replace the rising warm air.
- A circulation of rising warm air and sinking cold air inside the box is called convection current in gases.

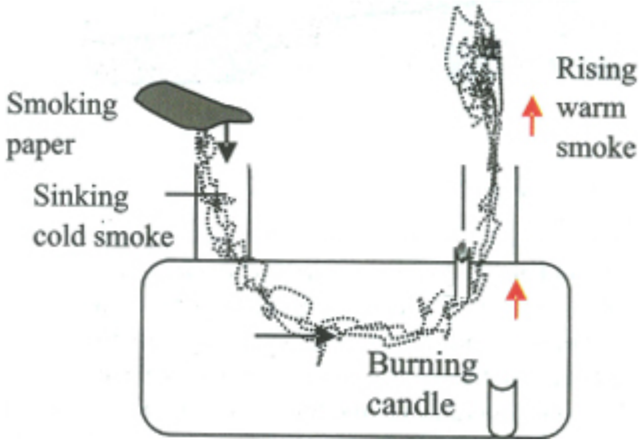



*Figure 8.4 Convection current in gases*

## Applications of convection

We will discuss the uses of convection under two headings:

- The **natural convection.** This is caused by differences in the density of the fluid.
- The **forced convection.** This is the circulation of liquid or gas using pumps and fans.

## Land and sea breezes

Land and sea breezes are phenomenal examples of the natural convection. Heat energy from the sun is absorbed by the land and sea water equally in the daytime. The land is a better conductor compared with the seawater and therefore warms the air close to its surface. The heated air becomes less dense, rises and moves toward the sea. Cold air from the sea moves towards the land to replace the rising warm air. A circulation of warm air rising and moving toward the sea and cold air moving towards the land is set up.

The cold breeze blowing from the sea towards the land is called **sea breeze.**

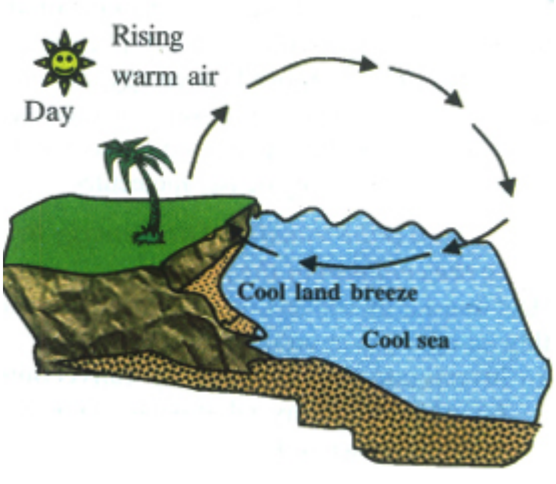



*Figure 8.5 The land breeze*

At night, the land loses most of its heat energy while the sea retains most of the heat energy absorbed during the day. This because the heat capacity of the sea water is higher than that of the land, therefore the sea, being hotter than the land, warms the air close to its surface. The warm air from the sea rises and moves towards the land and is replaced by cold air from the land. The cool breeze blowing from the land to the sea is called **land breeze.**

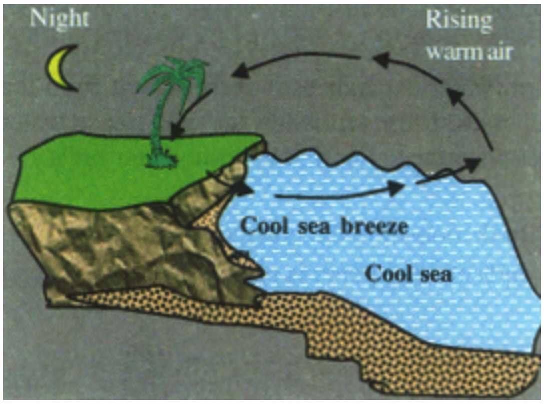



*Figure 8.6 The sea breeze*

## The car radiator

The car radiator, as a forced convector, uses a fan and pumps to increase the rate of circulation of water and air to achieve rapid cooling of the engines. Cold water is passed through the engine; the heat of the engine warms the water. The hot water rises to the top of the radiator and is cooled by the cool breeze blowing in from the outside and the radiator fan. The water cools and sinks to the bottom of the radiator and is returned to the engine to continue the cooling process.

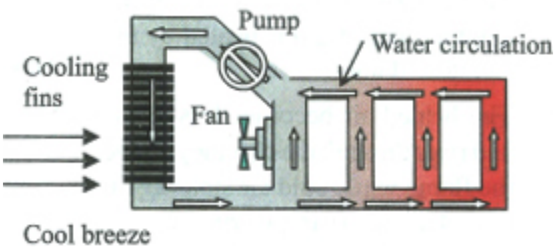



*Figure 8.7 Convection in car radiator*

## Convector heater

The convector heater is used to warm a room by convection. The heating element warms the air around it, the warmed air expands, becomes less dense and rises. Cold air moves in to replace the rising warm air. The movement of warm and cold air continues until the whole room is warm. Room warmers are usually placed near the floor to enable convection to take place.

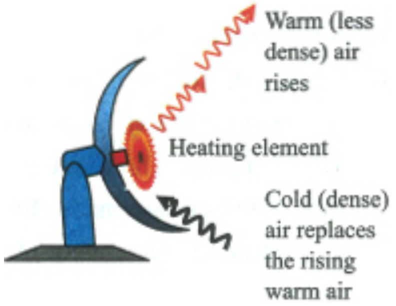


*Figure 8.8 A room convector*

## The domestic water supply

The domestic water supply is used to give continuous flow of hot and cold water by convection in the homes. The boiler or the heating element is placed at the bottom so that hot water will rise to the top by convection. The heating element heats the water around it; the heated water becomes less dense and rises to the top. Cold water descends through the pipe at the base of the of the storage tank to replace the rising hot water. The circulation is usually slow and may be increased by using pumps to boost the water supply.

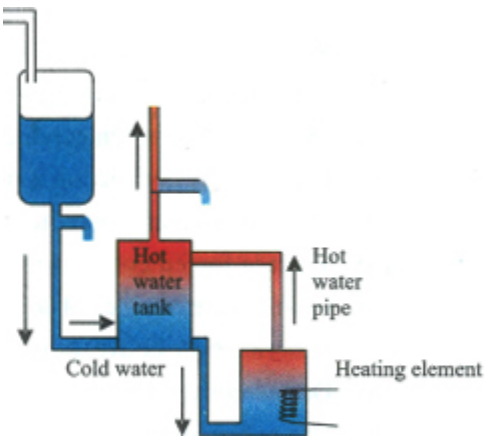


*Figure 8.9 Circulation of hot and cold water for domestic use*

## Refrigerator

The cooling unit of a refrigerator is at the top so that cold denser air from the freezer will sink to cool the food items in the other compartments. Warm air from the food items near the bottom rises to the top where they are cooled again and the circulation of cold and warm air continues until the entire refrigerator is cold.

## House ventilation

Modern buildings are well ventilated. Windows are put near the floor and ventilation holes near the ceiling so that cold and fresh air can enter from the window while the warm air can escape through the ventilation holes.

## Summary

- Convection is the mode of heat transfer in liquids and gases (fluid).
- Convection is the transfer of heat energy by internal movement of fluid molecules from the hotter to the colder part of the fluid.
- Convection is set up in the water because the warm water expands, becomes less dense and floats on denser water after absorbing heat from the flame.
- The two types of convection are the natural and forced convections. Land and sea breezes are examples of natural convection. The cold breeze blowing from the sea towards the land is called the sea breeze.
  The breeze blowing from the land to the sea is called land breeze.
- The boiler or the heating element of electric kettles and boilers are placed at the bottom so that hot water will rise to the top by convection.

## Practice questions 8b

1. Explain the following occurrences:
   (i) Smoke always rises upwards.
   (ii) Ventilation holes are put near the ceiling.
   (iii) Windows are made close to the floor.
   (iv) Heating elements of electric kettles are placed at the bottom.
   (v) Freezer compartments are always at the top of the refrigerator.
2. (a) What is convection?
   (b) Explain convection using kinetic theory of matter.
3. (a) Distinguish between conduction and convection.
   (b) Explain why convection is not possible in a solid.
   (c) Describe an experiment to demonstrate convection in a liquid.
4. (a) What is forced convection?
   (b) Give three examples of forced convection and one example of natural convection.
   (c) Describe how convection is forced in a car radiator.
5. (a) Define convection.
   (b) Use convection current in gases to explain land and sea breezes.
6. (a) Explain the term convection.
   (b) Explain why room warmers are put close to the floor while

air conditioners are placed close to the ceiling.

(c) State the advantage of having a chimney in the kitchen.

7. What part does convection play in the:

   (a) freezing of water?

   (b) circulation of hot and cold water in a domestic water supply?

8. Explain why water transfers heat energy by convection but does not transfer much heat by conduction.

# RADIATION

**OBJECTIVES**

At the end of the topic, students should be able to:

- explain radiation in terms of electromagnetic energy given by hot bodies;
- explain how heat radiation can be detected;
- state how the amount of heat radiated by a surface depends on:
  - colour of the surface;
  - temperature of the surface;
- state some uses of radiation.

Radiation is the third mode of heat transfer. Heat radiation can pass through a vacuum; therefore, molecules are not needed to transfer it. Energy from the sun reaches the earth by radiation because between the earth and the sun is a vacuum (empty space).

***Radiation is the transfer of heat energy by means of electromagnetic waves from hot to cold regions.***

All objects, (solids, liquids or gases) emit radiation if their temperature is higher than the temperature of their surroundings. Temperature and colour of the surface determine the amount of energy radiated by a substance. The hotter the object the more energy it radiates.

Heat radiation is also called **infrared radiation** because it is part of the wave found at the red end of the electromagnetic wave. When absorbed by any medium, it makes them hotter by increasing their temperature.

## Detection of heat radiation

Heat radiation can be absorbed when they hit a body. The radiation from a hot object is detected using heat sensitive devices. *A thermometer with its bulb painted black is used to detect radiation from a hot object*. Black surfaces absorb radiation more than any other surface, therefore, a thermometer with its bulb blackened, detects radiation better than a thermometer with the bulb painted in any other colour.

The amount of radiation from a body can be measured. The best way to detect radiation is to convert it to electrical signal which can be measured using a galvanometer. A thermopile is a device which detects and measures heat radiation by changing it to an electrical signal, see fig 9.10. A thermopile is an arrangement of thermocouples in series to increase the emf produced when radiation falls on the junctions. A galvanometer connected across the ends of the junctions deflects to measure the amount of heat radiation reaching the junctions.

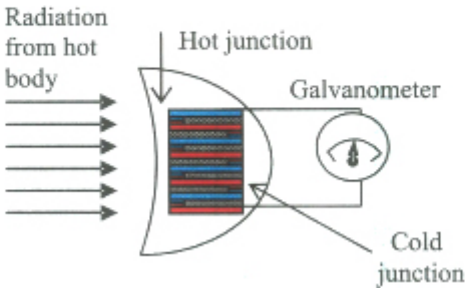



*Figure 9.10 Thermopile*

## Good and bad radiators

**The amount of radiation given out by the body depends on its temperature and the colour of its surface.** We can prove this by using a hollow copper cube known as **Leslie cube** (see fig 9.11) with the sides painted with different colours. One side is painted dull black; another side is highly polished to reflect heat away. The remaining sides are painted with other colours, some dull and some bright. The demonstration is done as follows:

(i) Boiling water is poured into the cube and a thermopile or blackened thermometer placed at equal distances from the surfaces.

(ii) The readings of the thermometer or thermopile in each position are taken.

(iii) The highest reading of the thermometer or the thermopile is obtained when it is facing the dull black surface while the least reading is obtained when it is facing the highly polished surface.

(iv) Using warm water gave the same result but the radiation from each surface is smaller.

**Conclusion:** Different surfaces radiate heat by different amount depending on the colour of their surface and temperature. **Dull black surfaces radiate heat best. They are good radiators of heat energy. Polished surfaces retain heat most; they are poor radiator of heat energy.** Dull coloured surfaces are good radiators of heat energy while bright surfaces are poor radiators of heat energy.

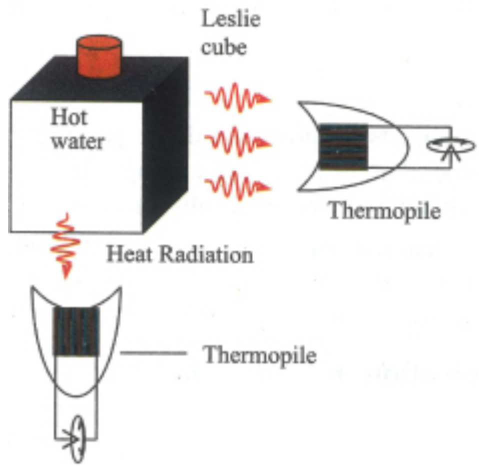



*Figure 9.11 Radiates from different surfaces*

## Good and bad absorbers of radiation

Some surfaces absorb heat radiation better than others do. The absorbing abilities of dull black surfaces and shiny (highly polished) surfaces can be investigated as follows:

a. Two metal plates having the same size are arranged as in Figure 9.12. Plate A is painted with dull black paint while plate B is polished.

b. A cork of the same weight is attached outside each plate with candle wax.

c. A heater (H) is placed at the middle of the plates so that the plates receive equal amount of heat radiation.

d. When the heater is switched on, the cork at the back of the dull black plate (A) drops first, while the cork at the shiny or polished plate remains.

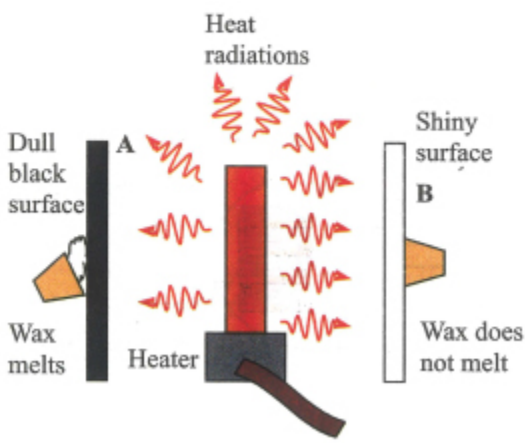



*Figure 9.12 Dull black surfaces absorb heat better than shiny surfaces.*

**Conclusion:** Dull black surfaces are good absorbers of heat radiation while shiny surfaces are bad absorbers of heat radiation.

In summary, dull black surfaces are both good absorbers and good radiators of heat energy. For this reason, car radiator and refrigerator cooling fins are painted with dull black paints. Shiny or polished surfaces are both bad absorbers and radiators of heat energy. They are used as reflectors to reflect heat radiation away, therefore, they can keep liquid hot or cold for a long time.

## The law of radiation

**Every object radiates heat energy if the temperature is higher than the temperature of its surroundings and absorbs heat energy when its temperature is less than the temperature of its surrounding.** A body which absorbs radiation of all frequencies reaching it, is called a **black body.** A black body is a perfect absorber and a perfect radiator. The rate of radiation or absorption is directly proportional to fourth power of the absolute temperature.

$$H = \text{Ïƒ}T^{4}$$

Ïƒ = Stefanâ€™s constant and T = Absolute temperature

## Uses of radiation

### 1. The vacuum flask

The vacuum or thermo flask is used to keep liquids hot or cold. It has the following essential parts:

- A double walled glass with a vacuum between the walls. The vacuum stops heat lost by conduction and convection because no molecule is present to transfer heat energy.
- Shiny (polished) surface. The outer walls of the vacuum flask are silvered to reduce loss of heat by radiation. This is because a shiny or silvered surface reflects heat radiation back to the liquid inside the flask.
- Plastic cover or cork. The plastic cover minimizes heat lost by evaporation and conduction.

The construction of a vacuum flask minimizes heat loss by conduction, convection, radiation and evaporation. This is how it keeps liquids hot or cold.

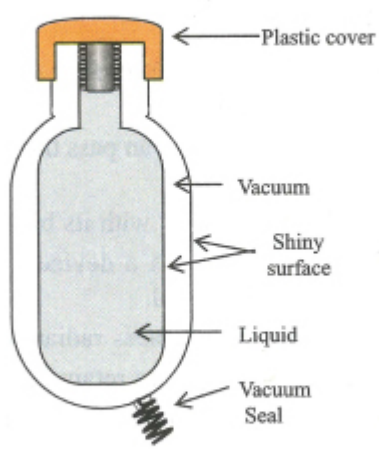


Figure 9.13 The vacuum flask

## Infrared radiation

Heat radiation from hot objects is called **infrared radiation.** The radiation from hot objects like the sun gets to the earth, travelling in straight lines at the speed of light. Giant concave mirrors reflect infrared radiation to its focus. In hot countries, the average temperature for a day is usually high; large concave mirrors can focus heat radiations from the sun to a blackened pot for cooking or for the generation of electricity.

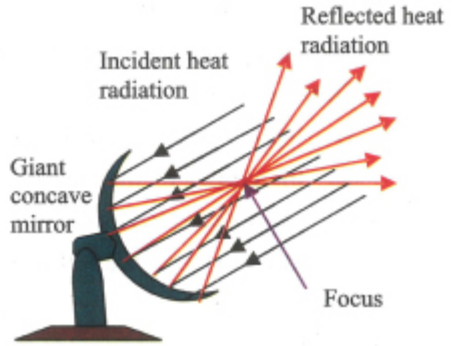



Figure 9.14 Heat reflector

## Other uses of radiation

- Fire fighters wear suits made with shiny materials to reduce absorption of heat. This is because shiny materials are good reflectors; therefore, they reflect heat radiation away from the fire fighter.
- Houses in hot countries are painted with white paints to reflect heat radiations away from the house.
- People living in hot countries wear white clothes to reflect heat radiation away from their body.
- The body of refrigerators are painted white to reduce the amount of heat energy absorbed from the warmer room. The back of the same refrigerator are painted black to remove heat energy from the circulating gas.
- Factory roofs are painted with white paint to reflect heat away from the factories.

## Summary

- Radiation is the transfer of heat energy by means of electromagnetic waves from hot to cold regions.
- Heat radiation can pass through a vacuum; therefore, molecules are not needed to transfer it.
- A thermometer with its bulb painted black is used to detect

radiation from a hot object.

- A thermopile is a device which detects and measures heat radiation by changing it to electrical signal.
- Dull black surfaces radiate heat best. They are good radiators of heat energy.
- Polished surfaces retain heat most; they are poor radiator of heat energy.
- Dull black surfaces are good absorbers of heat radiation while shiny surfaces are bad absorbers of heat radiation.
- A body which absorbs radiation of all frequencies reaching it, is called a black body.
- The vacuum or thermo flask is used to keep liquids hot or cold. Its construction minimizes heat lost by conduction, convection, radiation and evaporation.

## Practice questions 8c

1. What is radiation? How is radiation different from other modes of heat transfer?
2. Explain what you understand by radiation.
   (b) State how the rate of heat radiation depends on:
   (i) the temperature of the body;
   (ii) the colour of the surface.
3. (a) Distinguish between conduction, convection and radiation.
   (b) Explain why the body of a tea flask and an electric kettle are coated with shiny substances.
4. Explain the following statements.
   (i) A shiny teapot keeps tea hotter than a dull blue teapot.
   (ii) The back of a deep freezer is painted with black paint while the body is painted with white paint.
   (iii) Cooling fins of a car radiator is painted black.
5. Explain why a vacuum flask keeps a liquid hot for a long time.
6. Describe an experiment to show that dull colours are good emitter of heat radiation.
7. With the aid of a diagram, describe how heat radiation can be used to boil water fast. Give reasons why the colour of the pot used to boil the water should be dull black.

## Past questions

1. The mode of transference of heat which does not require any material medium is
   A. conduction.

B. convection.
C. evaporation
D. radiation.
E. transmission.

**NECO**

2. The silvered walls of a vacuum flask minimize lose of heat due to
   A. conduction and convection.
   B. conduction only.
   C. convection and radiation.
   D. convection only.
   E. radiation only

**NECO**

3. The heat from a fire in a closed room reaches someone far away in the room mainly by
   A. reflection
   B. diffusion
   C. conduction
   D. radiation
   E. convection

**NECO**

4. Some water is heated in a pot. The major mode(s) of heat transfer within the water is/are by
   A. conduction
   B. convection
   C. radiation
   D. conduction and radiation

**WASSCE**

5. Which of the following statements is **not** correct?
   A. A sea breeze is due to convection in air.
   B. Cotton materials are better than woollen ones for use in hot weather.
   C. Convectional currents play an important role in the cooling of the engine of a motor car.
   D. The vacuum space in a flask helps to reduce heat loss by radiation.

**WASSCE**

6. Which part of a vacuum flask prevents heat loss by radiation?
   A. The cork
   B. The vacuum
   C. The silvered surfaces
   D. The pad at the bottom

**WASSCE**

7. Land breeze occurs
   A. during the day.
   B. as a result of heat transfer by radiation.
   C. as a result of heat transfer by conduction.
   D. as a result of heat transfer by convection.

**WASSCE**

8. Solar energy reaches the earth by the process of
   A. conduction.
   B. radiation.
   C. reflection.
   D. convection.
   E. refraction.

**WAEC**

9. The heating element in an electric kettle is usually located near the bottom of the kettle because
   A. water is a good conductor of heat.
   B. Heat can be more quickly radiated to all parts of the water.
   C. No heat can be lost to the surroundings.
   D. The convectional currents which are set up can carry heat to all parts of the water.
   E. Molecules of the heating element can carry heat to all parts of the water.

**WAEC**

10. Which of the following colours of surfaces will radiate heat energy best?
   A. Red
   B. White
   C. Black
   D. Yellow
   E. Blue

**WAEC**

11. Heat transfer by convection in a liquid is due to the
   A. translational motion of the molecules of the liquid.
   B. increased vibration of the molecules of the liquid about their mean positions.
   C. expansion of the liquid as it is heated.
   D. latent heat of vaporisation of the liquid.
   E. ability of the liquid to evaporate at all temperature.

**WAEC**

12. The reason for making the cover of a vacuum flask airtight is to prevent heat loss by
   A. conduction

B. evaporation
C. radiation
D. convection

**JAMB**

13. Which of the following statements are correct?
    I. Land and sea breezes are natural convection currents
    II. Convection may occur in liquids or gases but not in solids
    III. The vacuum in a thermo flask prevents heat lost due to convection only
    A. I and II only
    B. II and III only
    C. I and III only
    D. I, II and III

**JAMB**

14. When heat is applied to one end of a metal rod, molecules at the other end begin to vibrate with greater amplitude than before because heat has been transferred by
    A. radiation
    B. convection
    C. conduction
    D. evaporation

**JAMB**

15. In which of the following are the substances arranged descending order of their thermal conductivities?
    A. Copper, steel, glass
    B. Steel, copper, glass
    C. Steel, glass, copper
    D. Copper ,glass steel

**JAMB**

16. The vacuum in a thermo flask helps to reduce heat transfer by
    A. convention and radiation
    B. convection and conduction
    C. conduction and radiation
    D. radiation only

**JAMB**

17. Which of the following phenomena explains the fact that a house whose roof is coated with white will be cooler in the hot season than one coated with black paint?
    A. Conduction
    B. Convection
    C. Refraction
    D. Reflection

18. Which of the following properties makes metals ideal for cooking utensils?
   A. High coefficient of expansion
   B. Good conduction of heat
   C. Low specific heat capacity
   D. Poor radiation of heat

**JAMB**

19. Which of the following phenomena CANNOT be explained by the molecular theory of matter?
   A. Expansion
   B. Conduction
   C. Convection
   D. Radiation
   E. Evaporation

**JAMB**

20. Which of the following is a reason why a concrete floor feels colder to the bare feet than a mat on the same floor during the rainy season?
   A. Mat is better conductor than the feet.
   B. Mat loses heat to the bare feet at a faster rate than the concrete floor.
   C. Mat loses heat to the bare feet while the concrete floor extracts heat from them.
   D. Concrete floor is a better conductor of heat than the mat.
   E. Mat is a better conductor than the floor.

**WAEC**

21 (a) Use the kinetic theory of matter to explain the mechanism by which heat is transmitted through solids and liquids.
   (b) (i) Draw and label a diagram showing the essential parts of a thermos flask.
   (ii) Explain how the flask can retain heat for a long time.

**WASSCE**

22 (a) (i) Give two modes of heat transfer other than conduction.
   (ii) Describe the experiment to show that water is a bad conductor of heat.

**NECO**

23 (a) By what different modes can heat be transferred? *Briefly* explain the differences between them.

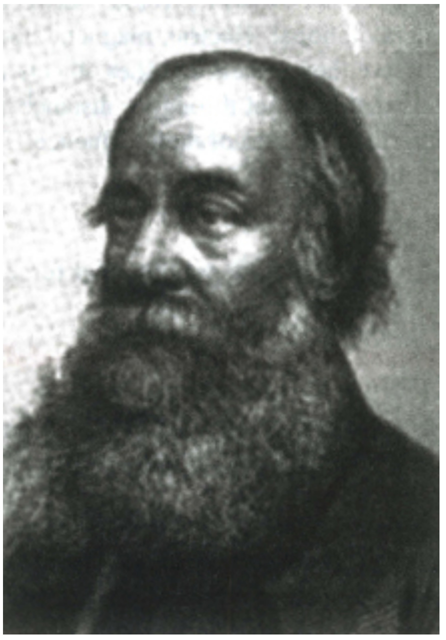
Each morning, a man fills a bucket with cold water and places it outside in the sunlight so that by evening he has warm water to wash with. What could he do to use the sunâ€™s ray more effectively to obtain hotter water?

**WAEC**

24 (a) (i) Mention **two** modes of heat transfer other than convection.

(ii) Explain land and sea breezes.

**WASSCE**



James Joule, British scientist, carried out several experiments to demonstrate existence of heat energy.