TRANSFER OF THERMAL ENERGY

Conduction

Convection

Radiation

Total Transfer

Introduction

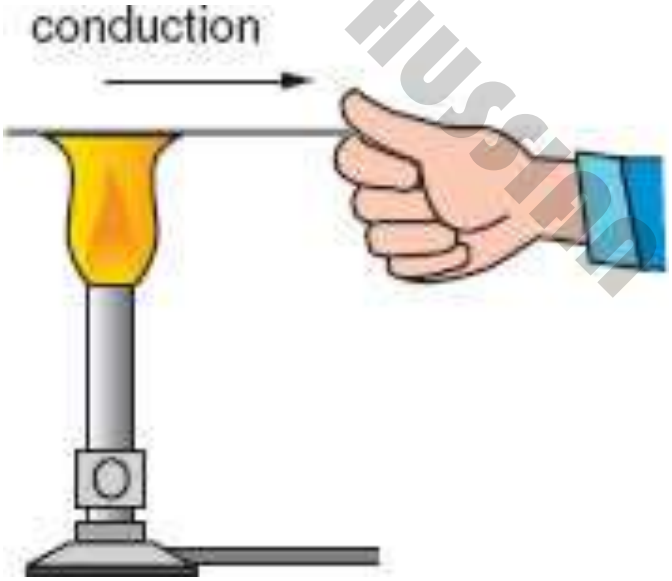
* Thermal energy is the total kinetic energy of the atoms or molecules in a body.
* The energy is transfer from a high temperature object to a lower temperature object.
* The amount of thermal energy transferred is the amount of heat that flowed.
* Thermal energy is transferred in three different ways: conduction, convection and radiation.

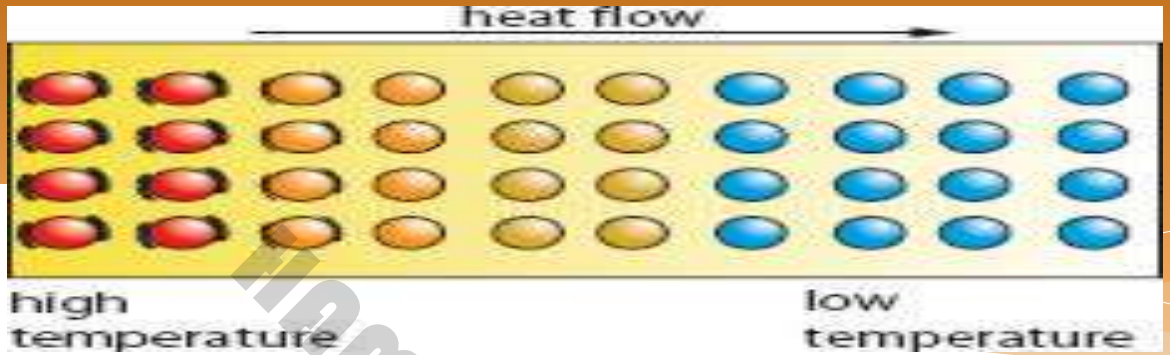
Describe in molecular terms how heat transfer occurs in solids.

Conduction

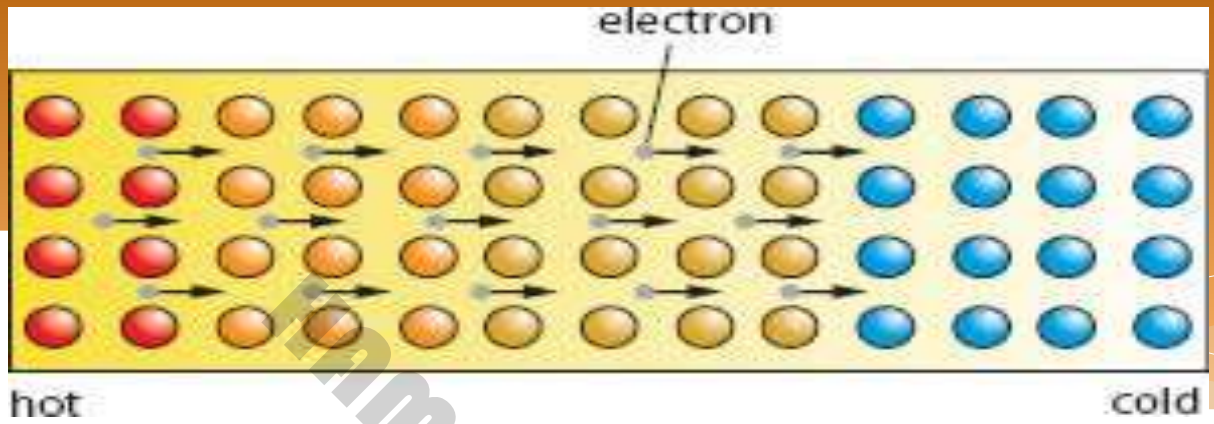
Conduction

* Conduction is the process by which thermal energy is transmitted through a medium from one particle to another.





* When one end of a rod is heated, the molecules gain energy and vibrate faster. These molecules collide with their less energetic neighbours.
* Their energy is transferred to these neighbouring molecules which in turn gain kinetic energy. Thermal energy is passed along the rod by the vibrating molecules.
* This transfer of energy continues on until the cold end reaches the same temperature as the hot end.

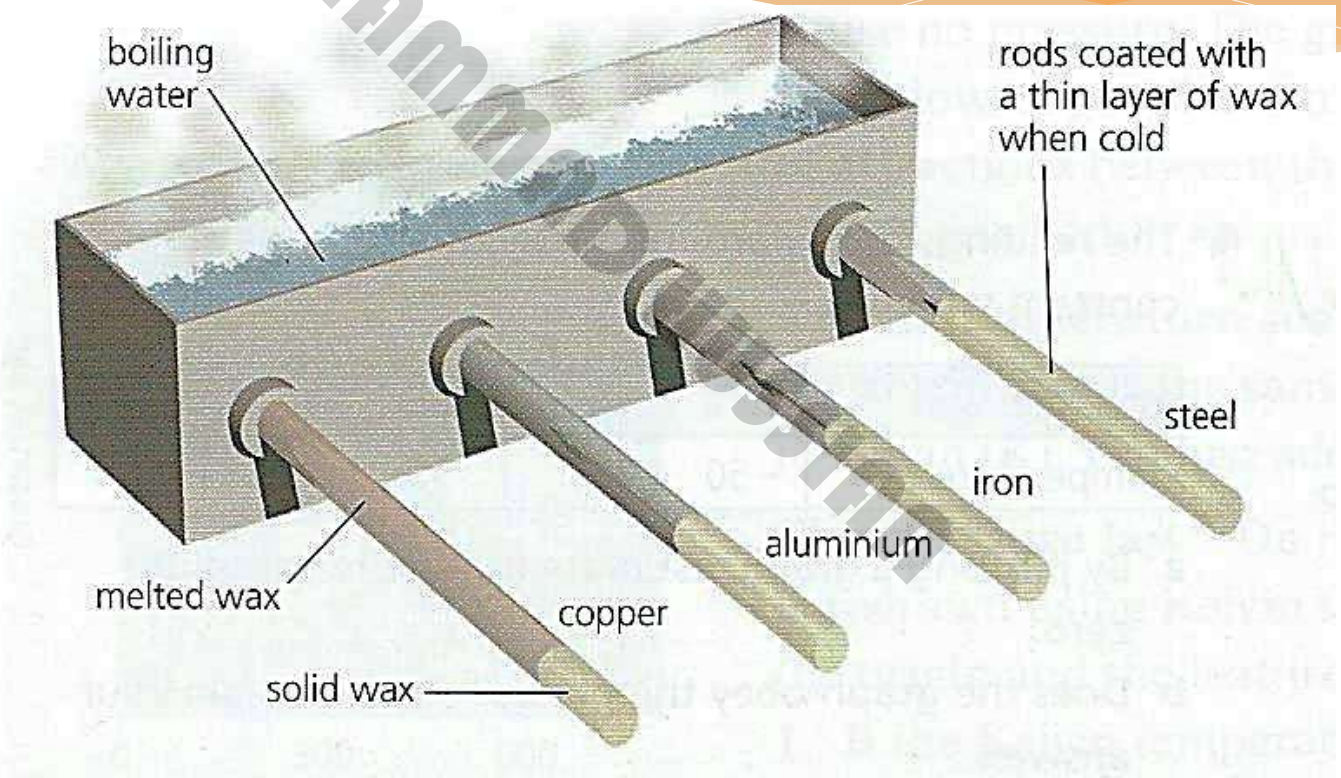


* Conduction of thermal energy in metals is far better than in other solids as conduction takes place through vibrating molecules as well as using free electrons in metals.
  * When heated, the free electrons gain energy and move faster.
  * They are free to travel in the spaces between the molecules before colliding with other electrons and molecules and transferring some of their energy to them.

* This process is much faster than the conduction by vibration of molecules in the body.
* Hence metal conducts heat much faster than non-metals which have no free electrons.
* Conduction cannot occurs when there are no particles present, so vacuum is a perfect insulator.
* Gases and liquids are poor heat conductor because their particles are so far apart.

Describe how to distinguish between good and bad conductors of heat.

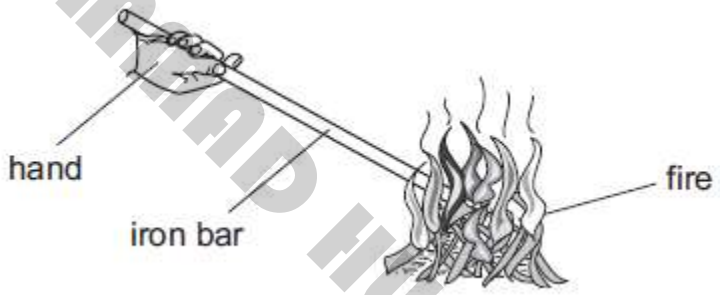
Conduction



* Comparing four good thermal conductors

Good conductors	Poor conductors (insulators)
Gold	Glass
Silver	Stone
Copper	Water
Iron	Plastics
Brass	Wood
Aluminium	Polystyrene foam
	Wool
	Fibreglass

1. An iron bar is held with one end in a fire. The other end soon becomes too hot to hold.



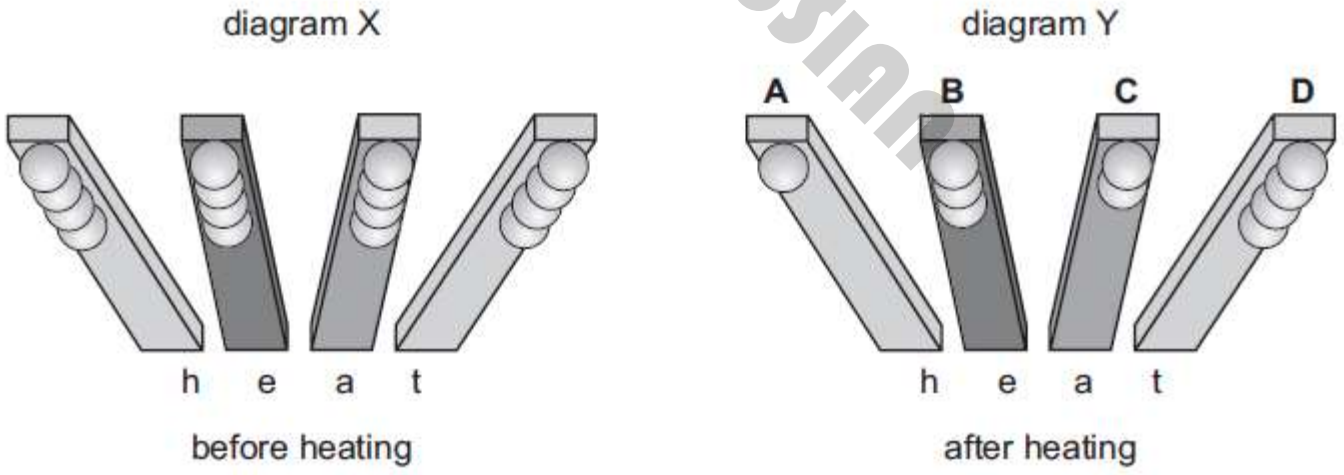
How has the heat travelled along the iron bar?

A. by conduction
B. by convection
C. by expansion
D. by radiation

2. An experiment is set up to find out which metal is the best conductor of heat. Balls are stuck with wax to rods made from different metals, as shown in diagram X.

   The rods are heated at one end. Some of the balls fall off, leaving some as shown in diagram Y.

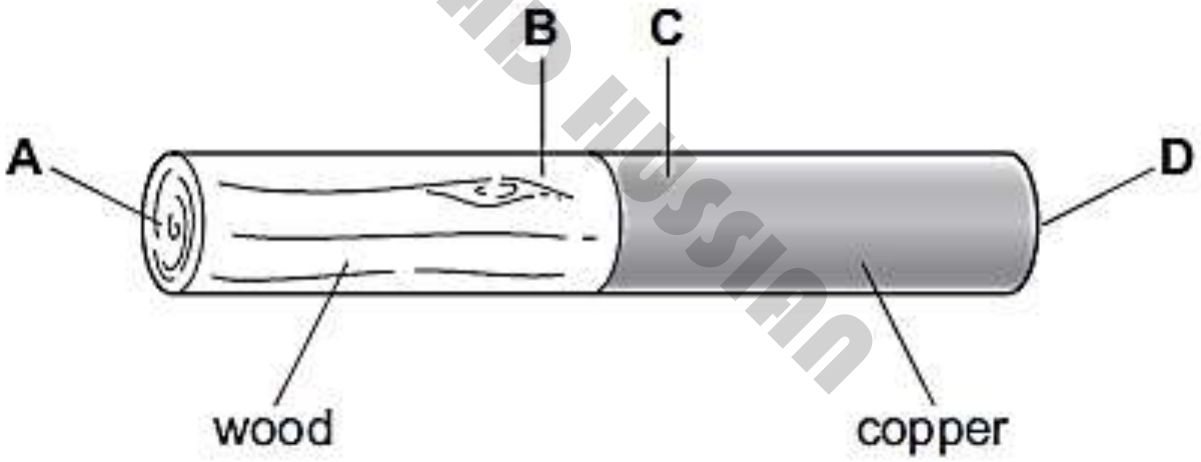
   Which labelled metal is the best conductor of heat?



A

3. A rod is made up of copper and wood joined together.

   After the rod is heated at the join in the centre for about a minute, where would the lowest temperature be?



A

4. A person holds a glass beaker in one hand and fills it quickly with hot water. It takes several seconds before his hand starts to feel the heat.

   Why is there this delay?

   A. Glass is a poor conductor of heat.
   B. Glass is a good conductor of heat.
   C. Water is a poor conductor of heat.
   D. Water is a good conductor of heat.

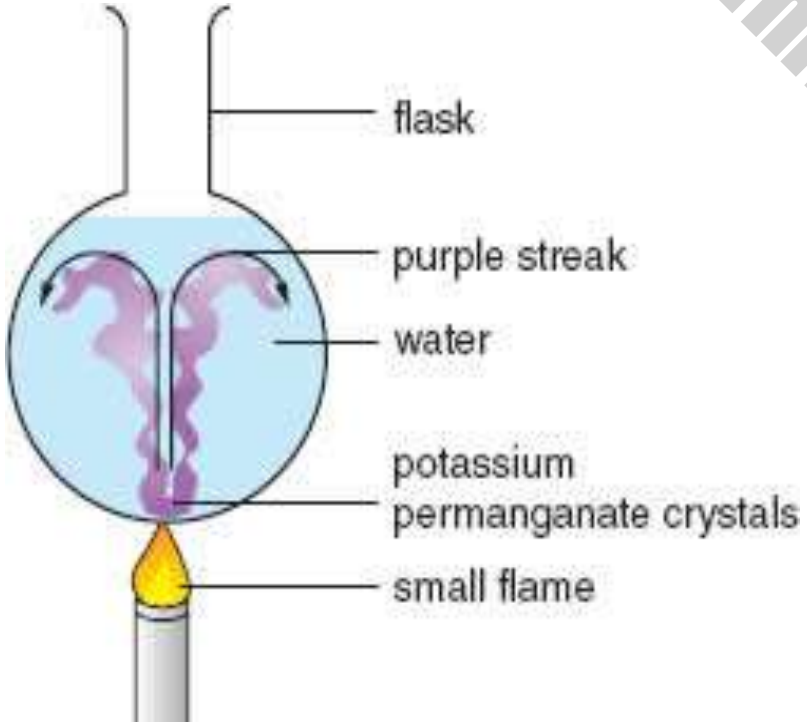
Describe convection in fluids in terms of density changes.

Convection

Convection

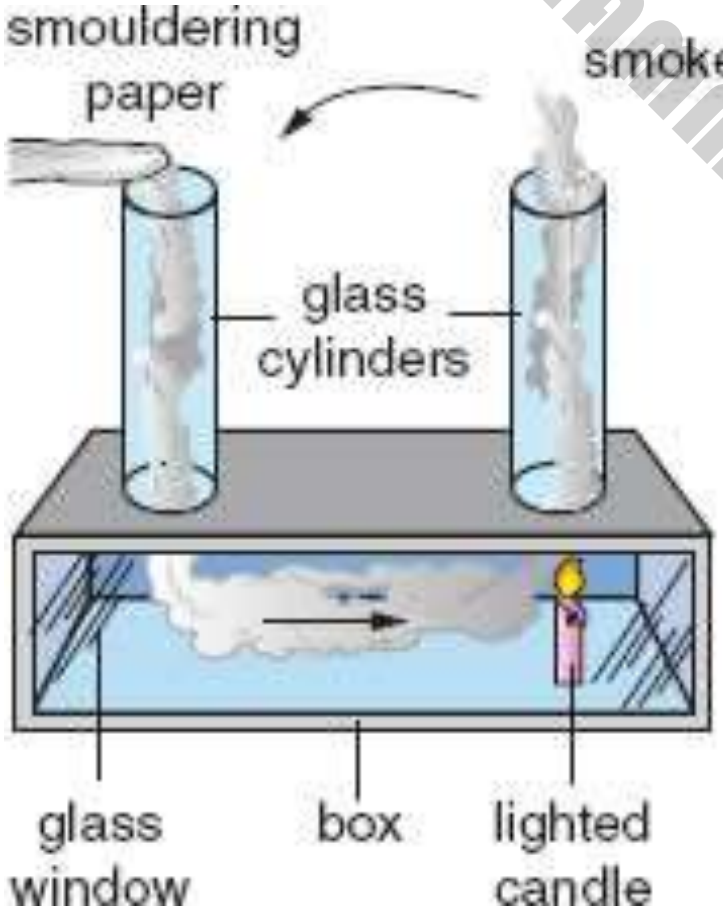
* Liquids and gases are poor thermal conductors, but their particles move all the time.
* When a liquid or gas is heated, energy is transferred to the particles, causing them to move faster and further apart.
* Convection is the process by which thermal energy is transmitted from one place to another by the movement of heated particles of a gas or a liquid.

Convection in Liquids



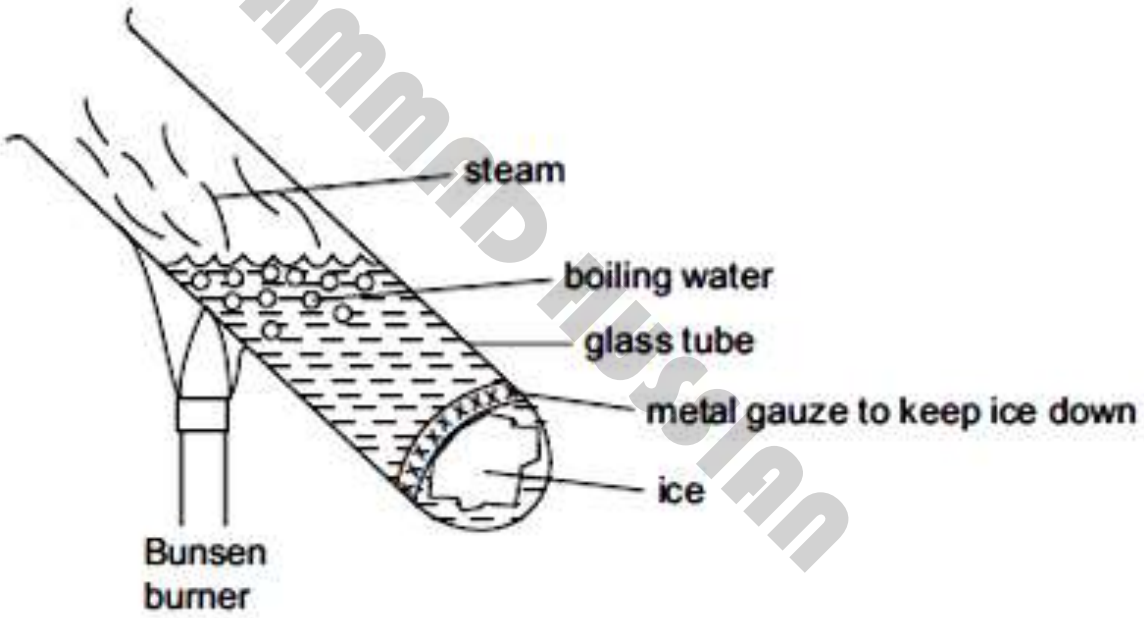
* When a liquid is heated, it expands, becomes less dense, and float upwards.
* The cold and denser liquid moves down to replace it.
* This in turn gets heated up.
* The circulation of liquid in this demonstration is called a convection current.

Convection in Gases



* Convection occurs much more readily in gases than in liquids because they expand much more than liquids when their temperature rises.

1. An experiment is carried out as shown in the diagram.



Why does the ice take a long time to melt, even though the water at the top of the tube is boiling?

A. Convection never occurs in water.
B. Ice is a poor conductor of heat.
C. The gauze prevents the energy reaching the ice.
D. Water is a poor conductor of heat.

2. Which line in the table is correct about conduction and convection?

	conduction	convection
A	can happen in a solid	can happen in a solid
B	can happen in a solid	only happens in fluids
C	only happens in fluids	can happen in a solid
D	only happens in fluids	only happens in fluids

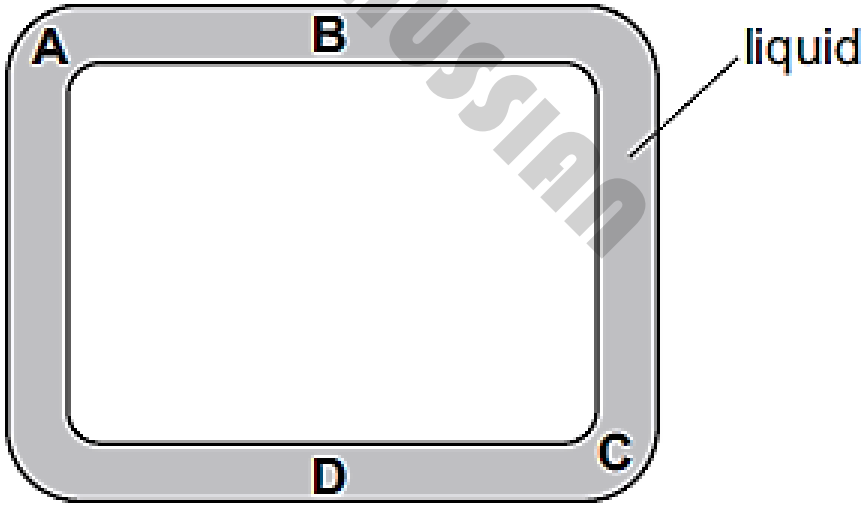
B

3. Density changes are responsible for which method of thermal energy transfer?

A. conduction only
B. convection only
C. radiation only
D. conduction, convection and radiation

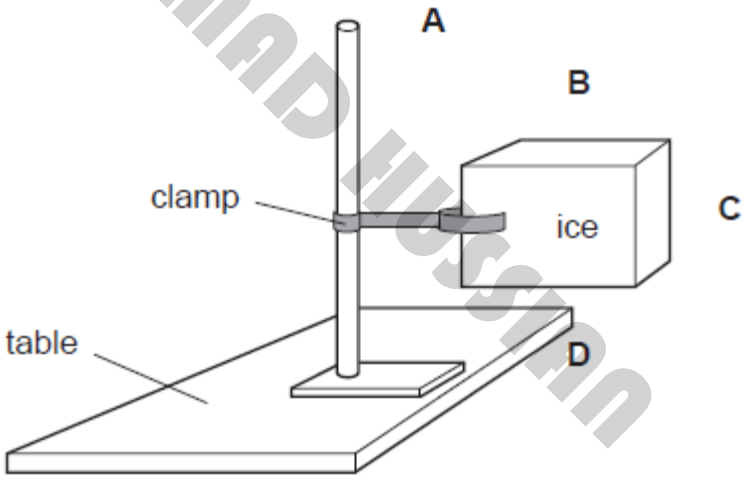
4. A heating element is positioned in a narrow sealed tube of liquid.

   What would be the best place to position the heating element in order to obtain the best circulation of the liquid through the tube?



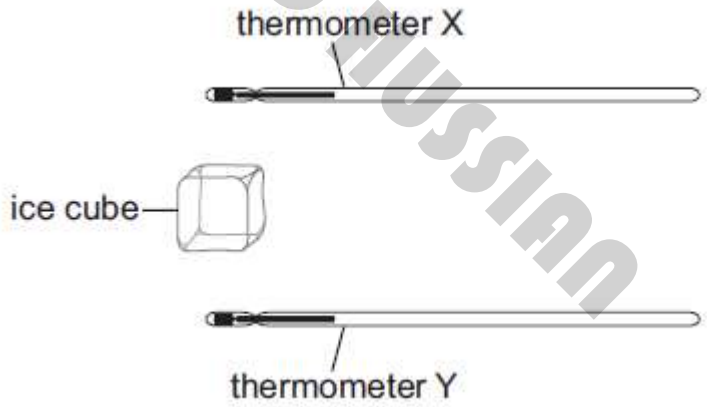
C

5. The diagram shows a block of ice placed in a warm room.
At which point is the temperature the lowest?



D

6. Thermometer X is held above an ice cube and thermometer Y is held the same distance below the ice cube. After several minutes, the reading on one thermometer changes. The ice cube does not melt.



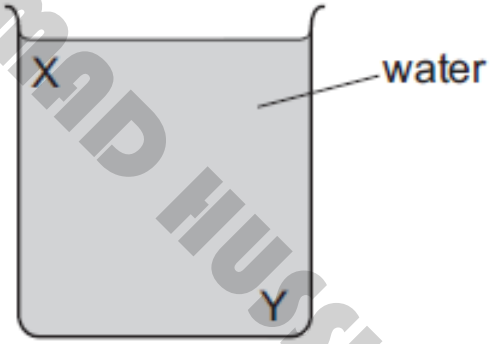
Which thermometer reading changes and why?

	thermometer	reason
A	X	cool air rises from the ice cube
B	X	warm air rises from the ice cube
C	Y	cool air falls from the ice cube
D	Y	warm air falls from the ice cube

C

7. A beaker contains water at room temperature.

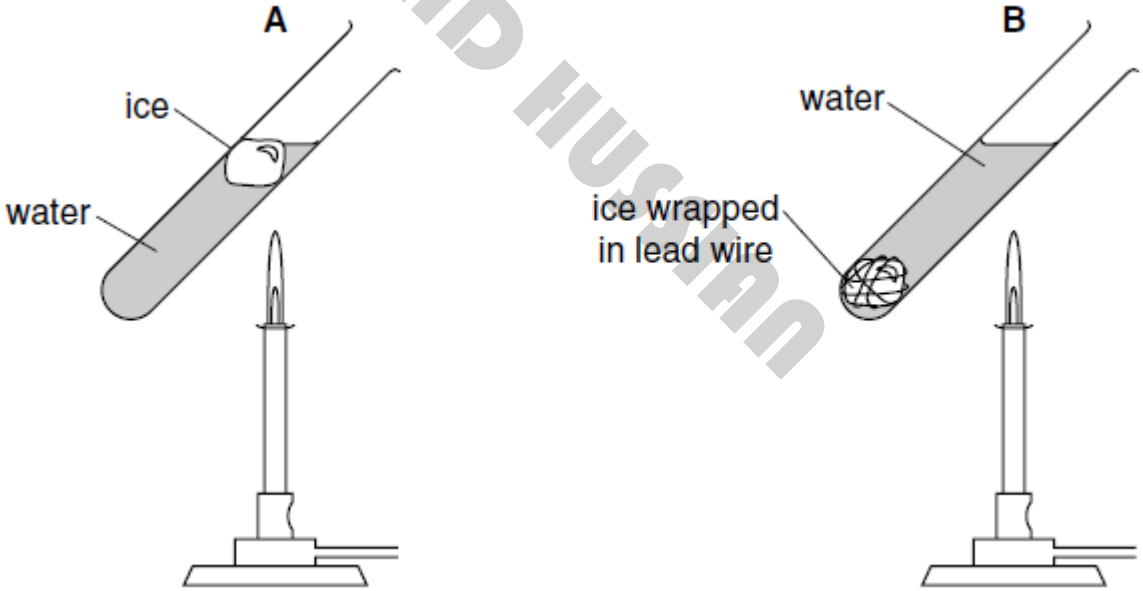
   How could a convection current be set up in the water?

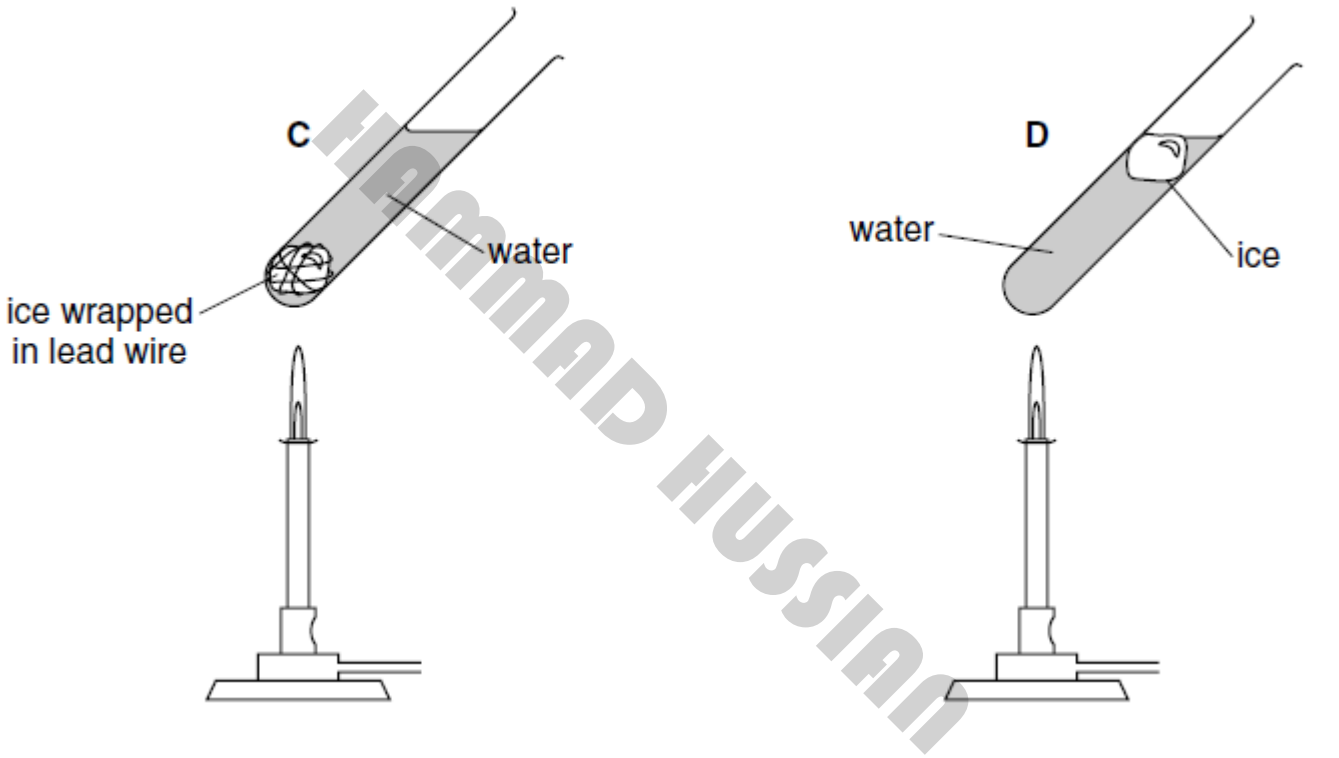


A. cool the water at X
B. cool the water at Y
C. stir the water at X
D. stir the water at Y

8. The diagrams show four identical pieces of ice that are heated in test-tubes of water.

   In which test-tube will the ice take the longest time to melt?





B

9. The diagram shows a fire.

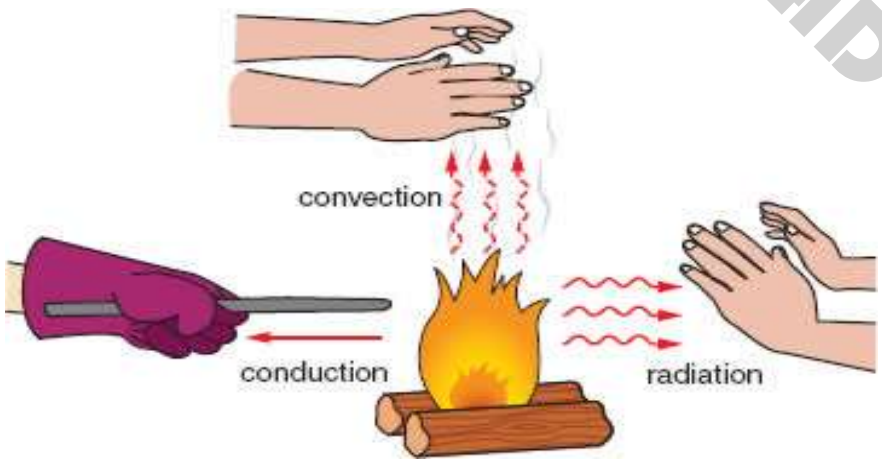
Why does the smoke rise above the fire?

A. Smoke evaporates more quickly at higher temperatures.
B. Smoke molecules diffuse more quickly at higher temperatures.
C. The density of the air is lower at higher temperatures.
D. The pressure of the air is greater at higher temperatures.

Describe the process of heat transfer by radiation.

Radiation

Radiation



* Radiation is the transfer of thermal energy by electromagnetic waves.
* Conduction and convection require a medium to transfer thermal energy. However radiation does not require any medium – it can take place in a vacuum.

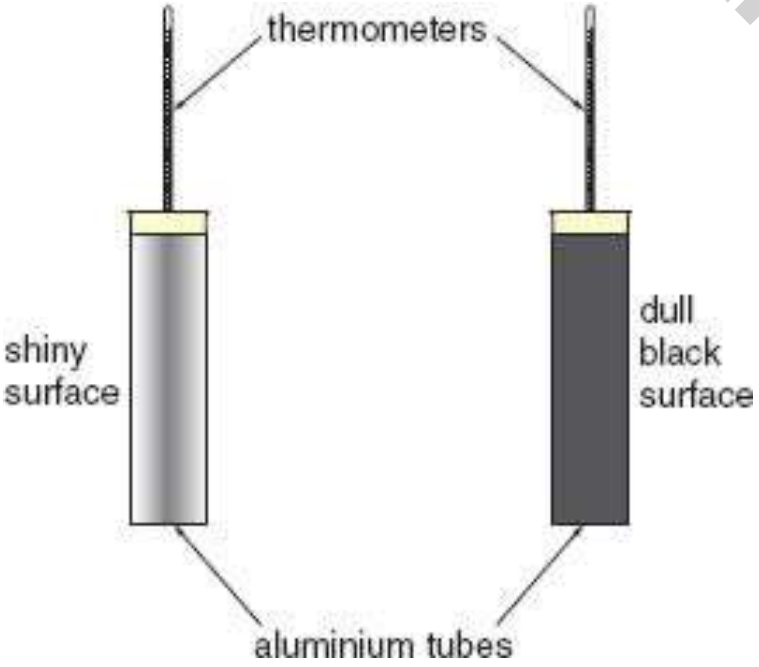
* The source of thermal energy in radiation transmits energy in the form of waves known as infra-red radiation.
* When absorbed, the energy of the waves transform into thermal energy of the receiving body.
* Radiation is the means by which energy reaches us from the Sun.
* The Sun's energy travels to Earth as electromagnetic waves at the speed of light.

Describe how to distinguish between good and bad emitters and good and bad absorbers of infra-red radiation.

Radiation

Emission of Radiation

* The hotter the object is, the more energy it radiates.



The temperature of the tube with the dull black surface is found to decrease more rapidly than that of the shiny tube.

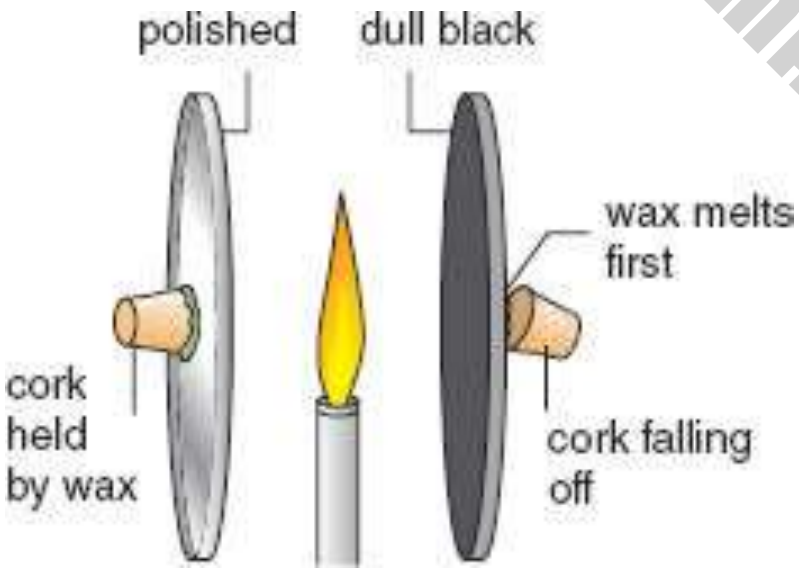
Example of Good Emitter

Cooling fins on the back of a refrigerator are dull black to radiate away more energy.

Example of Poor Emitter

At the end of a race, marathon runner wrap themselves in shiny blanket to prevent them from cooling down to quickly.

Absorption of Radiation



* A body's temperature rises when it absorbs radiation.
* Observation shows that the wax on the blackened lid melts in a short time, and the cork on it falls off.
* The shiny lid remains fairly cool and the wax on it remains unmelted.

Example of Good Absorber

The surface of a black bitumen road gets far hotter on a sunny day than the surface of a white concrete one.

Example of Poor Absorber

Fuel storage tanks are sprayed with shiny silver or white paint to reflect radiation from the Sun.

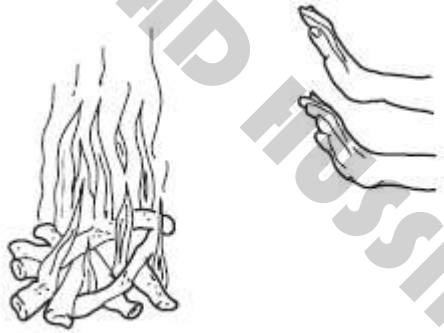
* The rate of energy transfer by radiation is affected by:
  * surface temperature
  * colour and texture of the surface
  * surface area

* The experiment shows that a dull black surface absorbs radiation much better than a shiny surface.
* A good emitter is also a good absorber.
* The shiny surface is a good reflector of thermal energy.

1. How does thermal energy (heat energy) travel through the vacuum between the Earth and the Sun?

   A. by conduction
   B. by convection
   C. by radiation
   D. by radioactive decay

2. A student warms her hands near a fire.

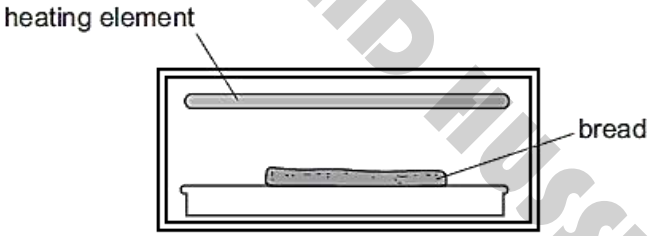


Which waves carry most heat to her hands and are these waves electromagnetic?

	waves	electromagnetic
A	infra-red	no
B	infra-red	yes
C	visible light	no
D	visible light	yes

B

3. Bread can be cooked by placing it below, but not touching, a heating element.

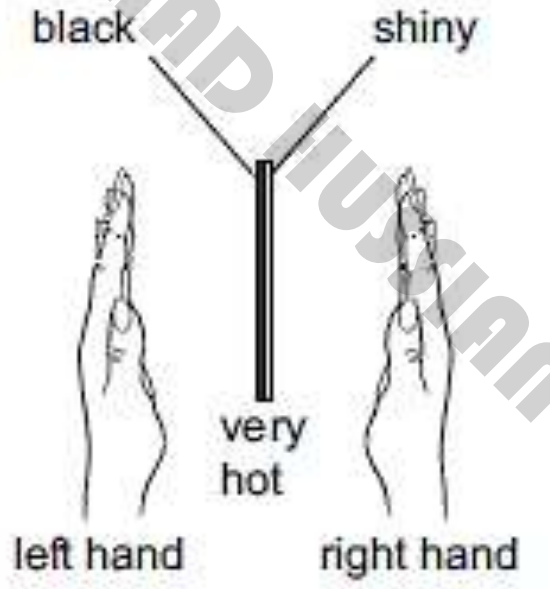


Which process transfers thermal energy from the heating element to the bread?

A. conduction
B. convection
C. insulation
D. radiation

4. The diagram shows a thick copper plate that is very hot. One side is black, the other is shiny.

   A student places her hands the same distance from each side as shown.

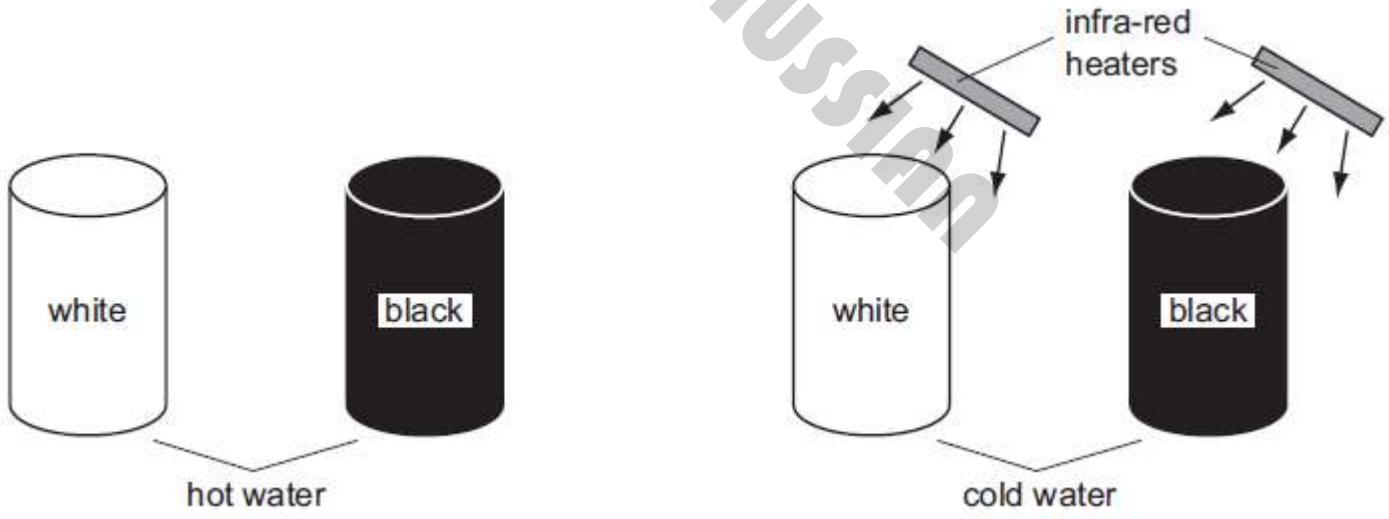


   Her left hand feels warmer than her right hand.

Which statement is the correct conclusion from the experiment?

A. The black side is hotter than the shiny one.
B. The black side radiates more heat.
C. The shiny side radiates more heat.
D. The shiny side is cooling down faster than the black side.

5. The diagrams show four cans in a cool room. They are painted as shown. One pair is filled with hot water and left to cool down. The other pair is filled with cold water and placed near infra-red heaters.



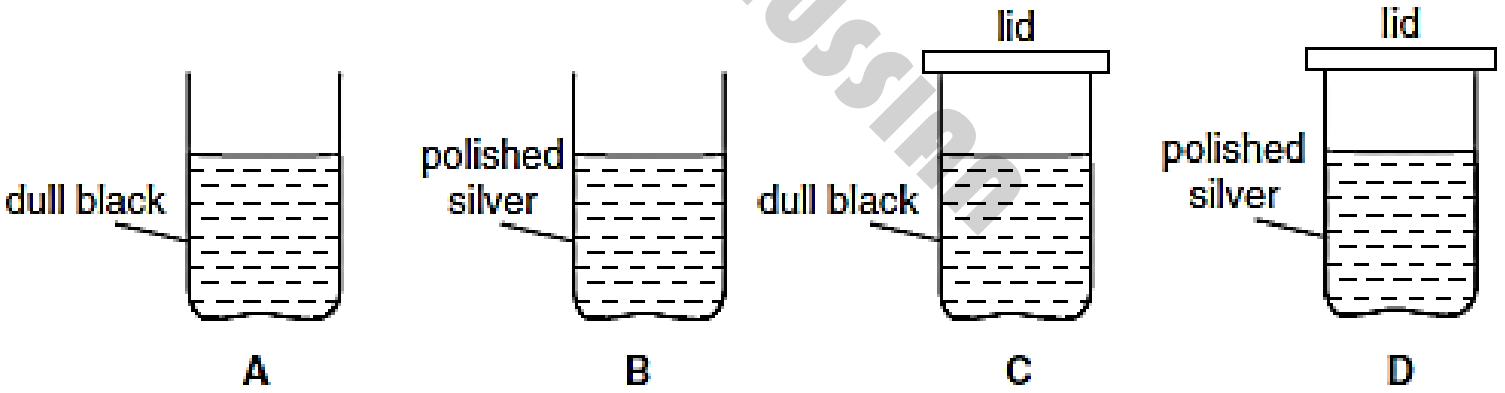
The hot water in the black can cools more quickly than the hot water in the white can. The cold water in the black can heats up more quickly than the cold water in the white can.

Which row shows the reasons for this?

	better emitter of infra-red	better absorber of infra-red
A	black	black
B	black	white
C	white	black
D	white	white

A

6. The diagram shows four similar cans. Each can contains the same volume of water initially at 80 °C. After five minutes, which can will contain the coolest water?

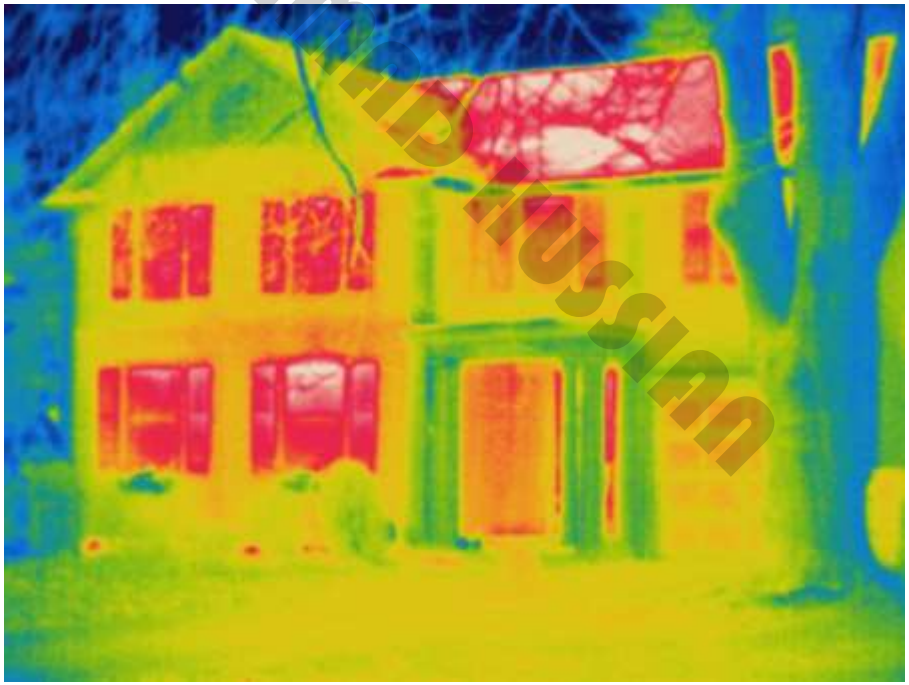


A

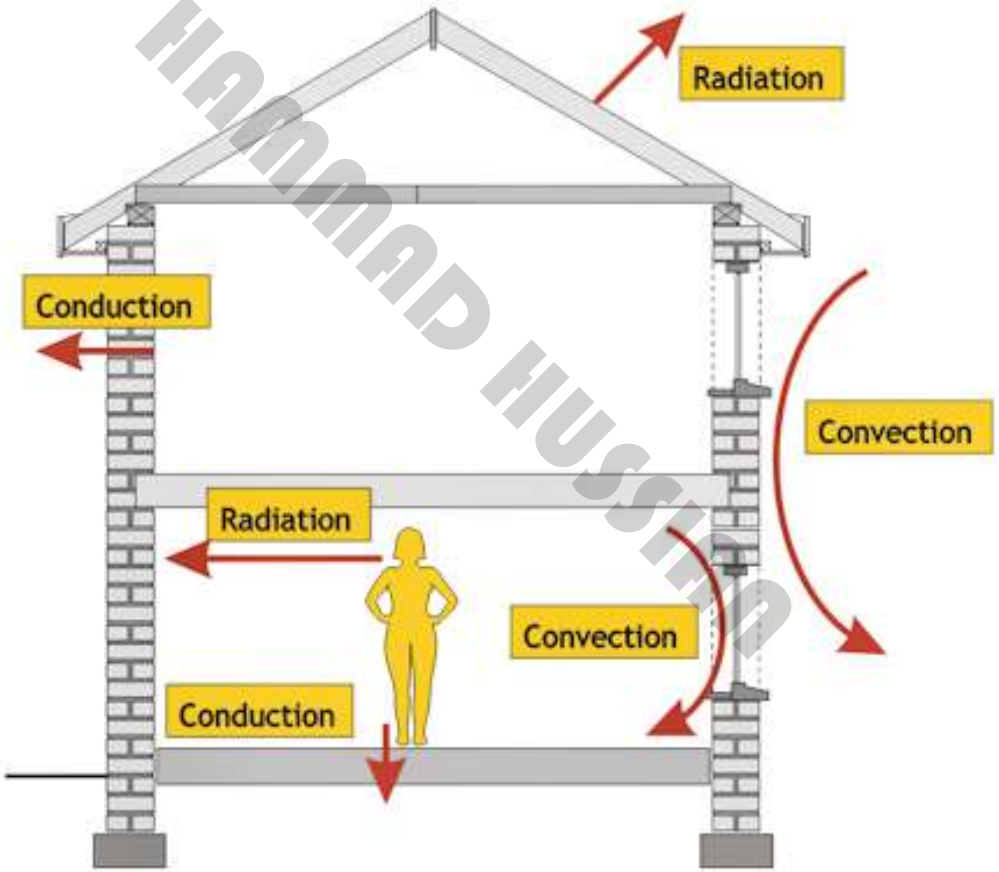
Describe how heat is transferred to or from buildings and to or from a room.

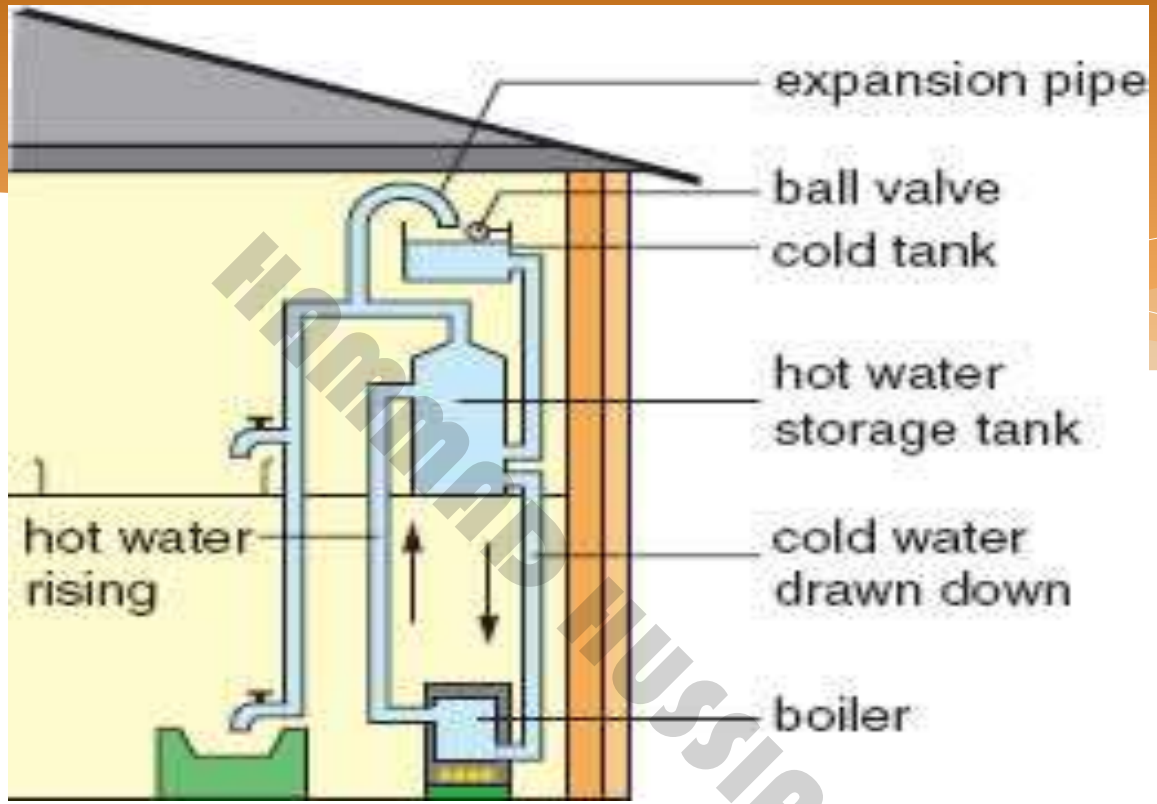
State and explain the use of the important practical methods of heat insulation for buildings.

Total transfer



Heat Transfer at Home

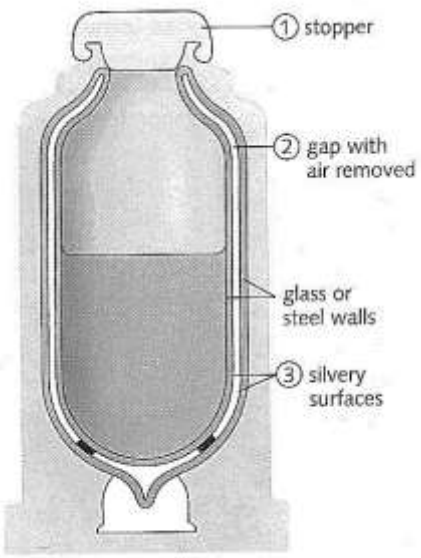




* Convection currents drive hot water from the top of the boiler into the hot water storage tank.
* Cold water from the storage tank is drawn down to the boiler, where it turn becomes heated.

* Houses in hot countries are often painted in white to keep them cool.
* Factory roofs are sometimes coated with aluminium paint. This reduces the absorption of radiation during the day, and cuts down the emission of radiation during the night.

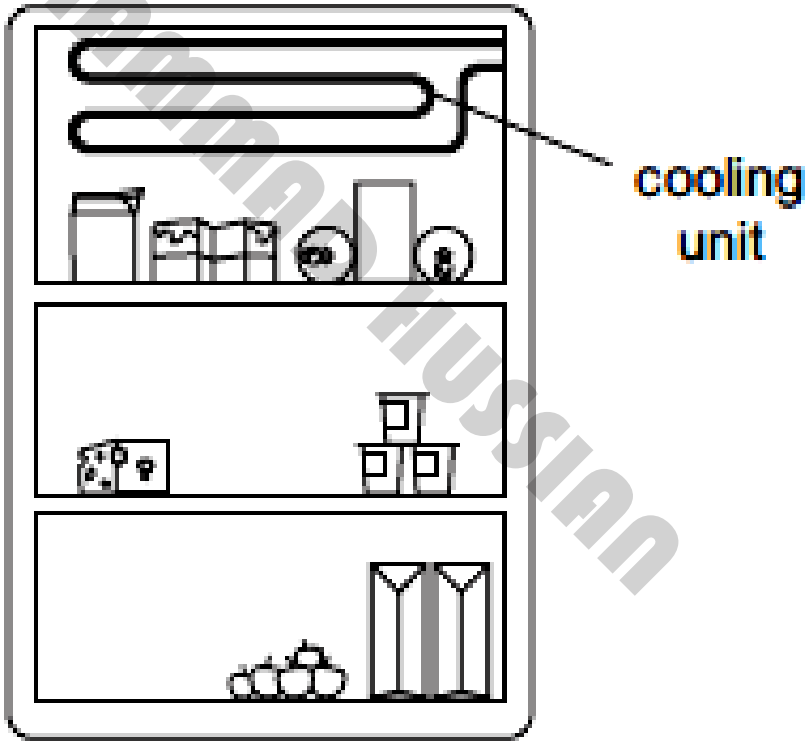
Vacuum Flask



A vacuum flask

* A vacuum flask can keep drinks hot (or cold) for hours. It has these features for reducing the rate at which thermal energy flows out (or in):
  * An insulated stopper to reduce *conduction* and *convection*.
  * A double-walled container with a gap between the walls. Air has been removed from the gap to reduce *conduction* and *convection*.
  * Walls with silvery surface to reduce *thermal radiation*.

1. The diagram shows a cooling unit in a refrigerator.



Why is the cooling unit placed at the top?

A. Cold air falls and warm air is displaced upwards.
B. Cold air is a bad conductor so heat is not conducted into the refrigerator.
C. Cold air is a good conductor so heat is conducted out of the refrigerator.
D. Cold air stops at the top and so prevents convection.

2. There is a vacuum between the double walls of a vacuum flask.

   Which types of heat transfer are reduced by the vacuum?

   A. conduction and convection
   B. conduction and radiation
   C. convection and radiation
   D. conduction, convection and radiation

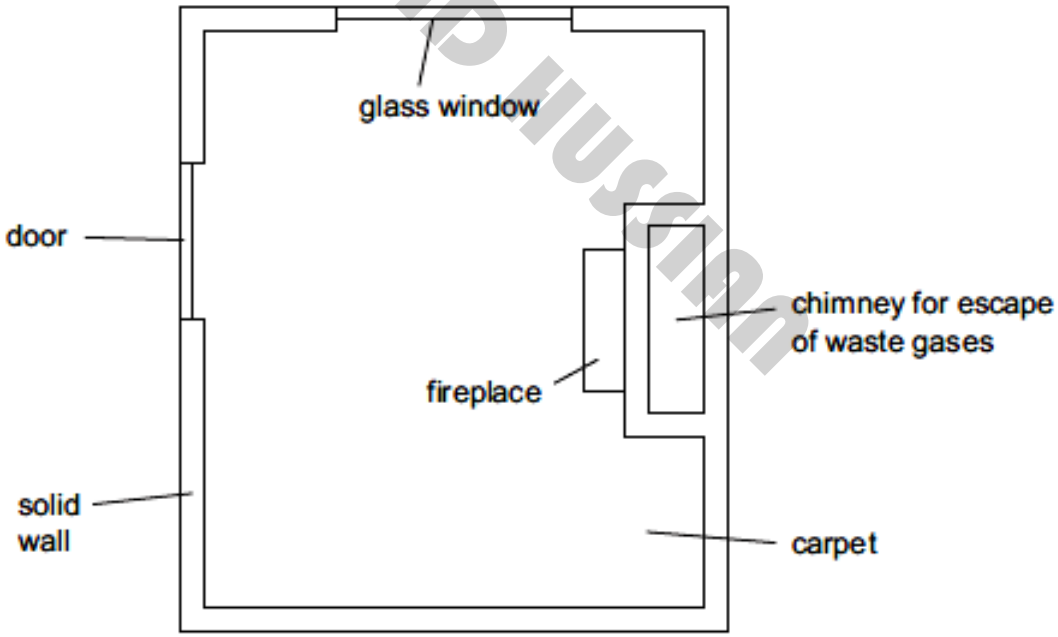
3. The heat from the hot water in a metal radiator passes through the metal and then spreads around the room.

What are the main processes by which the heat is transferred through the radiator and then spread around the room?

	through the metal radiator	around the room
A	conduction	conduction
B	conduction	convection
C	radiation	conduction
D	radiation	convection

B

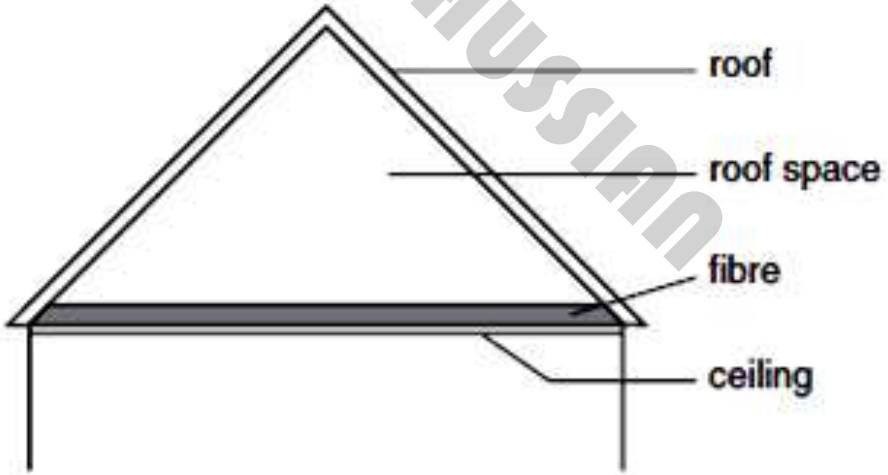
4. The diagram shows a room seen from above. It is cold outside the room. The room is heated by a small fire in the fireplace.



Where is most heat lost by convection?

A. carpet
B. chimney
C. glass window
D. solid wall

5. Fibre is used for home insulation in a cold country, as shown in the diagram.

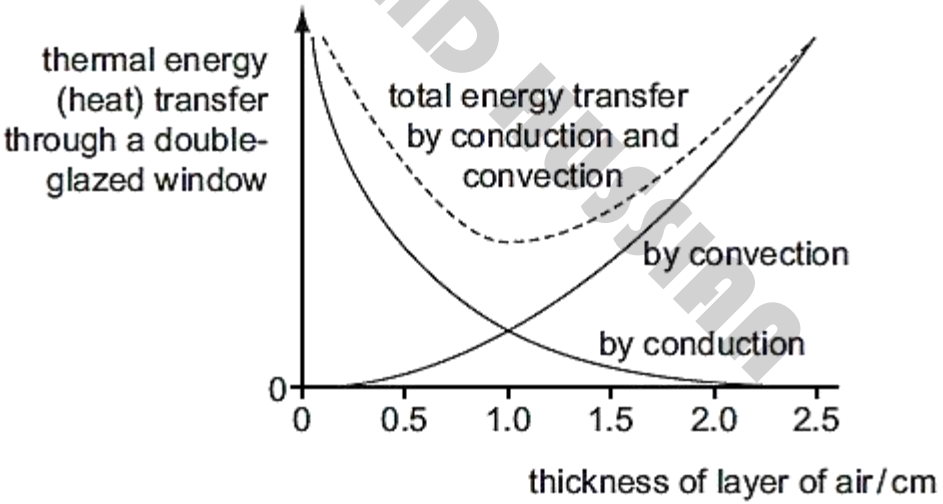


Heat cannot easily escape through the ceiling because the fibre

A. traps air.
B. is warm.
C. is tightly packed.
D. heats the roof space.

6. A double-glazed window has two sheets of glass separated by a layer of air.

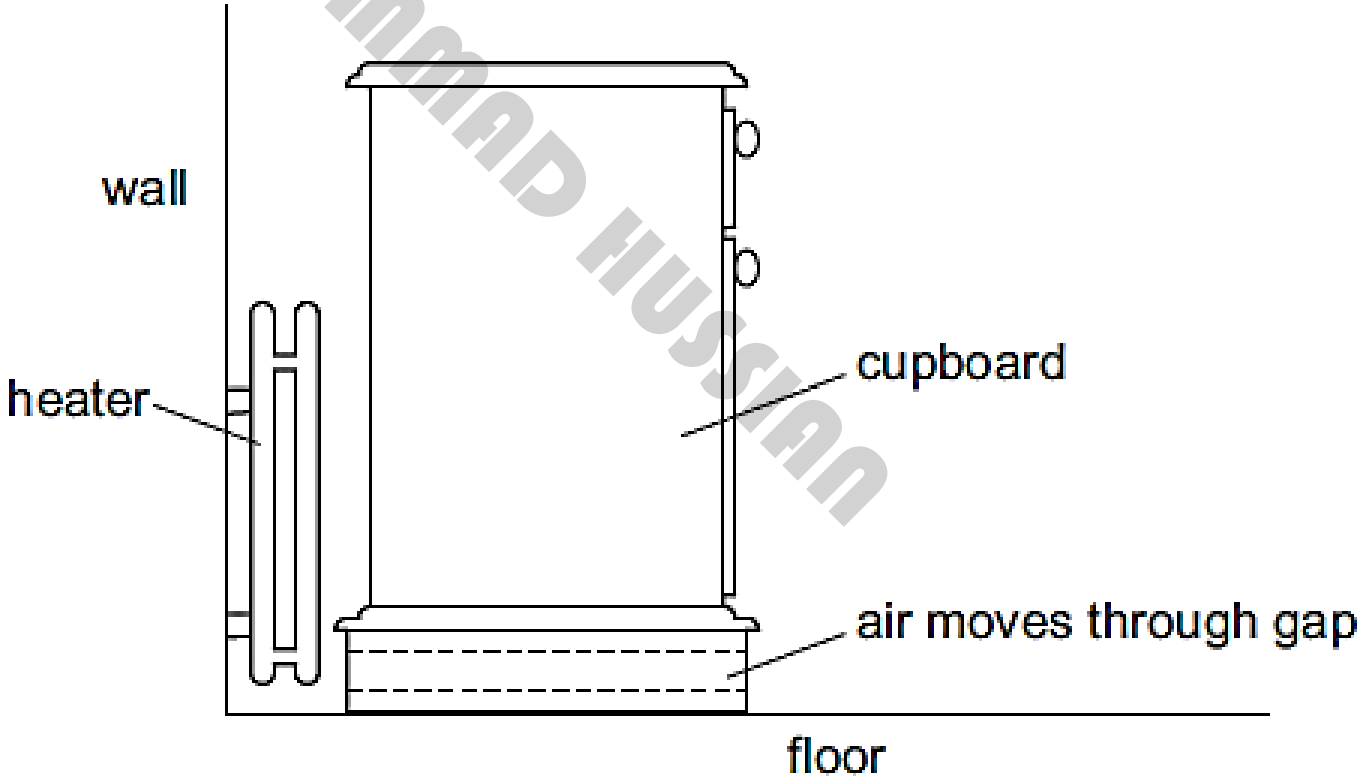
   Thermal energy is conducted and convected through the layer of air. The amount of conduction and convection varies with the thickness of the layer of air, as shown in the graph.



Which thickness of air produces the smallest energy transfer, and why?

A. 0.5 cm because there is little convection
B. 1.0 cm because the total thermal energy transfer is least
C. 1.5 cm because the total thermal energy transfer is small and conduction is low
D. 2.0 cm because there is little conduction

7. A cupboard is placed in front of a heater. Air can move through a gap under the cupboard.



Which line in the table describes the temperature and the direction of the air that moves through the gap?

	air temperature	air direction
A	cool	away from the heater
B	cool	towards the heater
C	warm	away from the heater
D	warm	towards the heater

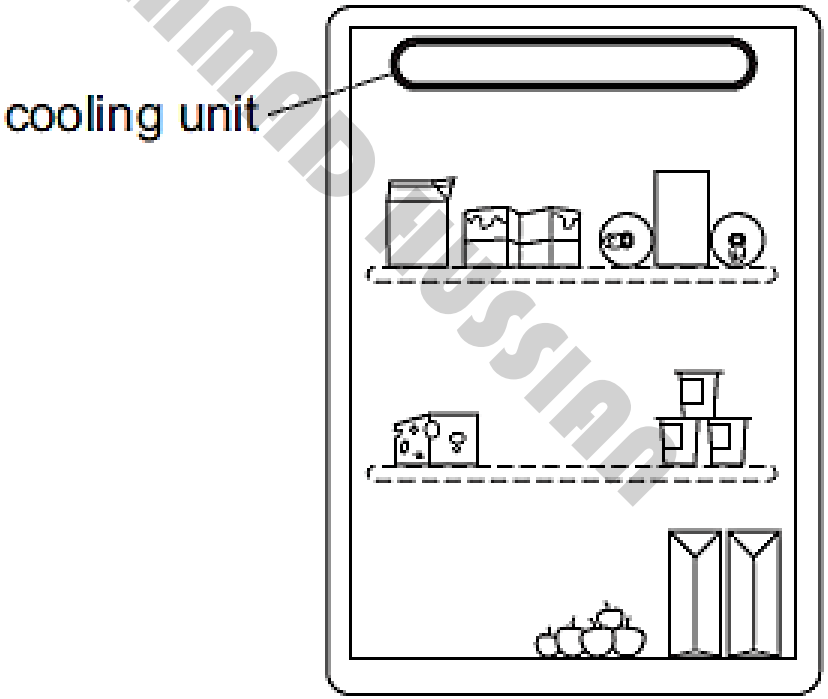
B

8. Hot liquid in a vacuum flask cools extremely slowly. This is because some methods of heat transfer cannot take place in a vacuum.

   Which methods cannot take place in a vacuum?

   A. conduction and convection only
   B. conduction and radiation only
   C. convection and radiation only
   D. conduction, convection and radiation

9. The diagram shows a refrigerator. The cooling unit is placed at the top. The cooling unit cools the air near it.

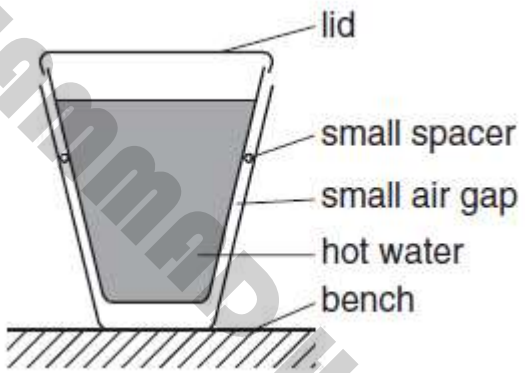


What happens to the density of this air as it cools and how does it move?

	density of the air	movement of the air
A	decreases	moves down
B	decreases	stays where it is
C	increases	moves down
D	increases	stays where it is

C

10. Two plastic cups are placed one inside the other. Hot water is poured into the inner cup and a lid is put on top as shown.



Which statement is correct?

A. Heat loss by radiation is prevented by the small air gap.

B. No heat passes through the sides of either cup.

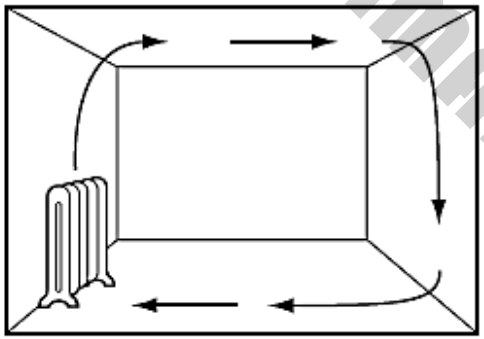
C. The bench is heated by convection from the bottom of the outer cup.

D. The lid is used to reduce heat loss by convection.

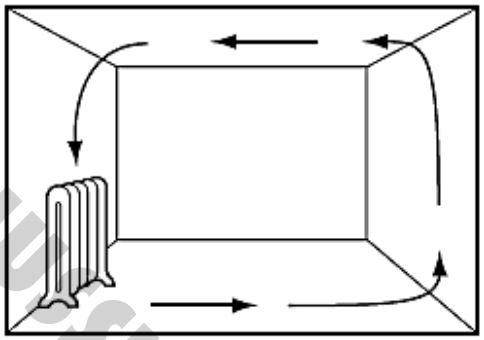
11. A heater is placed in a room.

Which diagram shows the movement of air as the room is heated?

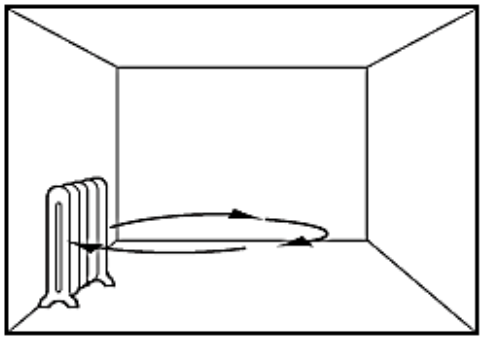
A



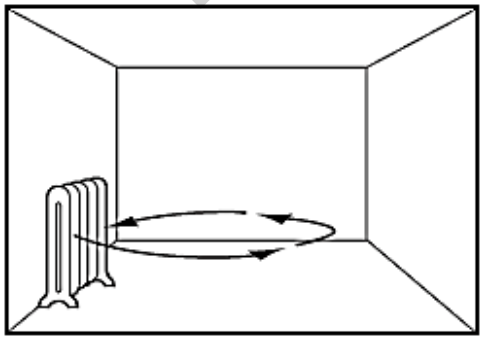
B



C

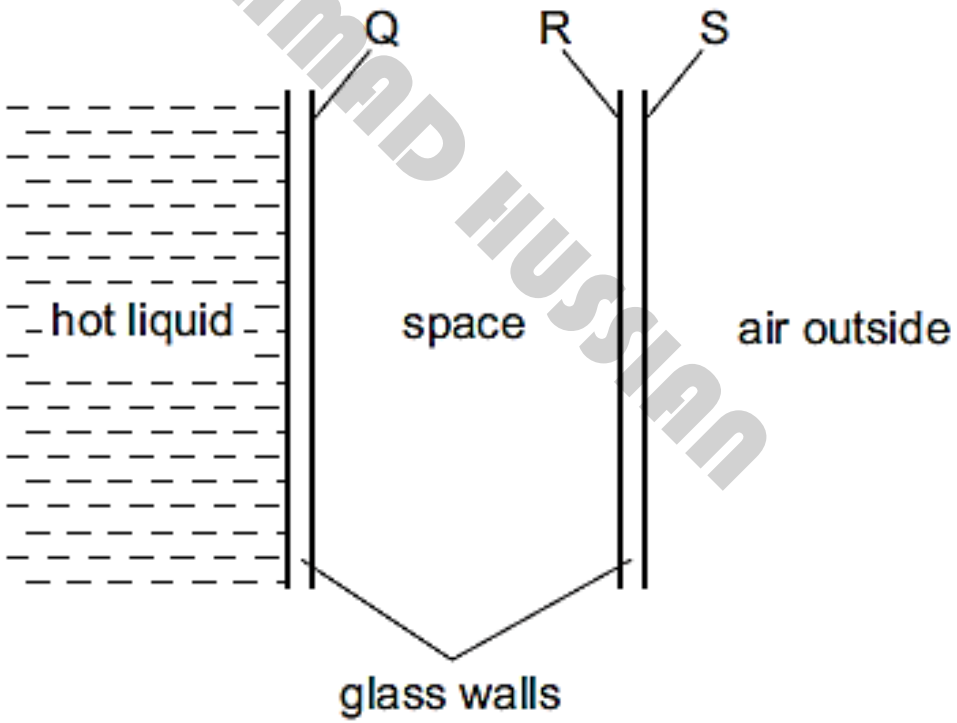


D



A

12. A student needs a double-walled glass vessel to contain a hot liquid.



What reduces heat losses by radiation?

A. a vacuum in the space between the walls
B. painting surface Q black
C. painting surface R black
D. painting surface S silver