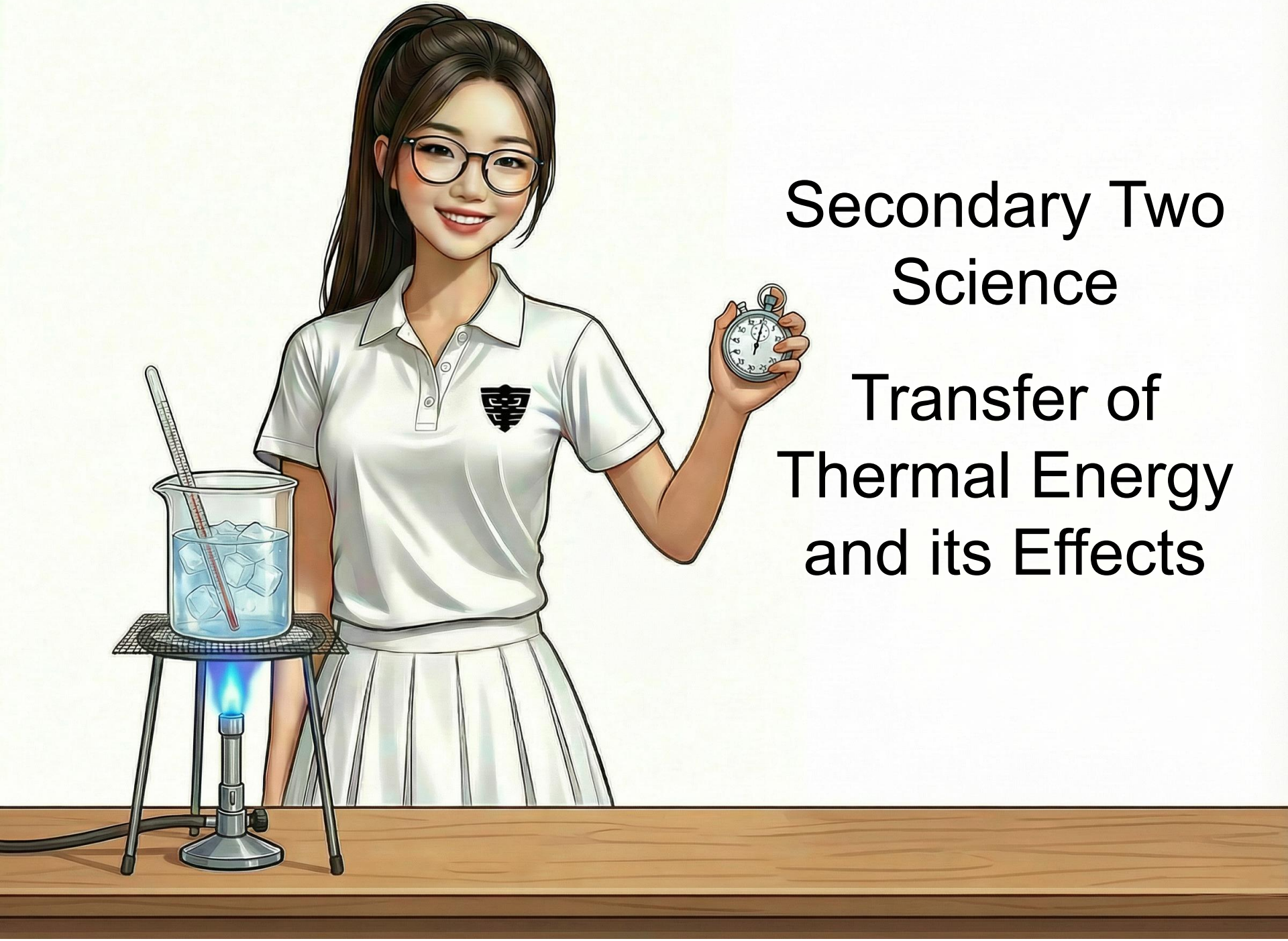
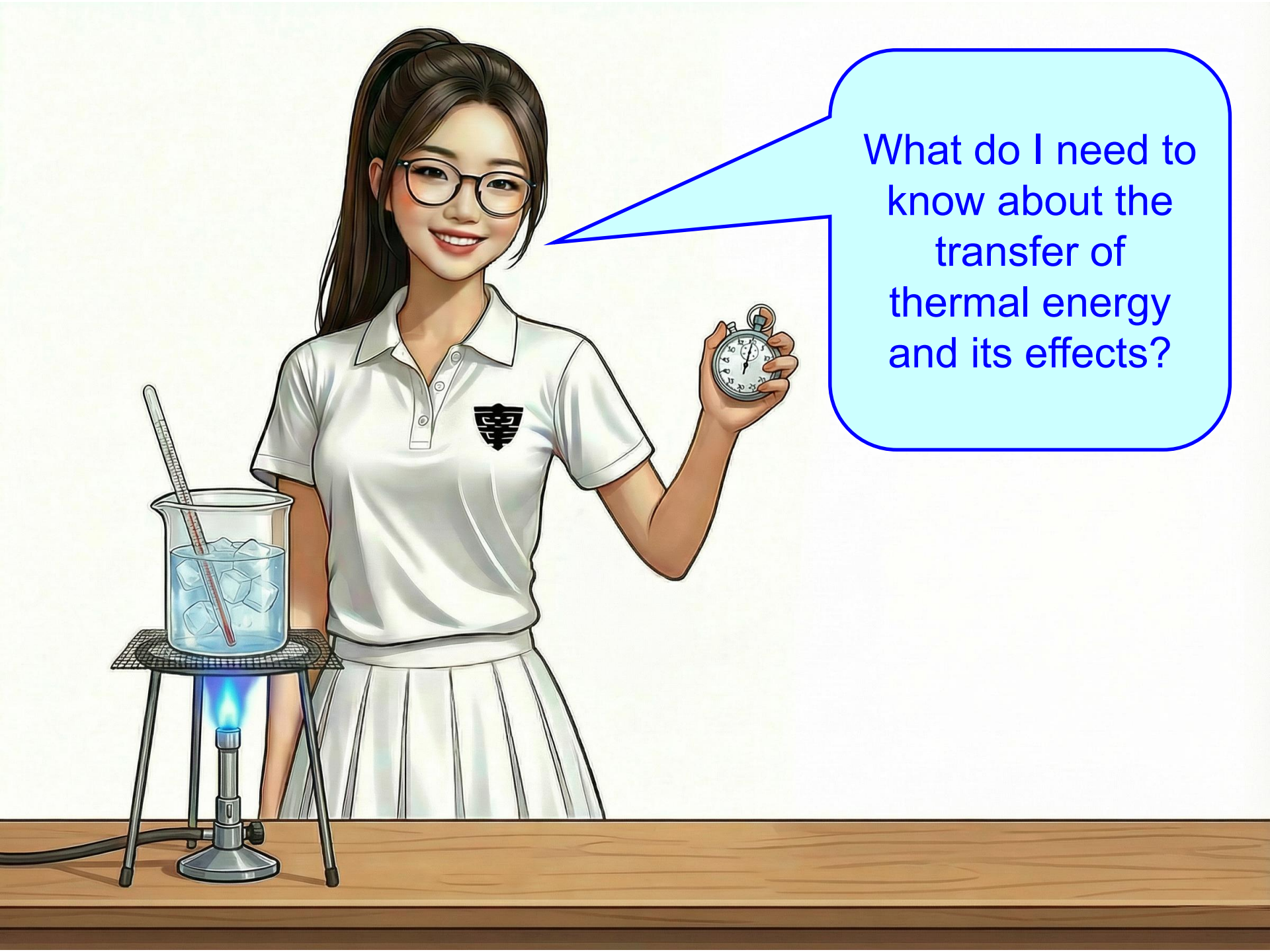


Secondary Two Science

Transfer of Thermal Energy and its Effects


What do I need to know about the transfer of thermal energy and its effects?

The Transfer of Thermal Energy and its Effects

- State that the SI unit of temperature is kelvin (K).
- Infer that generally, solids, liquids, and gases expand when thermal energy is absorbed and contract when thermal energy is given out.
- Infer that thermal expansion results in a change in volume, and therefore the density of the substance.
- Describe some effects and applications of expansion and contraction in everyday life.
- Explain the transfer of thermal energy through conduction, convection, and radiation.
- Show an understanding that the rate of thermal energy loss or gain by a body through radiation is affected by the **a)** colour and texture of the surface **b)** surface temperature.
- Infer from experiments that different materials have different rates of thermal energy transfer.
- Explain applications of transfer of thermal energy through conduction and convection (*e.g.*, in cooling, heating and insulation).
- Explain applications of transfer of thermal energy through radiation (*e.g.*, radiant heaters, solar radiation).
- Show an awareness of the various proposed causes (man-made and natural) of climate change (*e.g.*, global warming).

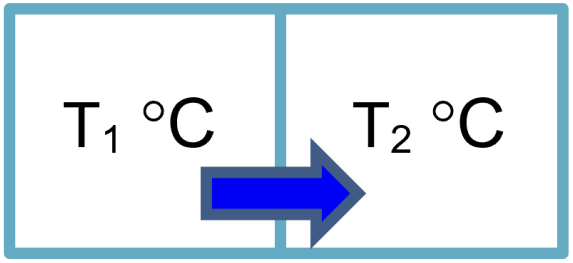
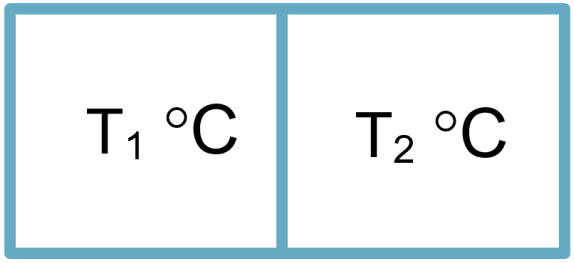
The Transfer of Thermal Energy and its Effects

- **Thermal energy** refers to the **energy possessed by a system due to its temperature**.

- A hotter system will have more thermal energy than a colder one (is this always true?).

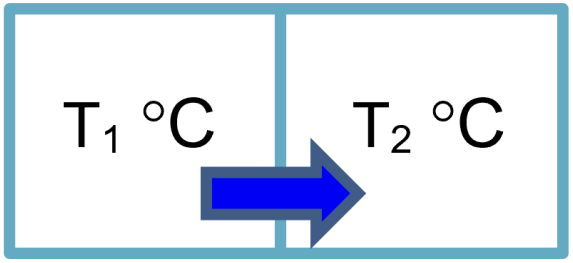
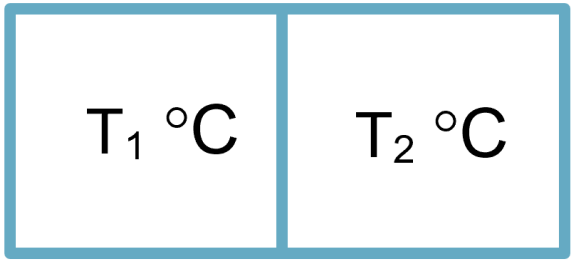
- Thermal energy is transferred from a region of higher temperature (hotter object) to a region of lower temperature (cooler object) until both regions have the same temperature. The greater the difference in temperature, the greater the rate at which the thermal energy is transferred.

The Transfer of Thermal Energy and its Effects

Blocks in Contact	Blocks in Contact After Some Time
	
T_1 °C > T_2 °C Thermal energy transfers from the hotter object to the cooler object. The hotter object loses thermal energy while the cooler object gains thermal energy. The temperature of the hotter object drops and that of the cooler object rises.	T_1 °C = T_2 °C When both objects are at the same temperature, there is no net transfer of thermal energy between the objects.

- The SI unit for thermal energy is the ……

The Transfer of Thermal Energy and its Effects

Blocks in Contact	Blocks in Contact After Some Time
	
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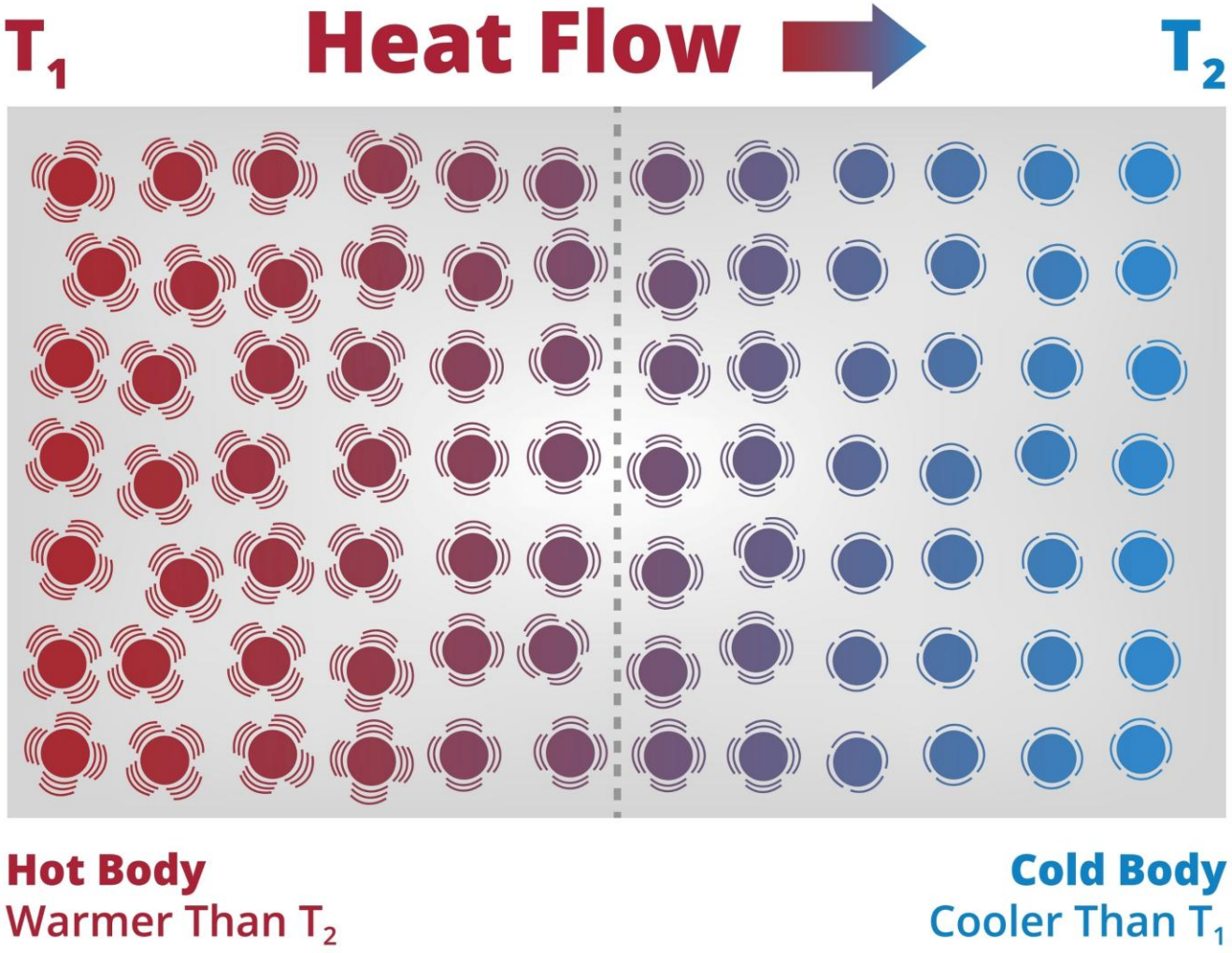
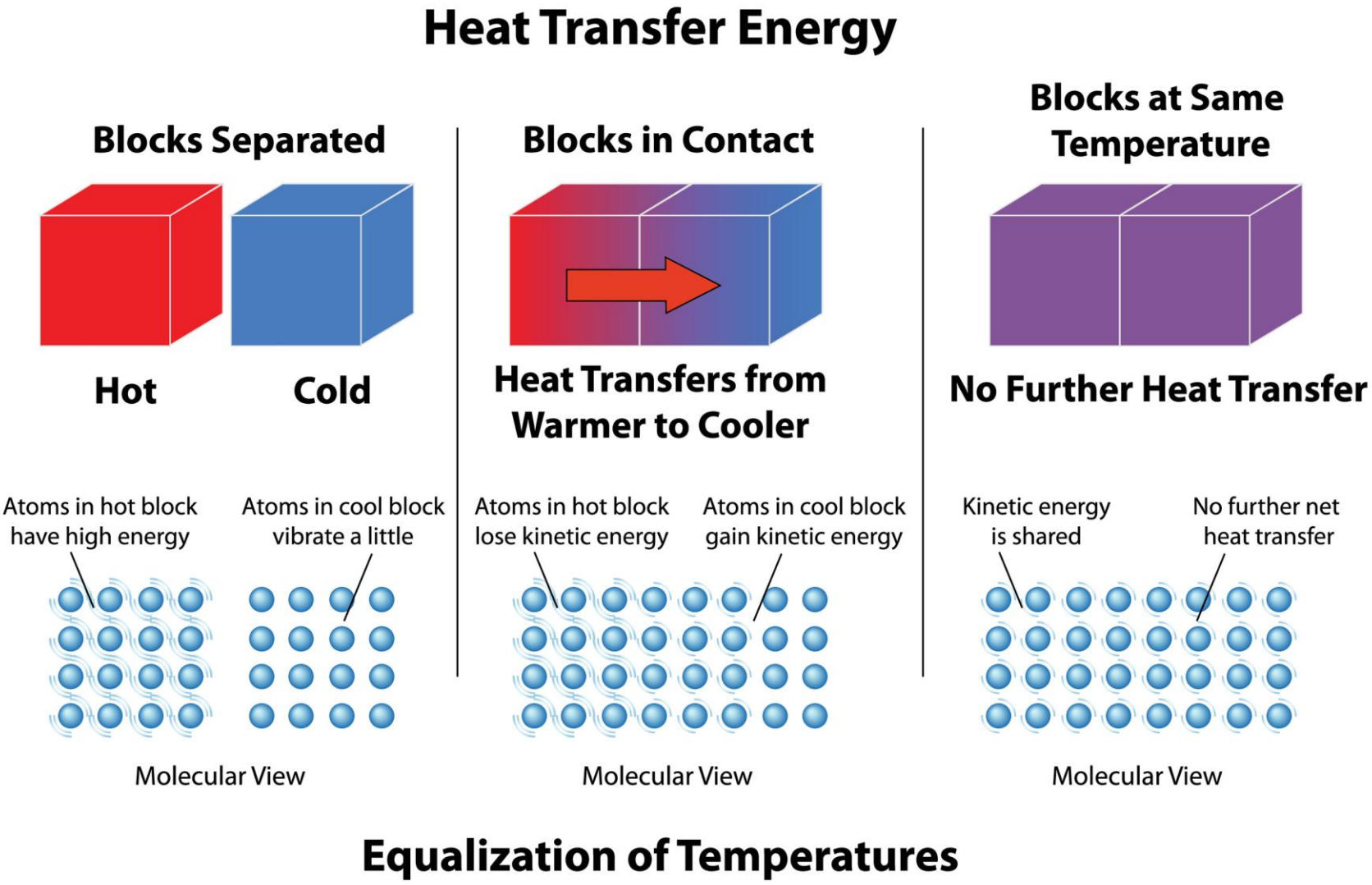
- The SI unit for thermal energy is the Joule (J)

The Transfer of Thermal Energy and its Effects



The Transfer of Thermal Energy and its Effects



The Transfer of Thermal Energy and its Effects

Difference between Thermal Energy and Temperature

- Temperature is a different concept from thermal energy.
- Temperature is a **measure of the average kinetic energy of the particles in a system**. When the particles of a system move faster, they have more kinetic energy. This results in the system having a higher temperature.
- The SI unit for temperature is the Kelvin (K).
- Other unit of temperature is degree Celsius (°C).

The Transfer of Thermal Energy and its Effects

1.5L Electric Kettle

Energy:
High Temperature,
Low Mass

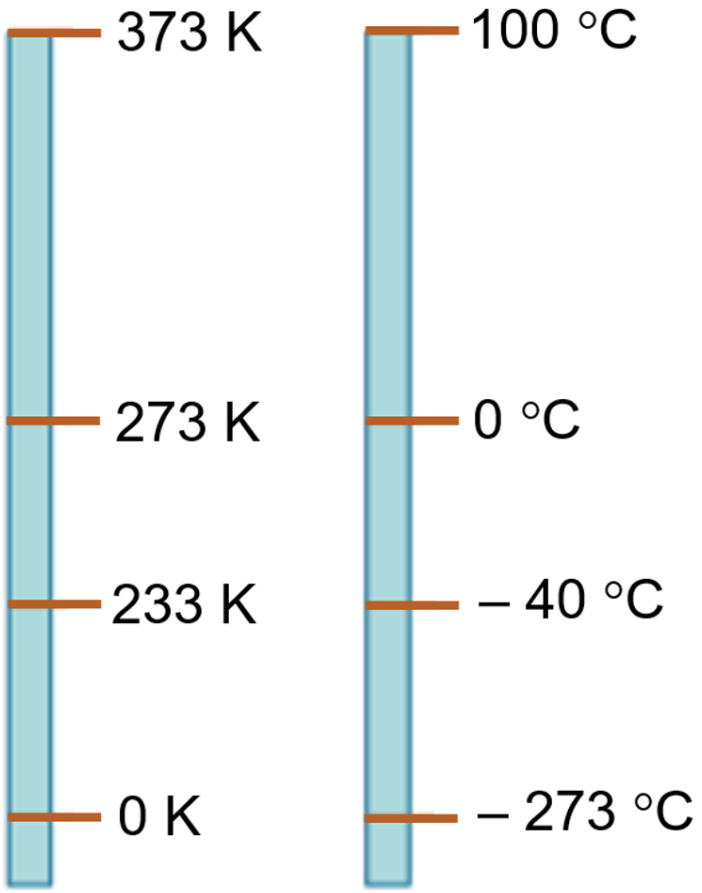
Lower Total Thermal Energy

Large Bathtub

Energy:
Lower Temperature,
High Mass

Higher Total Thermal Energy

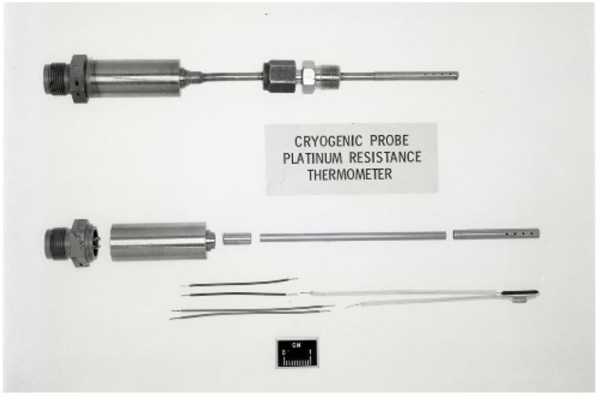
The Transfer of Thermal Energy and its Effects



0 K = – 273 °C

The Transfer of Thermal Energy and its Effects

- Thermometers are used to measure temperature. Examples include…

a) Infrared thermometer	**b)** Thermistor thermometer
	
c) Resistance thermometer	**d)** Thermocouple thermometer
	

The Transfer of Thermal Energy and its Effects

Quick Check 1.

1. What is 25 °C in K?

2. A thermometer recorded the hottest and coldest temperatures of the day as 23 °C and 12 °C. What is the change in temperature expressed in K?

The Transfer of Thermal Energy and its Effects

Quick Check 1.

1. What is 25 °C in K?

25 + 273 = 298 K

2. A thermometer recorded the hottest and coldest temperatures of the day as 23 °C and 12 °C. What is the change in temperature expressed in K?

The Transfer of Thermal Energy and its Effects

Quick Check 1.

1. What is 25 °C in K?

$$25 + 273 = 298 \text{ K}$$

2. A thermometer recorded the hottest and coldest temperatures of the day as 23 °C and 12 °C. What is the change in temperature expressed in K?

$$(23 + 273)\text{ K} - (12 + 273)\text{ K}$$
$$= 11\text{ K} \checkmark$$

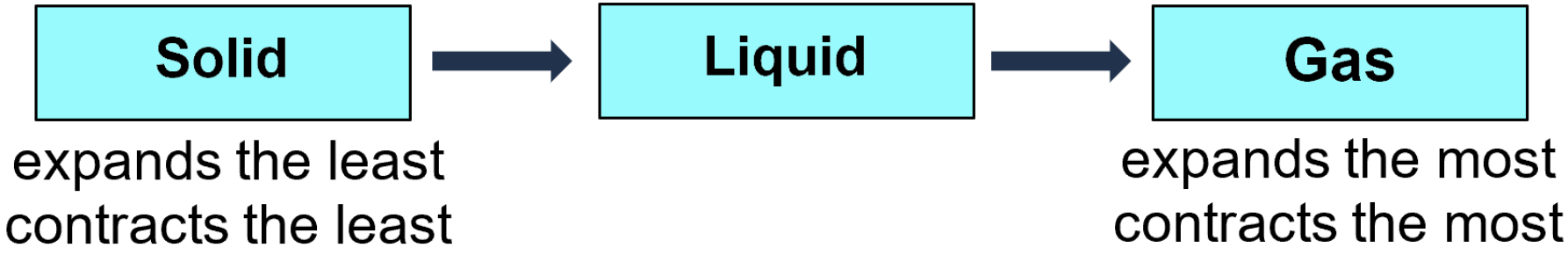
Not $(23 - 12) + 273 = 284\text{ K}$ ✗

Note: 1 °C is the same temperature interval as 1 K.

The Transfer of Thermal Energy and its Effects

Effects of Transfer of Thermal Energy

- When heated, objects generally **expand**, *i.e.*, they increase in volume and become less dense.
- When cooled, objects generally **contract**, *i.e.*, they decrease in volume and become denser.
- Solids, liquids and gases expand and contract to different extents.

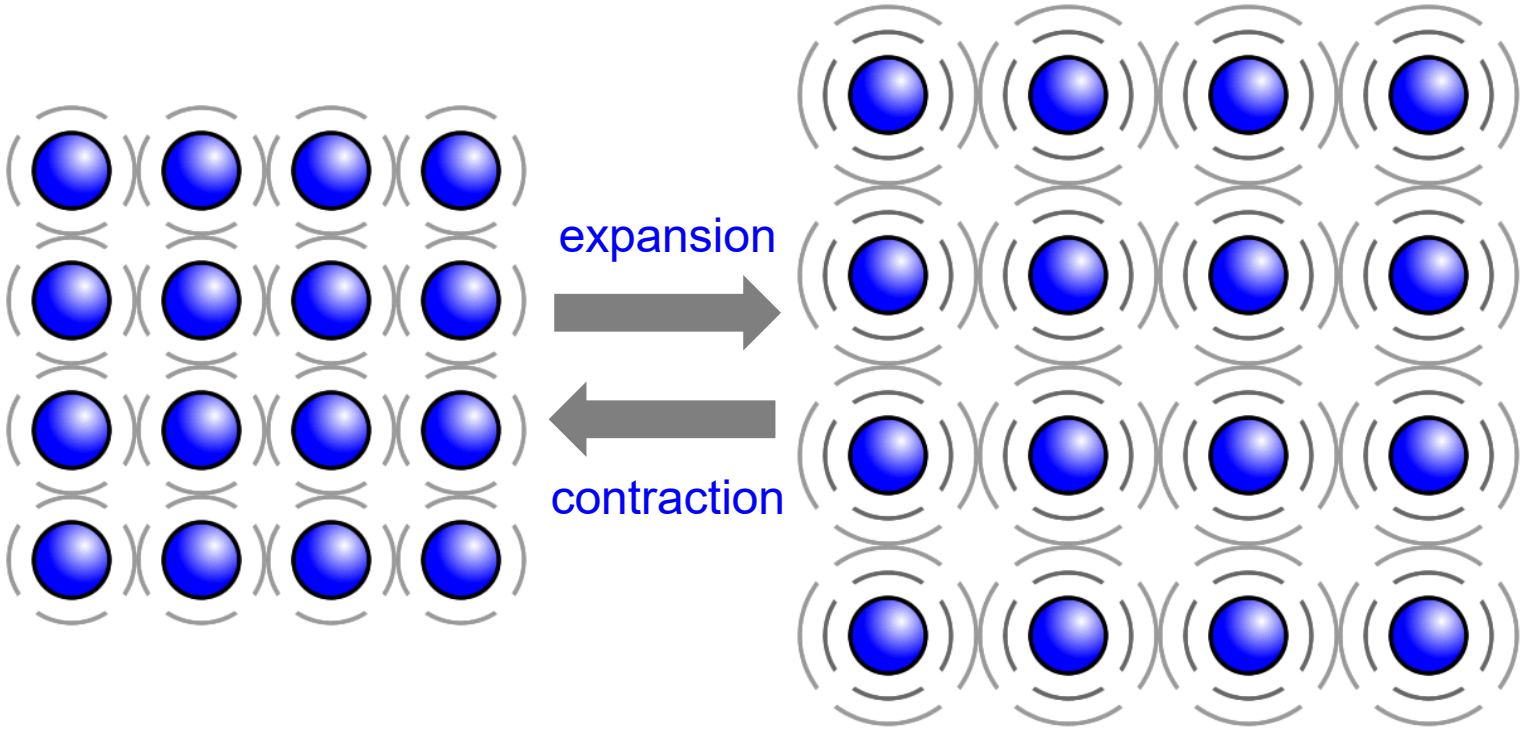


The Transfer of Thermal Energy and its Effects

- For any state, the size of the particles is unchanged when the object is heated or cooled.
- However, the spaces between the particles of the gas increase the most when heated, followed by the liquid and then the solid, where the spaces between the particles increase the least.
- During cooling, the spaces between the particles of the gas decrease the most while the spaces between the particles of the solid decrease the least.
- Forces resulting from expansion and contraction can be very large. In our everyday life, accommodations have been made for expansion and contraction.

The Transfer of Thermal Energy and its Effects

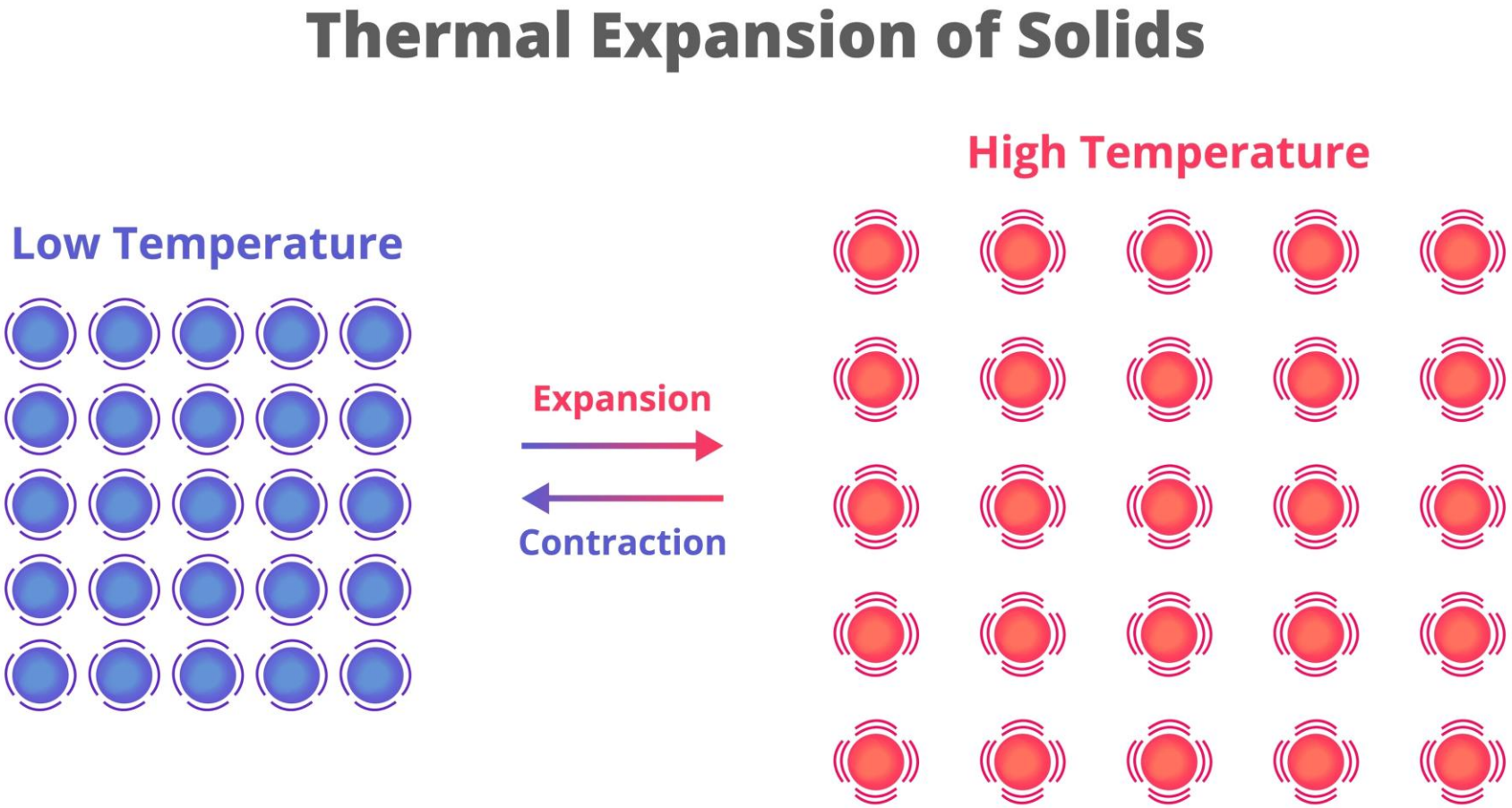
Thermal Expansion of Solids



- Lower Temperature

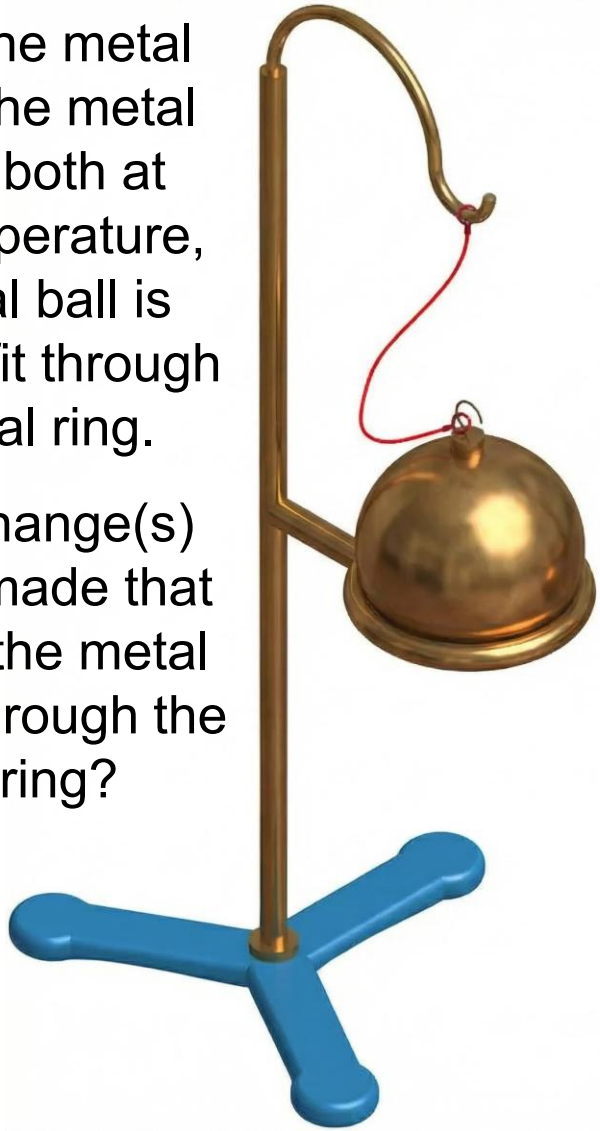
- Higher Temperature

The Transfer of Thermal Energy and its Effects



The Transfer of Thermal Energy and its Effects

- When the metal ball and the metal ring are both at room temperature, the metal ball is unable to fit through the metal ring.
- What change(s) could be made that will allow the metal ball to fit through the metal ring?



The Transfer of Thermal Energy and its Effects

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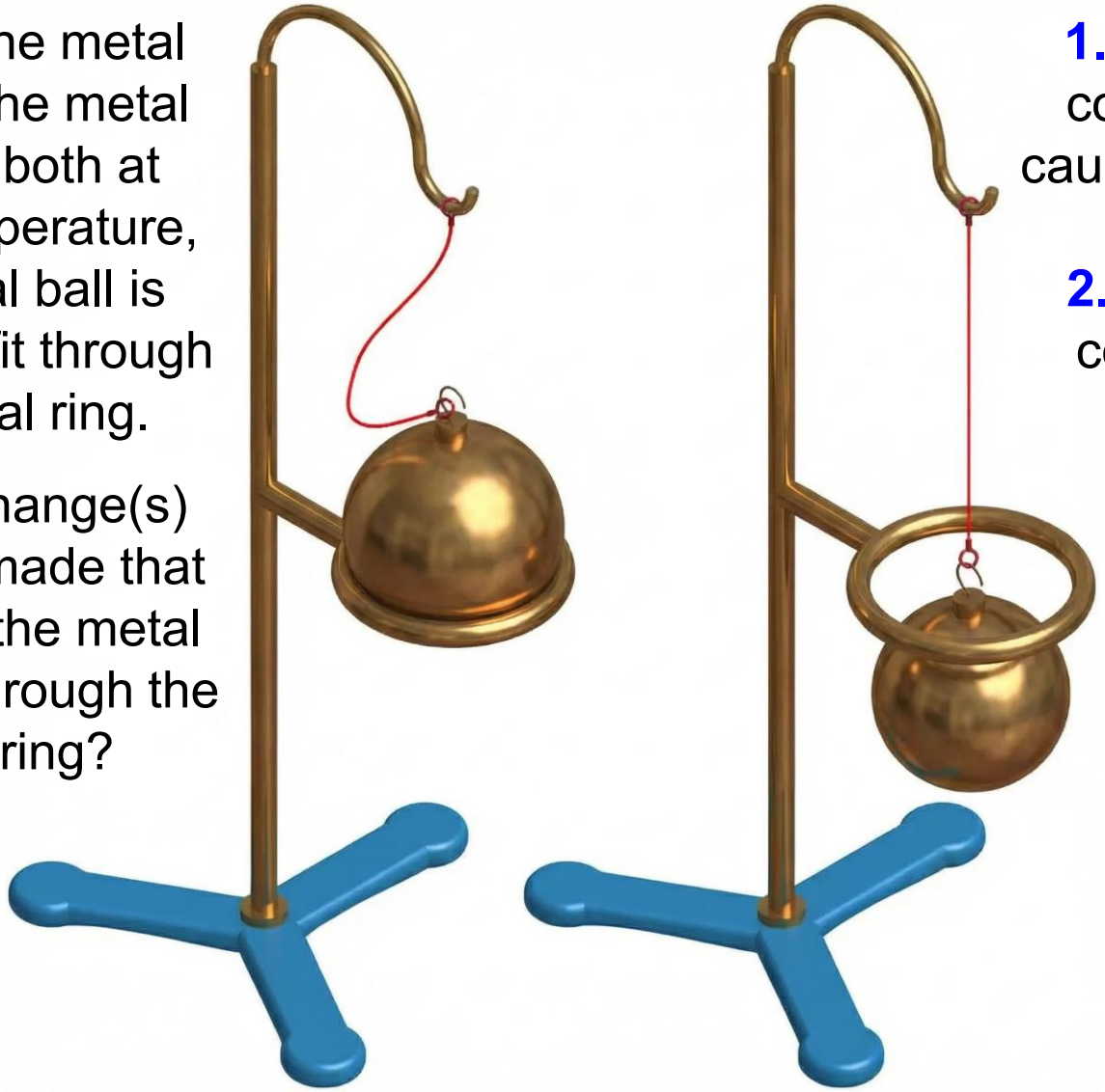


1. The metal ring could be heated, causing it to expand.

2. The metal ball could be cooled causing it to contract.

The Transfer of Thermal Energy and its Effects

- Hence, structures are designed to take the effects of expansion and contraction into consideration.

gaps in railway tracks

gaps in pavement

sagging overhead electric wires

rollers in bridges

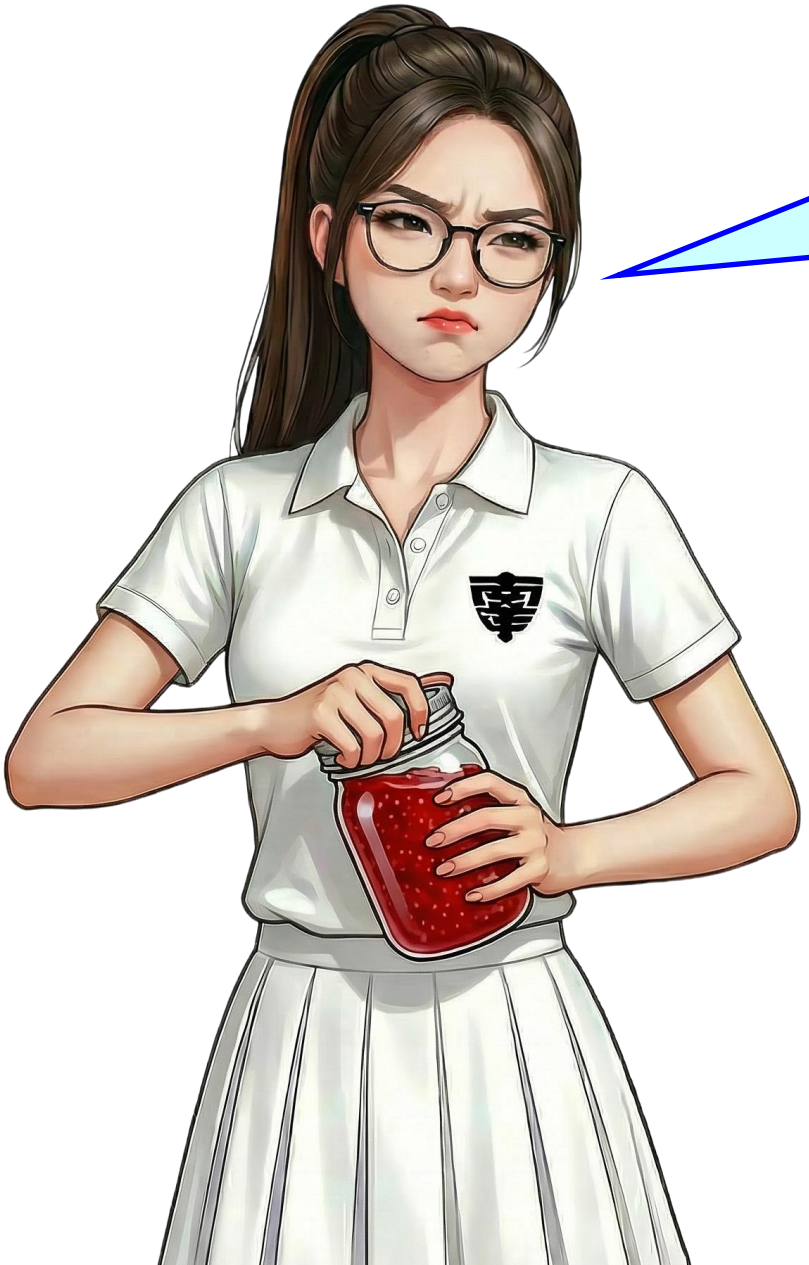
loops in pipes

The Transfer of Thermal Energy and its Effects

Applications of Expansion and Contraction

- The effects of expansion and contraction due to the transfer of thermal energy can be applied in daily life.
- Some examples of applications include opening a jar, a bimetallic strip, a liquid-in-glass thermometer and a hot air balloon.

The Transfer of Thermal Energy and its Effects



The metal lid is stuck on this glass jar! What should I do?

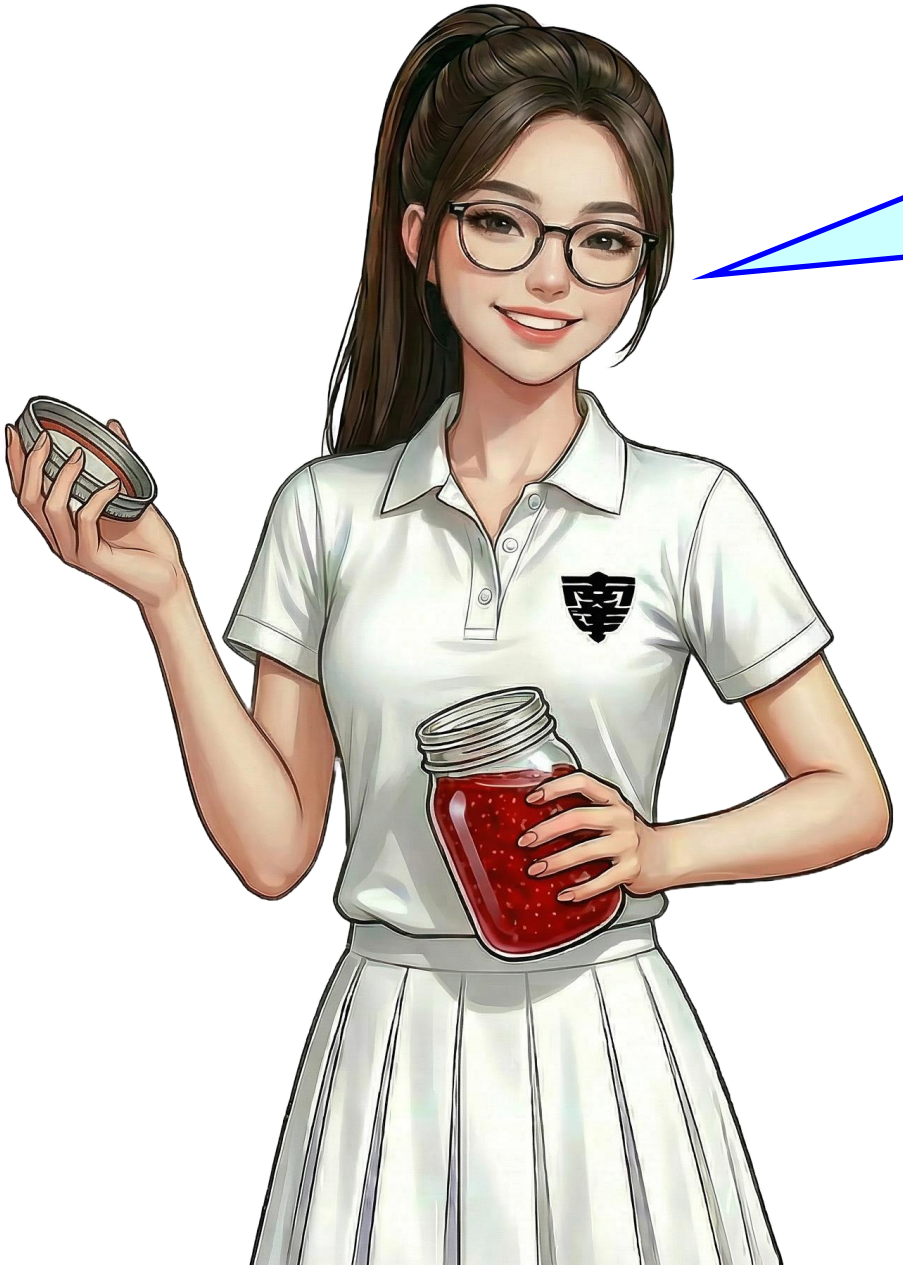
A) Heat the metal lid.

B) Heat the glass jar.

C) Cool the metal lid.

D) Cool the glass jar.

The Transfer of Thermal Energy and its Effects



Heat the metal lid or cool the glass jar. That seems to work!

A) Heat the metal lid. ✓

B) Heat the glass jar. ✗

C) Cool the metal lid. ✗

D) Cool the glass jar. ✓

The Transfer of Thermal Energy and its Effects

Quick Check 2:

1. What happens if there are no gaps on railway tracks?

2. Explain why overhead wires need to have some sag between adjacent towers.

3. What will happen to a dented ping pong ball when you place it in a glass of hot water? Explain.

The Transfer of Thermal Energy and its Effects

Quick Check 2:

1. What happens if there are no gaps on railway tracks?

   The railway tracks will bend and warp (or buckle) due to thermal expansion.

2. Explain why overhead wires need to have some sag between adjacent towers.

3. What will happen to a dented ping pong ball when you place it in a glass of hot water? Explain.

The Transfer of Thermal Energy and its Effects

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1. What happens if there are no gaps on railway tracks?

   The railway tracks will bend and warp (or buckle) due to thermal expansion.

2. Explain why overhead wires need to have some sag between adjacent towers.

   The overhead wires will contract when cooled and may snap if there is no sag.

3. What will happen to a dented ping pong ball when you place it in a glass of hot water? Explain.

The Transfer of Thermal Energy and its Effects

Quick Check 2:

1. What happens if there are no gaps on railway tracks?

   The railway tracks will bend and warp (or buckle) due to thermal expansion.

2. Explain why overhead wires need to have some sag between adjacent towers.

   The overhead wires will contract when cooled and may snap if there is no sag.

3. What will happen to a dented ping pong ball when you place it in a glass of hot water? Explain.

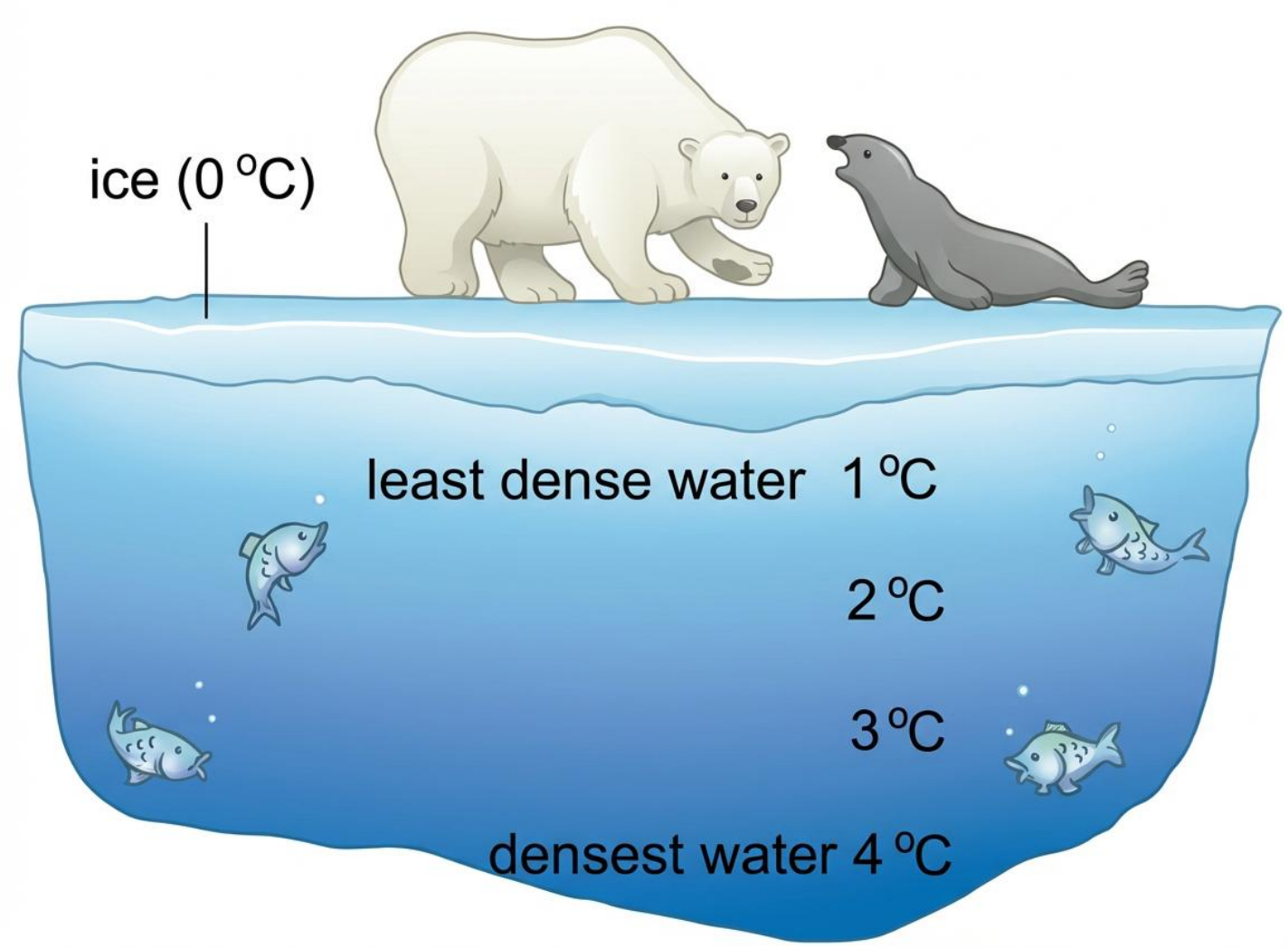
   Heat from the boiling water makes the air inside the ping pong ball expands, causing the dent to be filled out.

The Transfer of Thermal Energy and its Effects

- Railway tracks with no gaps to accommodate thermal expansion will buckle and bend out of shape at high temperatures.

The Transfer of Thermal Energy and its Effects

The Unusual Expansion and Contraction of Water



The Transfer of Thermal Energy and its Effects

The Unusual Expansion and Contraction of Water

- As water is cooled to 4 °C, it contracts like other liquids. But when it is further cooled to below 4 °C, water expands. This means the volume of water is smallest at 4 °C so the density of water is greatest at 4 °C.
- When water freezes to form ice, the volume of ice is larger than the volume of water. Thus, the density of ice is smaller than the density of water. This explains why ice floats on water.
- In nature, the water below the ice remains at a temperature suitable for the survival of organisms in the water.

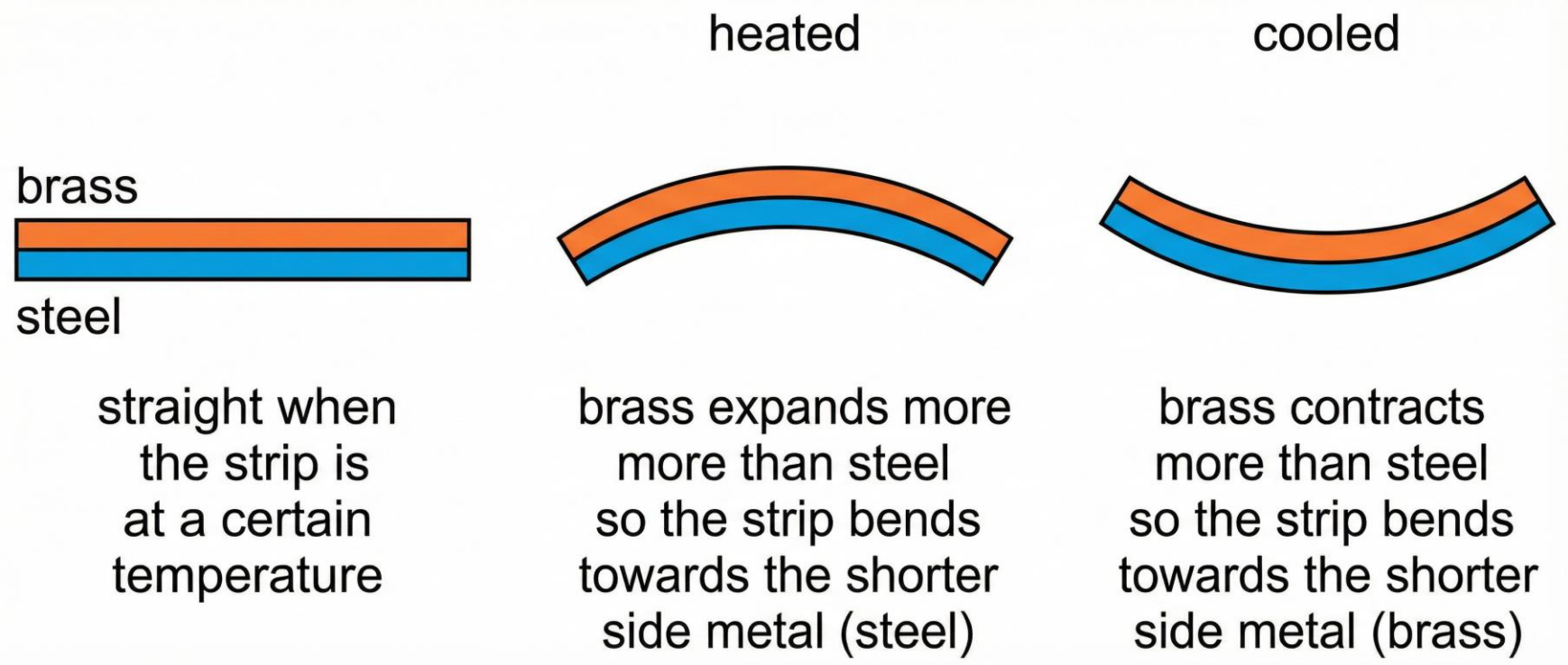
The Transfer of Thermal Energy and its Effects

Bimetallic Strips

- A **bimetallic strip** is made up of **two metals that expand at different rates upon the same change in temperature**.
- For example, brass, which expands and contracts more than steel, can be securely joined together with steel to make a bimetallic strip.
- When heated, one metal expands more than the other metal, so it bends one way. When cooled, one metal contracts more than the other so it bends the other way. The metal that expands more is also the metal that contracts more.

The Transfer of Thermal Energy and its Effects

Bimetallic Strips

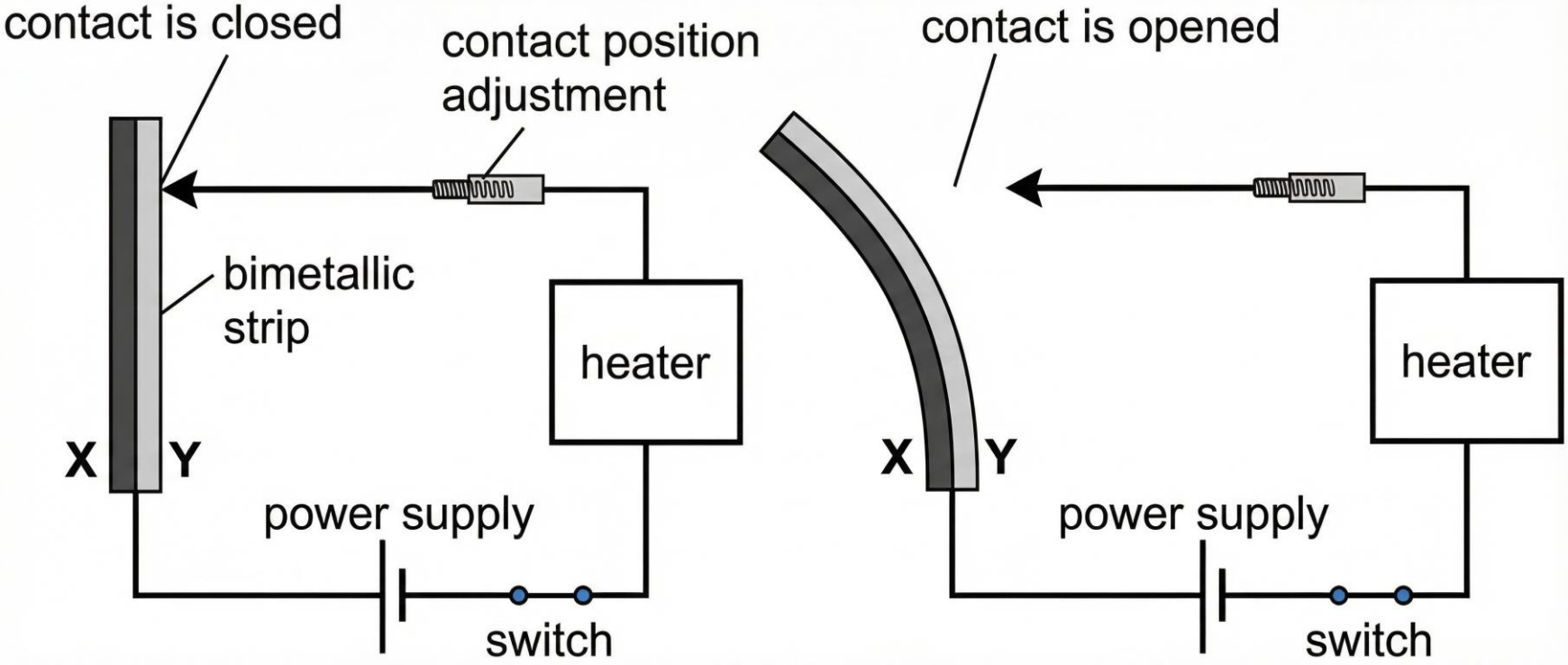


- Bimetallic strips are used in bimetallic thermometers and thermostats. Thermostats are used to control temperature by turning on or off heaters or coolers when it becomes too hot or too cold.

The Transfer of Thermal Energy and its Effects

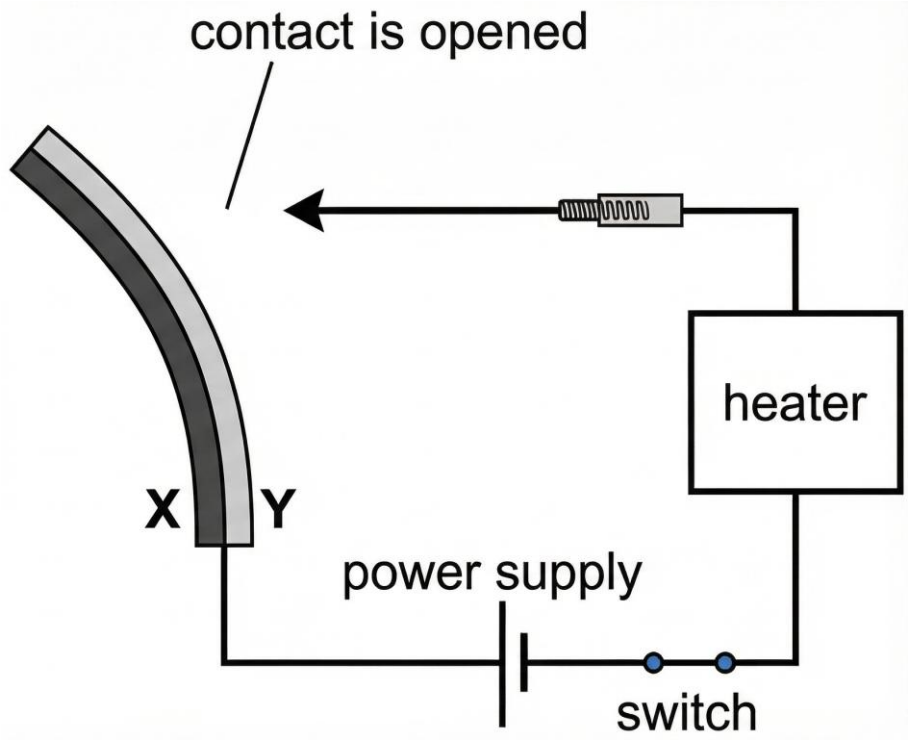
Bimetallic Strips

- The following shows a circuit connection using a bimetallic strip to turn off the heating device in an oven when it gets too hot.



The Transfer of Thermal Energy and its Effects

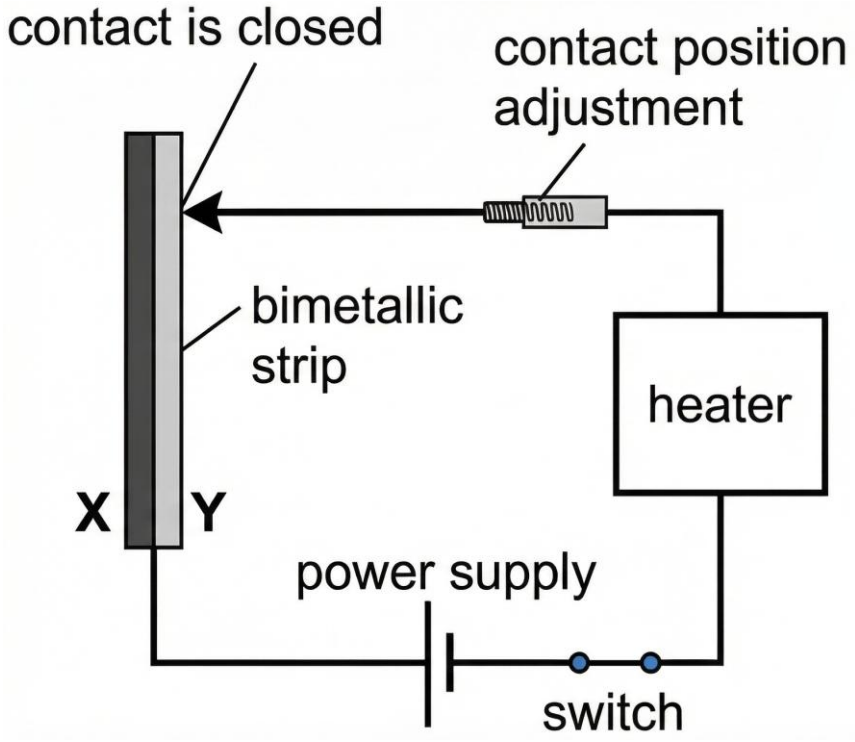
Bimetallic Strips



- When the heater in the oven is switched on, the bimetallic strip starts to expand.
- Metal **Y** expands more than metal **X**, causing the bimetallic strip to bend away from the contact. This results in an opened circuit. The heater stops heating and the oven starts to cool down.

The Transfer of Thermal Energy and its Effects

Bimetallic Strips



- The bimetallic strip then cools down and returns to its original position. The circuit closes and the heater starts to work again.
- The cycle repeats itself to maintain a constant temperature in the oven.

The Transfer of Thermal Energy and its Effects

Bimetallic Strips

Quick Check 3:

1. For the oven circuit shown previously, how would you move the contact position to maintain the temperature of the oven at a higher temperature?

2. If the heater is replaced by a cooling device, how should a bimetallic strip be installed to stop a cooling device when it I too cold?

The Transfer of Thermal Energy and its Effects

Bimetallic Strips

Quick Check 3:

1. For the oven circuit shown previously, how would you move the contact position to maintain the temperature of the oven at a higher temperature?

   To maintain the temperature of the oven at a higher temperature, the contact position adjustment should be moved closer to the bimetallic strip (moved towards the left).

2. If the heater is replaced by a cooling device, how should a bimetallic strip be installed to stop a cooling device when it I too cold?

The Transfer of Thermal Energy and its Effects

Bimetallic Strips

Quick Check 3:

1. For the oven circuit shown previously, how would you move the contact position to maintain the temperature of the oven at a higher temperature?

   To maintain the temperature of the oven at a higher temperature, the contact position adjustment should be moved closer to the bimetallic strip (moved towards the left).

2. If the heater is replaced by a cooling device, how should a bimetallic strip be installed to stop a cooling device when it I too cold?

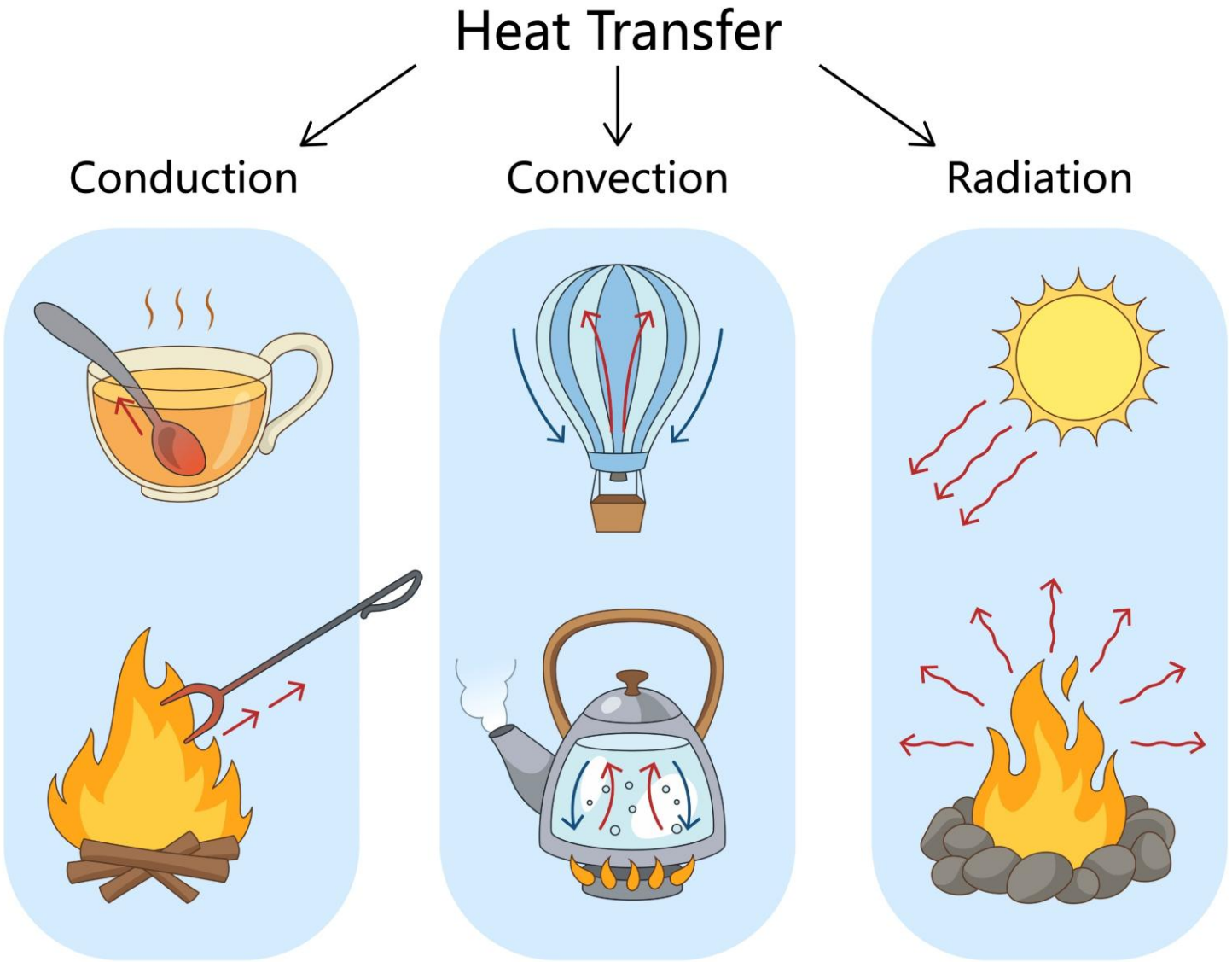
   The bimetallic strip should be installed by flipping it such that the metal **Y** is on the left and metal **X** is on the right.

The Transfer of Thermal Energy and its Effects

Transfer of Thermal Energy

- There are 3 main ways to transfer thermal energy:
  - → Conduction
  - → Convection
  - → Radiation

The Transfer of Thermal Energy and its Effects



The Transfer of Thermal Energy and its Effects

Feature	Conduction	Convection	Radiation
What is it?	Thermal energy moves through a material by particle collisions.	Thermal energy is carried through a liquid or gas by movement of particles.	Thermal energy moves by infrared rays.
Needs particles (matter?)	✓	✓	✗ Can travel through vacuum.
Works best in…	Solids, especially metals.	Liquids and gases (fluids).	Through space and air (and between objects that are not touching).
Can it happen in a vacuum?	✗	✗	✓
How it happens	Faster particles bump into slower ones and pass on their energy.	Hot fluid (low density) rises and cold fluid (high density) sinks (convection current).	Hot objects emit infrared radiation, which is absorbed by other objects.
Example	The tip of a metal spoon in a hot cup of tea starts to feel warm.	Water circulating in a cooking pot. Air circulating in an air-conditioned room.	Feeling the warmth from the sun.
Key condition	Objects touch for thermal energy to be conducted from one to the other.	Particles in the fluid must be able to move freely (circulate).	No particles are required. Radiation travels in straight lines.

- They are all ways that thermal energy moves from a hotter place to a cooler place.
- They all happen faster when the temperature difference is bigger.

The Transfer of Thermal Energy and its Effects

CONDUCTION

The metal wok conducts thermal energy from the hot flame to the cooler food. The wooden handle is a poor conductor of thermal energy, so the student does not burn her hand.

The Transfer of Thermal Energy and its Effects

Conduction

- **Conduction** is the **transfer of thermal energy through a medium without the physical movement of the medium itself**.
- Conduction occurs at the atomic level as follows:

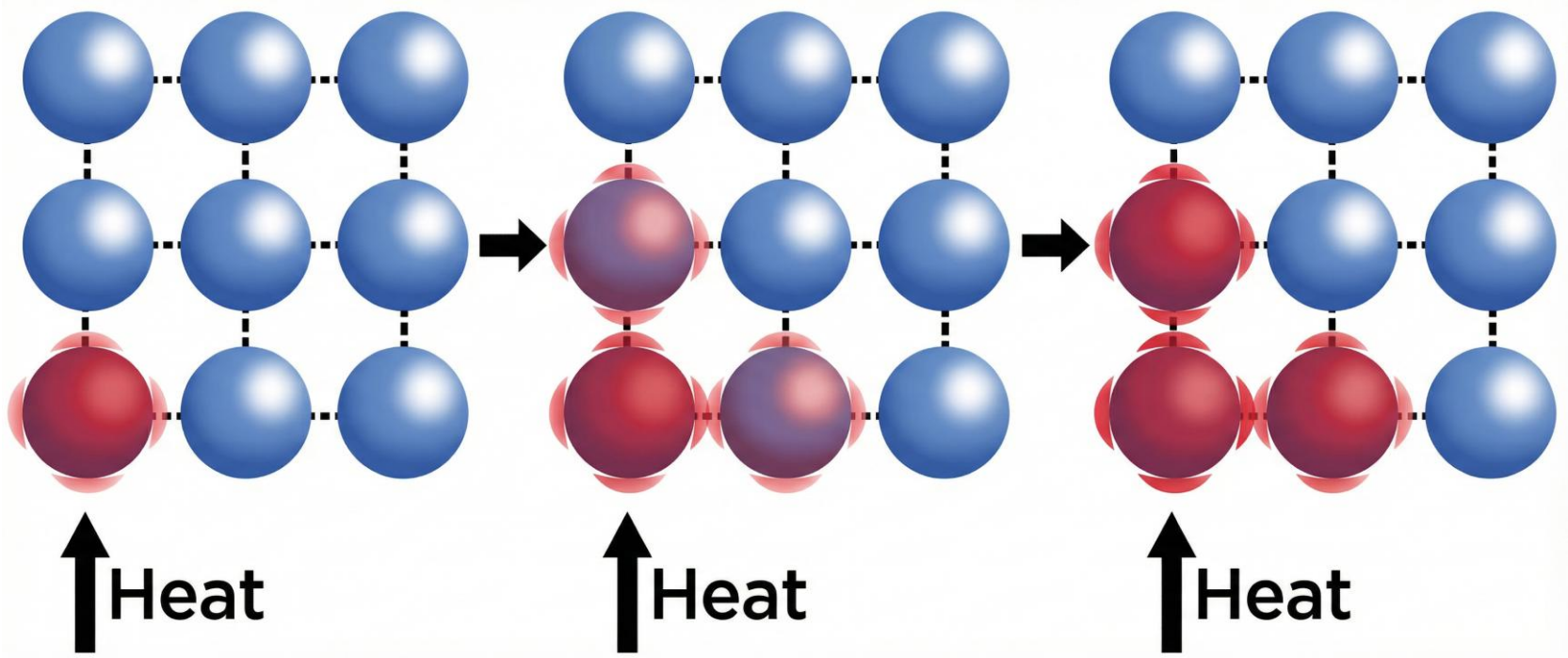
→ When one part of the object is heated, particles at the heated end gain heat to vibrate / move faster and more vigorously.

→ These particles collide with the particles next to them (neighbouring particles) to transfer energy and make them vibrate/move faster and more vigorously.

The Transfer of Thermal Energy and its Effects

Conduction

- This process continues until the energy is passed down to the cooler end of the object and all the particles vibrate / move faster and more vigorously.



The Transfer of Thermal Energy and its Effects

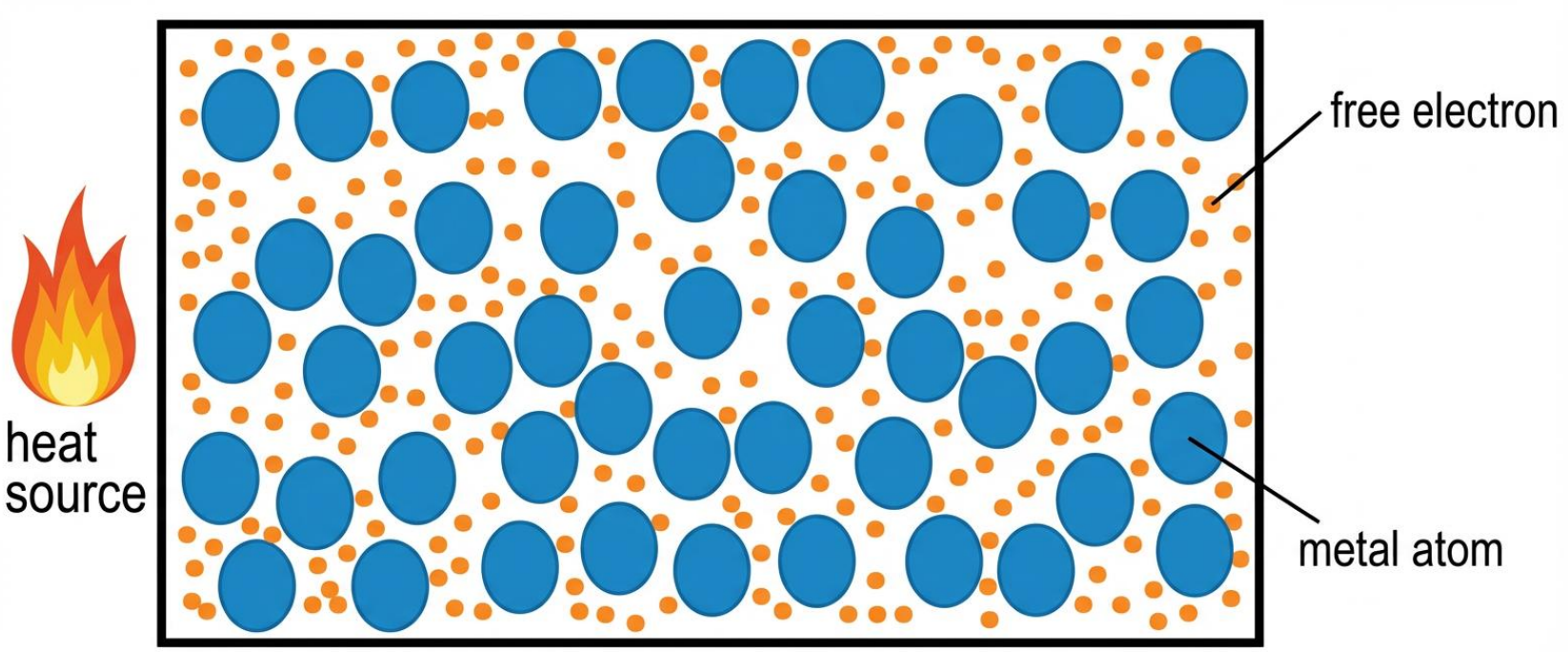
Conduction

- All 3 states of matter can conduct heat. But they do not conduct heat equally well.
- Solids conduct better than liquids which conduct better than gases.
- Solids are better heat conductors than liquids and gases because their particles are more closely packed than in liquids and gases, and are regularly arranged in fixed positions so it is easier to transfer energy.

The Transfer of Thermal Energy and its Effects

Conduction

- Amongst the solids, metals are better thermal conductors than most non-metals.
- Metals have free electrons to help transfer energy quickly.



The Transfer of Thermal Energy and its Effects

Conduction

- Applications of Conduction:

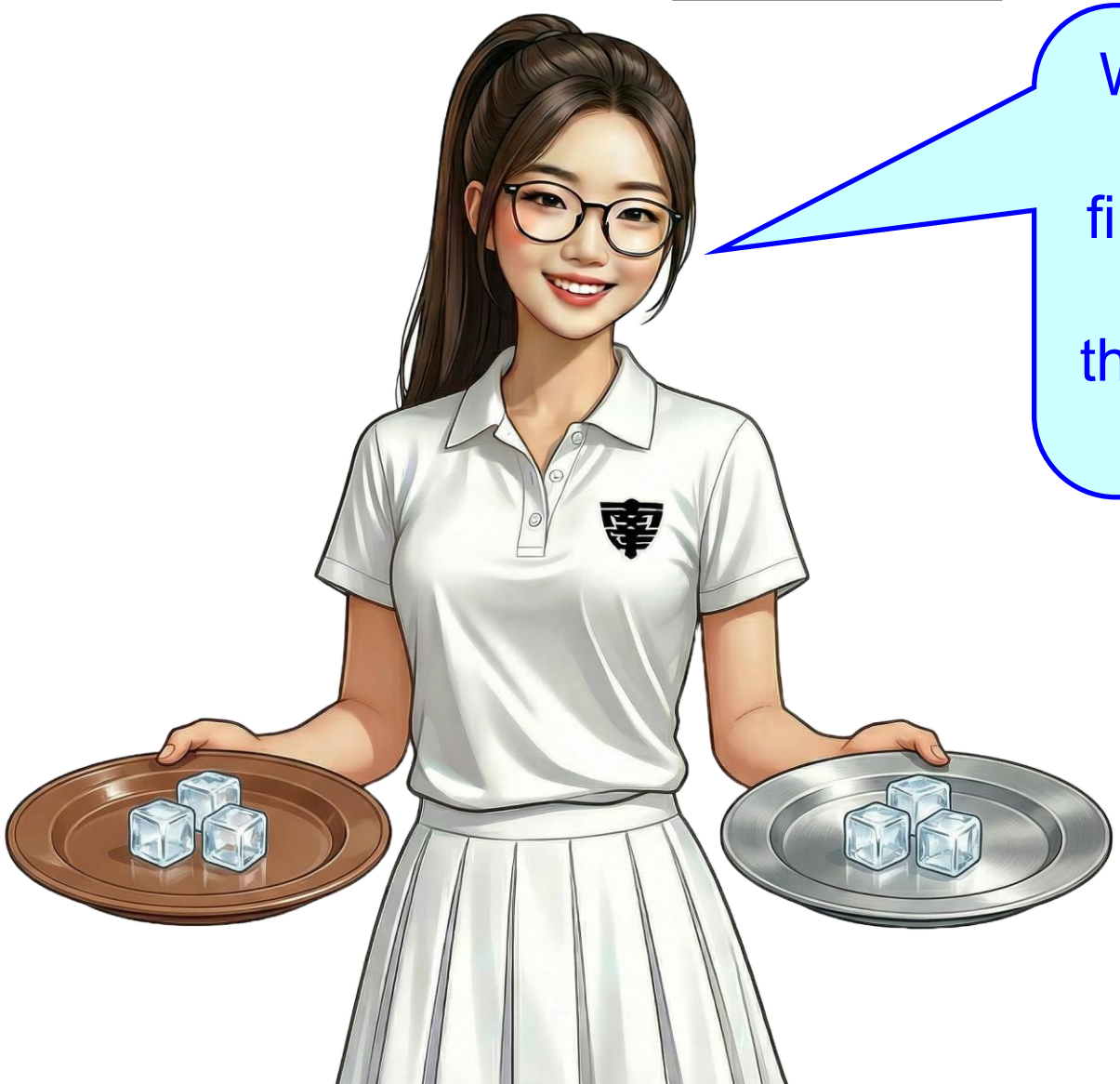
→ Cooking utensils.

The body is made of steel (good conductor) to conduct thermal energy quickly to the food inside.

The pot's handle is made of plastic (poor conductor) so that it does not become too hot to hold.

The Transfer of Thermal Energy and its Effects

Conduction



Which plate will the ice-cubes melt on first, the brown plate made of plastic or the silver plate made of metal? Why?

The Transfer of Thermal Energy and its Effects

Conduction

The metal plate. Metals are good conductors of thermal energy and will conduct thermal energy from the warmer surroundings to the colder ice-cubes.

The Transfer of Thermal Energy and its Effects

Conduction

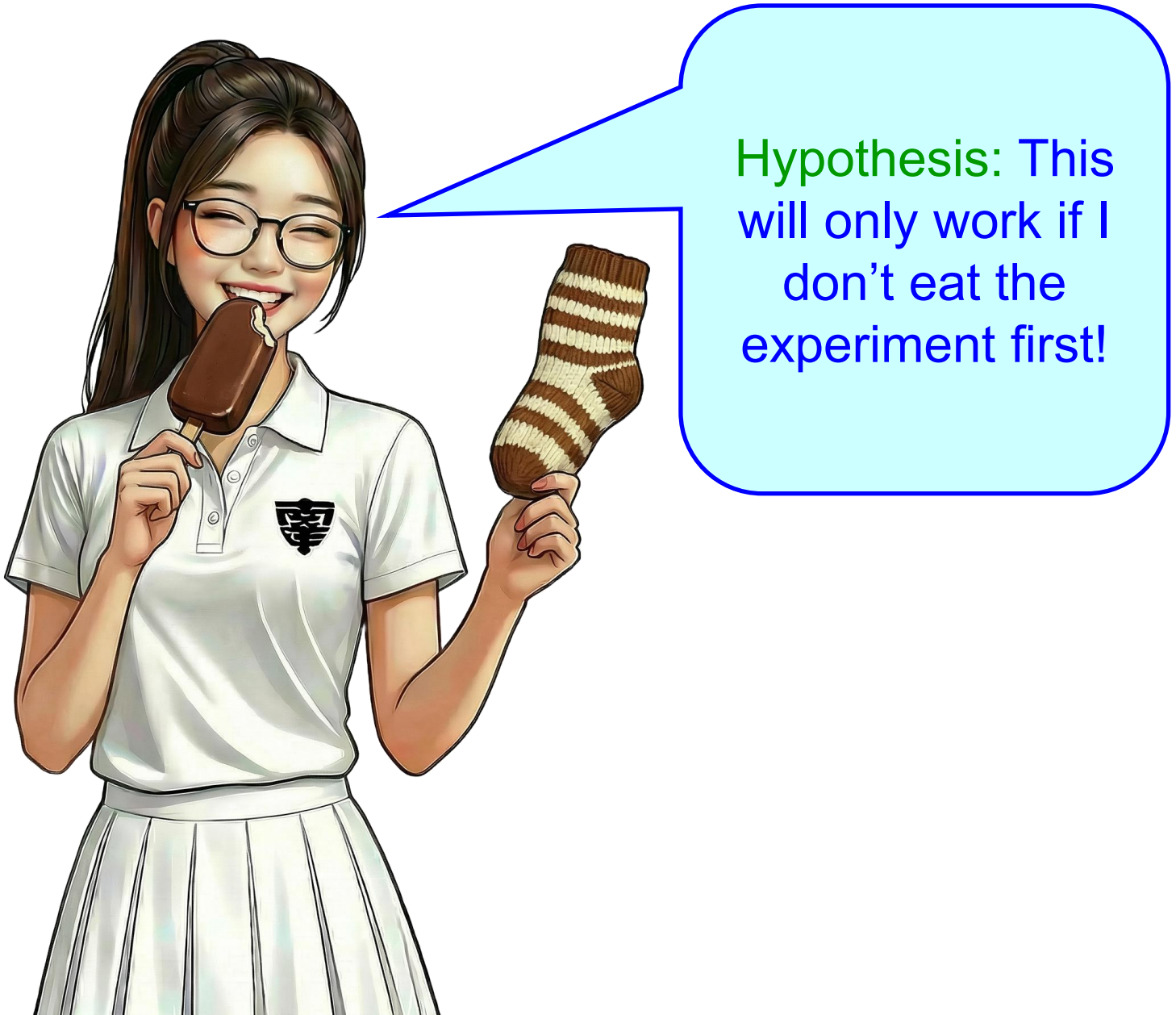
- Applications of Conduction:

→ Animals such as polar bears and sheep have thick fur which traps air to reduce heat loss by conduction.

- Winter clothes and fur trap air (poor thermal conductor). This reduces loss of thermal energy to the surroundings by conduction, keeping the individual warm.

The Transfer of Thermal Energy and its Effects

The Transfer of Thermal Energy and its Effects



The Transfer of Thermal Energy and its Effects

Quick Check 4.

1. A student has two ice-cream bars. Ice-cream bar **A** is directly exposed to its surroundings while ice-cream bar **B** is wrapped with a sock.

   Both ice-cream bars are then left in the same environment. Predict which ice-cream bar will melt first and explain your answer.

The Transfer of Thermal Energy and its Effects

Quick Check 4.

1. A student has two ice-cream bars. Ice-cream bar **A** is directly exposed to its surroundings while ice-cream bar **B** is wrapped with a sock.

   Both ice-cream bars are then left in the same environment. Predict which ice-cream bar will melt first and explain your answer.

   Bar **A** will melt first. Thermal energy is transferred from the hotter surroundings to the cooler ice-cream.

   Always state the direction in which the thermal energy is moving, from hotter… to colder…

The Transfer of Thermal Energy and its Effects

Quick Check 4.

1. A student has two ice-cream bars. Ice-cream bar **A** is directly exposed to its surroundings while ice-cream bar **B** is wrapped with a sock.

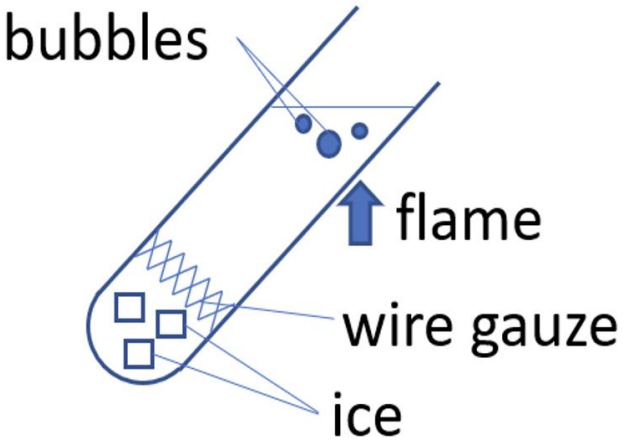
   Both ice-cream bars are then left in the same environment. Predict which ice-cream bar will melt first and explain your answer.

   Bar **A** will melt first. Thermal energy is transferred from the hotter surroundings to the cooler ice-cream. The ice-cream with insulation will reduce the rate of transfer of thermal energy from the surrounding to the ice-cream. So, the ice-cream with insulation (ice-cream **B**) will melt slower than the other ice cream **A**.

The Transfer of Thermal Energy and its Effects

Quick Check 4.

2. The diagram below shows a test tube containing ice being heated.



(a) After some time, bubbles are observed when the water at the top boils. Predict what will happen to the ice at the bottom at this instance. Explain.

(b) What do you think is the purpose of the wire gauze?

The Transfer of Thermal Energy and its Effects

Quick Check 4.

2. The diagram below shows a test tube containing ice being heated.

(a) After some time, bubbles are observed when the water at the top boils. Predict what will happen to the ice at the bottom at this instance. Explain.

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The Transfer of Thermal Energy and its Effects

Quick Check 4.

2. The diagram below shows a test tube containing ice being heated.

(a) After some time, bubbles are observed when the water at the top boils. Predict what will happen to the ice at the bottom at this instance. Explain.

Ice remains a solid. Since water is a poor thermal conductor, the rate of transfer of thermal energy to the ice will be very slow.

(b) What do you think is the purpose of the wire gauze?

The Transfer of Thermal Energy and its Effects

Quick Check 4.

2. The diagram below shows a test tube containing ice being heated.

(a) After some time, bubbles are observed when the water at the top boils. Predict what will happen to the ice at the bottom at this instance. Explain.

Ice remains a solid. Since water is a poor thermal conductor, the rate of transfer of thermal energy to the ice will be very slow.

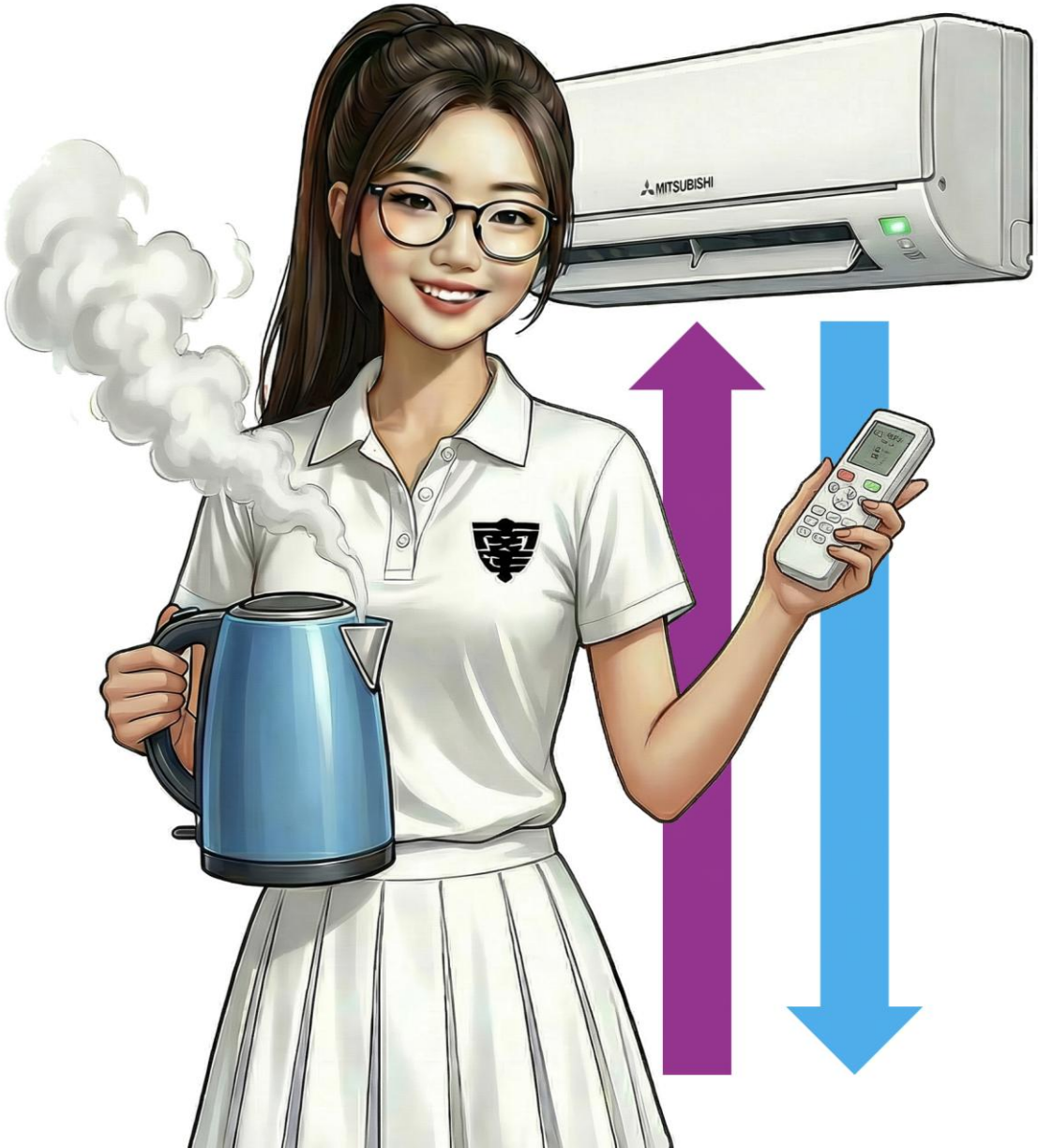
(b) What do you think is the purpose of the wire gauze?

The wire gauze is placed to prevent the ice from floating upwards.

The Transfer of Thermal Energy and its Effects

- What do you think?

The Transfer of Thermal Energy and its Effects



COVECTION

Convection currents occur inside kettles while the water is being heated and inside rooms cooled by air conditioners.

The Transfer of Thermal Energy and its Effects

Convection

- **Convection** is the **transfer of thermal energy due to the movement of the medium, arising from density differences in the medium**.

→ It is the main form of heat transfer in liquids and gases because they can flow (particles of liquids and gases are free to move about).

→ **Note:** As atoms in solids only vibrate about their fixed positions, hence convection does not occur in solids.

The Transfer of Thermal Energy and its Effects

Convection

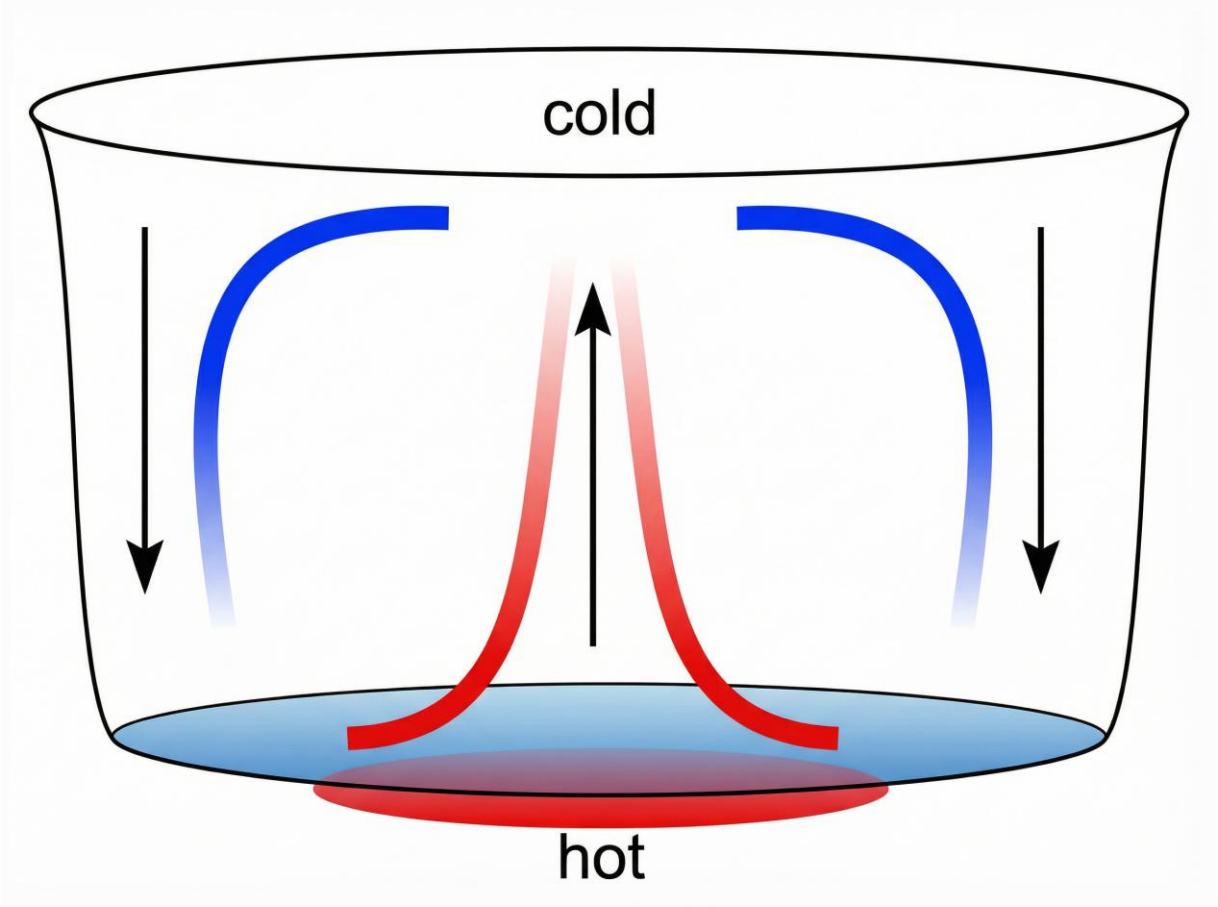
- How convection works.

Heating	Cooling
When the liquid / gas is heated at the bottom, it **expands to become less dense** and **rises** to the top.	When the liquid / gas is cooled at the top, it **contracts to become denser** and **sinks** to the bottom.
Cooler liquid / gas at the top is **denser** so it **sinks** down to be heated.	Warmer liquid / gas at the bottom is **less dense** so it **rises** up to be cooled.
This process continues to set up a **convection current** to heat up all the liquid / gas.	This process continues to set up a **convection current** to cool down all the liquid / gas.

The Transfer of Thermal Energy and its Effects

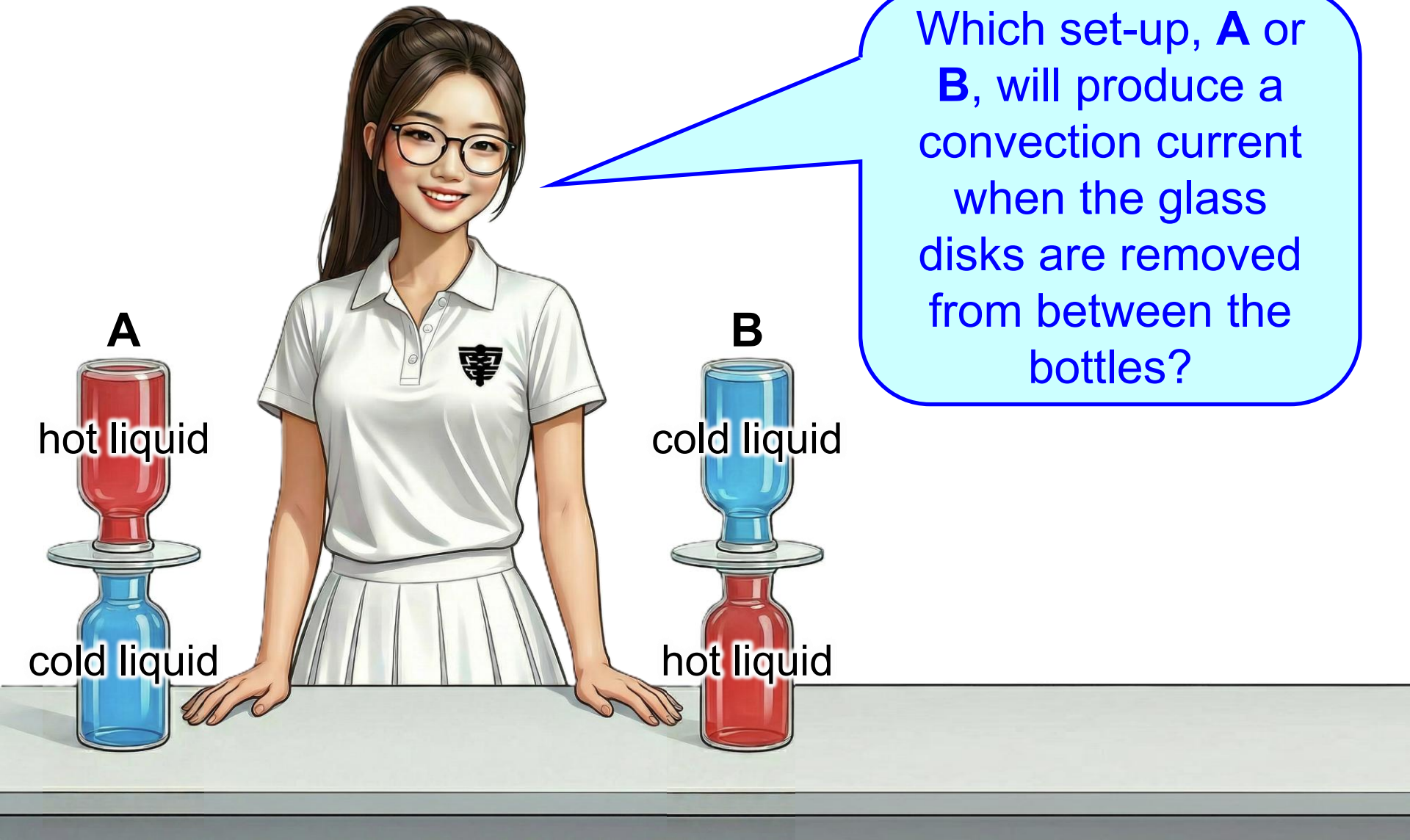
Convection

- How convection works.



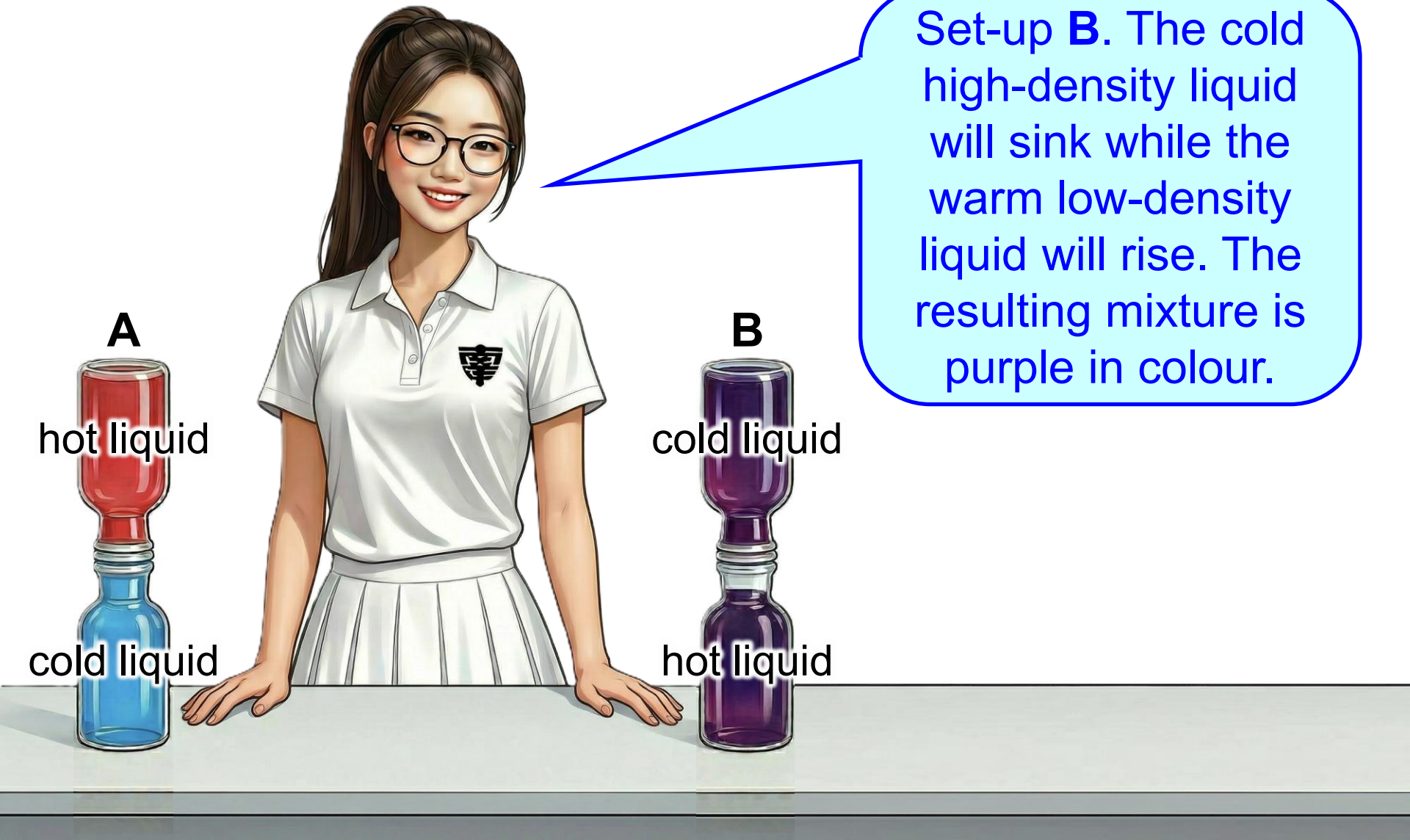
The Transfer of Thermal Energy and its Effects

Convection



The Transfer of Thermal Energy and its Effects

Convection



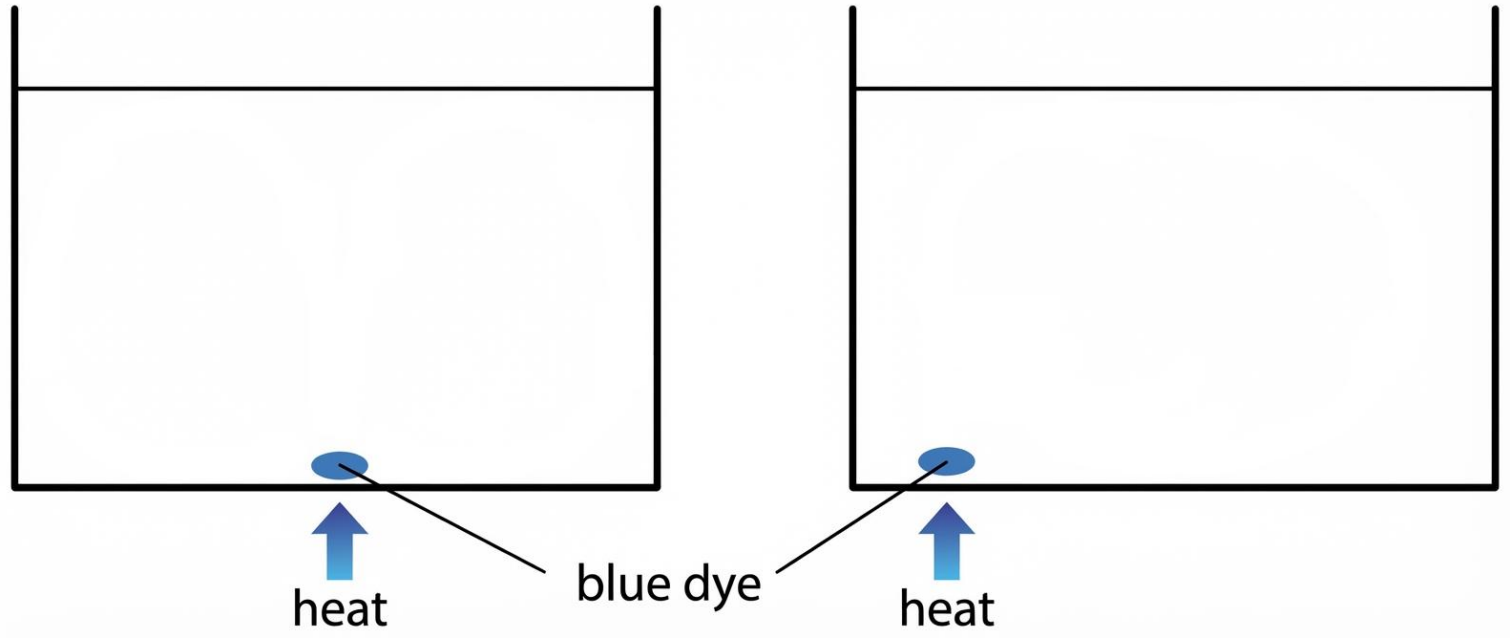
The Transfer of Thermal Energy and its Effects

Convection

Quick Check 5.

A blue dye is placed directly above the heat source in the containers.

(a) Draw the convection current in the containers.



The Transfer of Thermal Energy and its Effects

Convection

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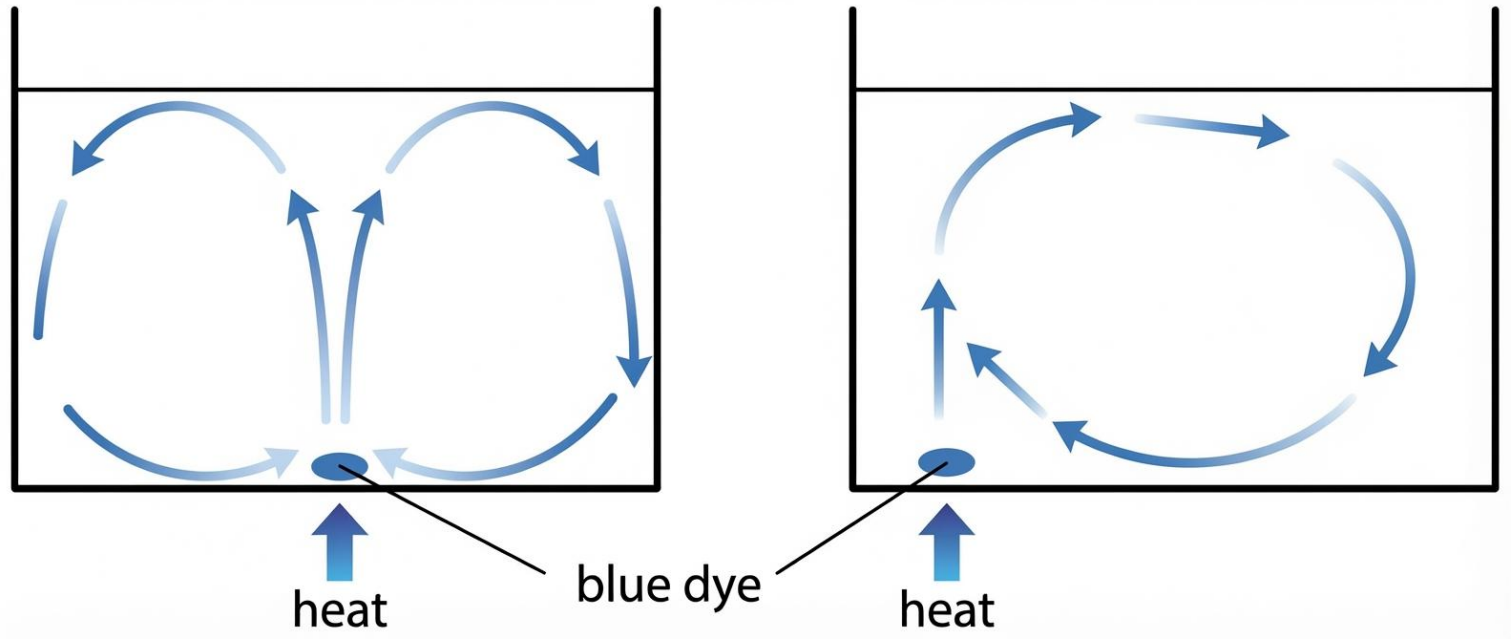


The Transfer of Thermal Energy and its Effects

Convection

Quick Check 5.

(b) Describe how the convection current is set-up in the containers.

The Transfer of Thermal Energy and its Effects

Convection

Quick Check 5.

(b) Describe how the convection current is set-up in the containers.

When the water directly above the heat source is heated at the bottom, it expands to become less dense and rises to the top.

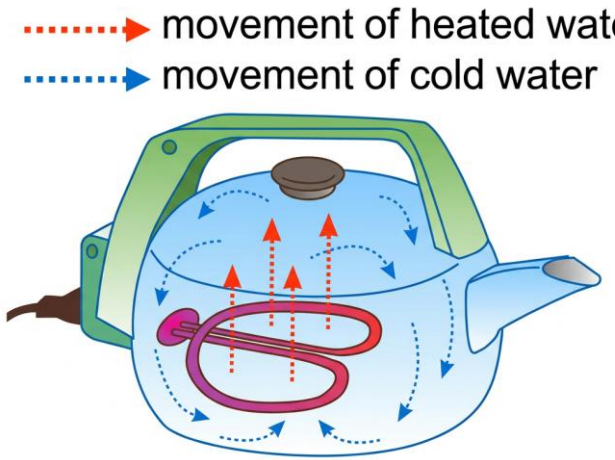
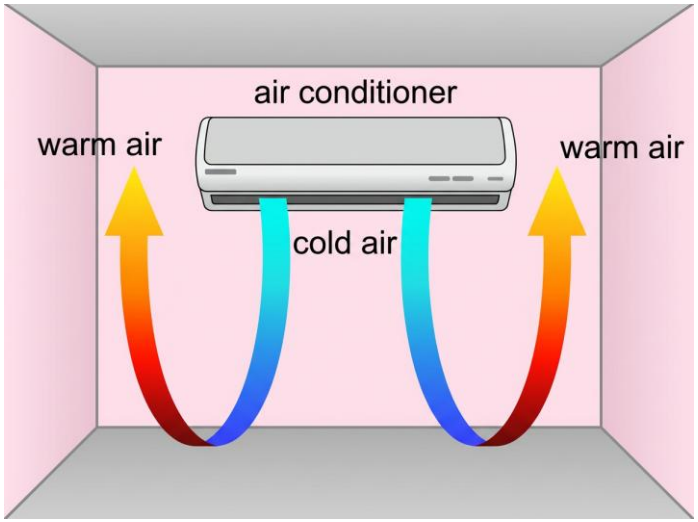
Cooler water at the top is denser so it sinks to the bottom.

This process continues to set up a convection current.

The Transfer of Thermal Energy and its Effects

Convection

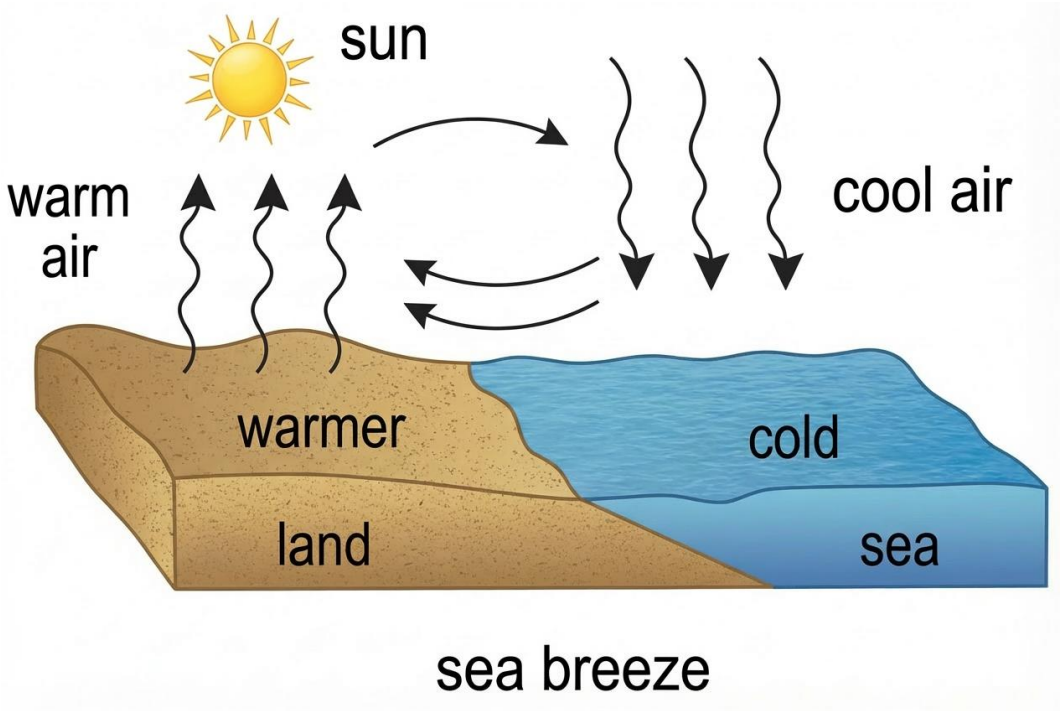
- Examples of applications of convection:

	
Heaters are placed at the bottom of an electric kettle to set up convection currents in water to heat up all the water efficiently.	Air-conditioners are placed near the ceiling of a room to set up convection currents in air to cool down all the air in the room efficiently.

The Transfer of Thermal Energy and its Effects

Convection

- Convection in nature – **Sea breeze** (during daytime):



sea breeze

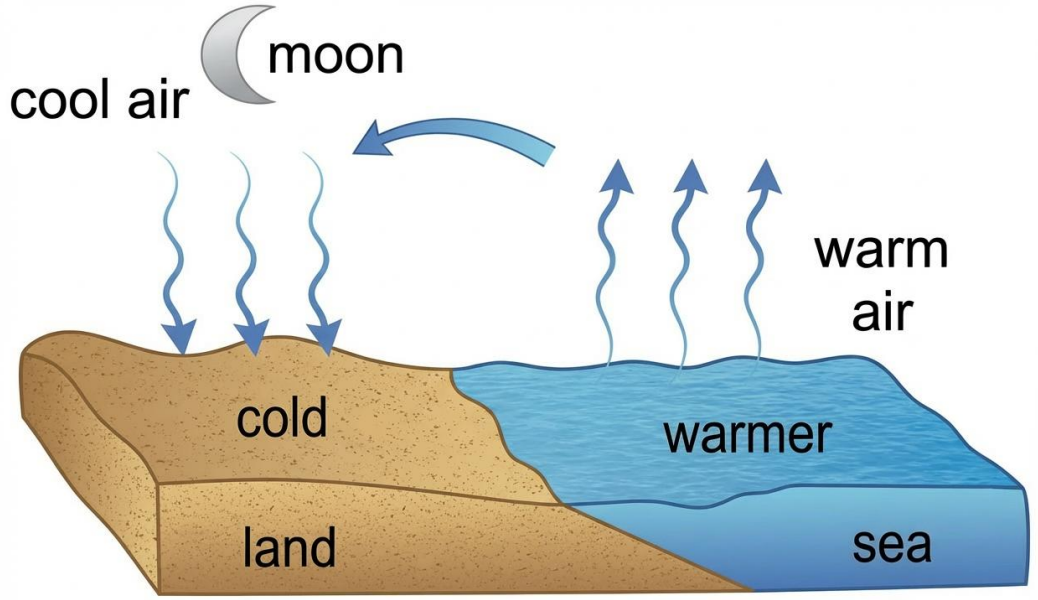
- Due to the Sun, land heats up faster than water*.
- Air above the land gets hot, expands to become less dense and rises.
- Air above the water is cooler, denser and flows towards the land to replace the rising hot air.

*Water needs to absorb a lot of thermal energy in order for its temperature to increase by just 1 °C. Water is said to have a *high specific heat capacity*.

The Transfer of Thermal Energy and its Effects

Convection

- Convection in nature – **Land breeze** (during night-time):



land breeze

- At night, land cools faster than water.
- Air above the water is warmer and less dense so it rises.
- Air above the land is cooler, denser and flows towards the water to replace the rising hot air.

The Transfer of Thermal Energy and its Effects

Convection

Quick Check 6. Teacher demonstration – Teabag rocket:

A teabag is opened and the tealeaves are removed. The teabag is stood upright on a table and the top is set-on-fire.

The Transfer of Thermal Energy and its Effects

Convection

Quick Check 6. Teacher demonstration – Teabag rocket:

(a) Predict what happens to the teabag as it burns.

(b) Based on your observations, what happens to the teabag as it burns? Write down your observations.

The Transfer of Thermal Energy and its Effects

Convection

Quick Check 6. Teacher demonstration – Teabag rocket:

(a) Predict what happens to the teabag as it burns.

(b) Based on your observations, what happens to the teabag as it burns? Write down your observations.

As the tea bag burns to about half of its original height, the teabag is lifted / rises upwards.

The teabag continues to burn and rise until it has all become ash.

The Transfer of Thermal Energy and its Effects

Convection

Quick Check 6. Teacher demonstration – Teabag rocket:

(c) Explain what you observed in part **(b)**.

The Transfer of Thermal Energy and its Effects

Convection

Quick Check 6. Teacher demonstration – Teabag rocket:

(c) Explain what you observed in part **(b)**.

The air around the tea bag is heated up and expands.

The hot air becomes less dense and it rises.

When some of the tea bag has been burnt up, the tea bag is lifted along with the hot air with an upward net force acting on it.

The Transfer of Thermal Energy and its Effects

Convection

Quick Check 6. Teacher demonstration – Teabag rocket:

(c) Explain what you observed in part **(b)**.

The Transfer of Thermal Energy and its Effects

RADIATION

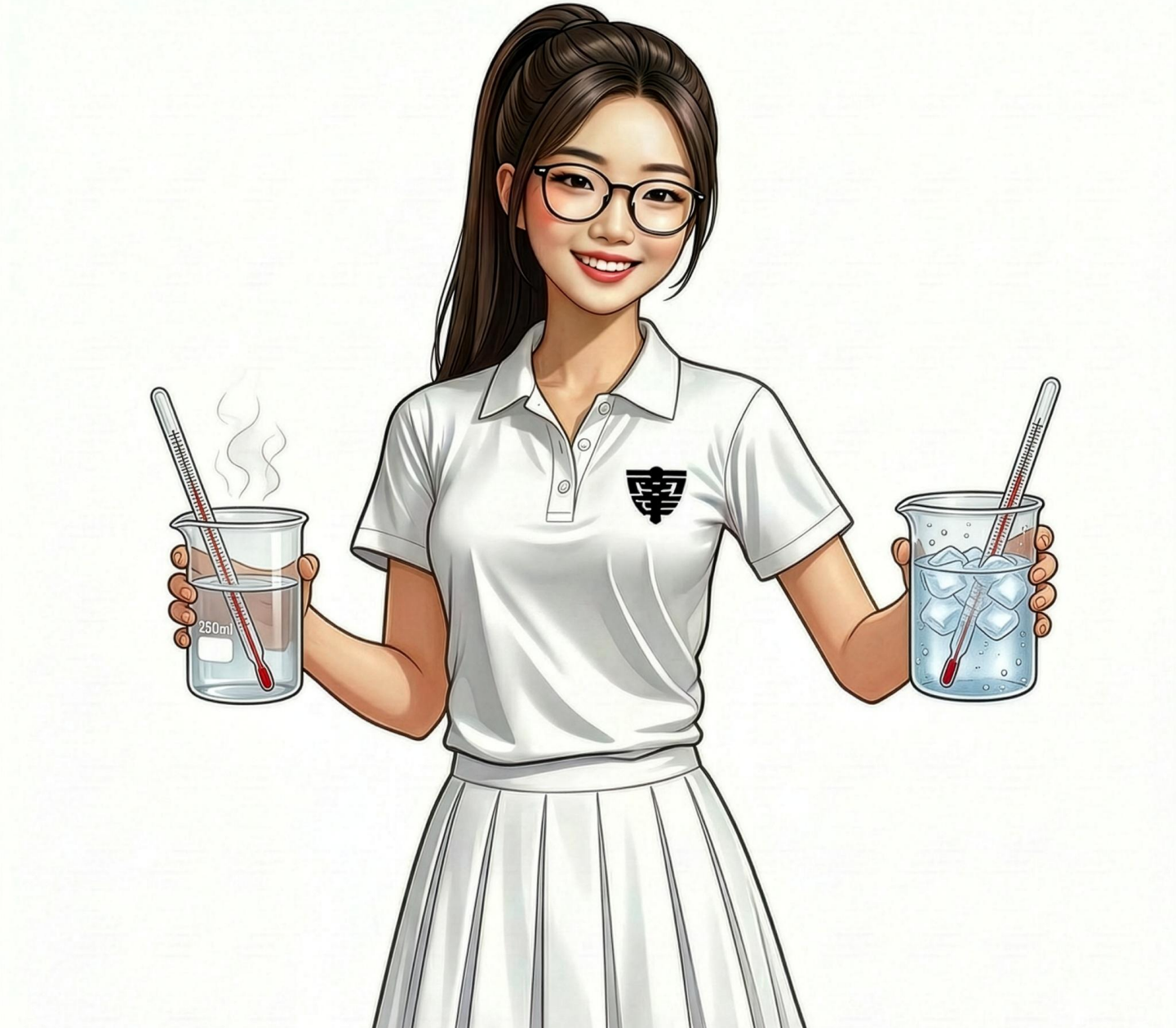
Thermal energy travels from the Sun to the Earth through the vacuum of space in the form of infrared radiation.

The Transfer of Thermal Energy and its Effects

Radiation

- **Radiation** is the **transfer of thermal energy in the form of infrared radiation without the need of a medium**.
- Any object that is warmer than its surroundings will give out or **emit** thermal energy by radiation.
- If an object is colder than its surroundings, it will take in or **absorb** thermal energy by radiation.

The Transfer of Thermal Energy and its Effects



The Transfer of Thermal Energy and its Effects

- Warmer objects emit thermal energy by radiation.
- Colder objects absorb thermal energy by radiation.
- Heat radiates from warmer to colder until they reach the same temperature (thermal equilibrium).

The Transfer of Thermal Energy and its Effects

Radiation

- Factors affecting rate of radiation:

1. Nature of the surface (texture and colour):
   → The **darker** the surface, the **faster radiation** is absorbed or emitted.

   → The **rougher** the surface, the **faster radiation** is absorbed or emitted.

2. Surface area of the object:
   → The **larger** the surface area, the **higher the rate of radiation** absorbed or emitted.

3. Surface temperature of the object:
   → The **higher** the surface temperature, the **higher** the rate of radiation emitted.

The Transfer of Thermal Energy and its Effects

Radiation

- Factors affecting rate of radiation:

1. Nature of the surface (texture and colour):

	Absorber of radiation (when cooler than their surroundings)		**Emitter of radiation** (when warmer than their surroundings)	
	Good absorber of radiation	**Poor absorber** of radiation	**Good emitter** of radiation	**Poor emitter** of radiation
Colour of surface	Black and dull	White and shiny	Black and dull	White and shiny
Type of surface	Rough	smooth	Rough	Smooth

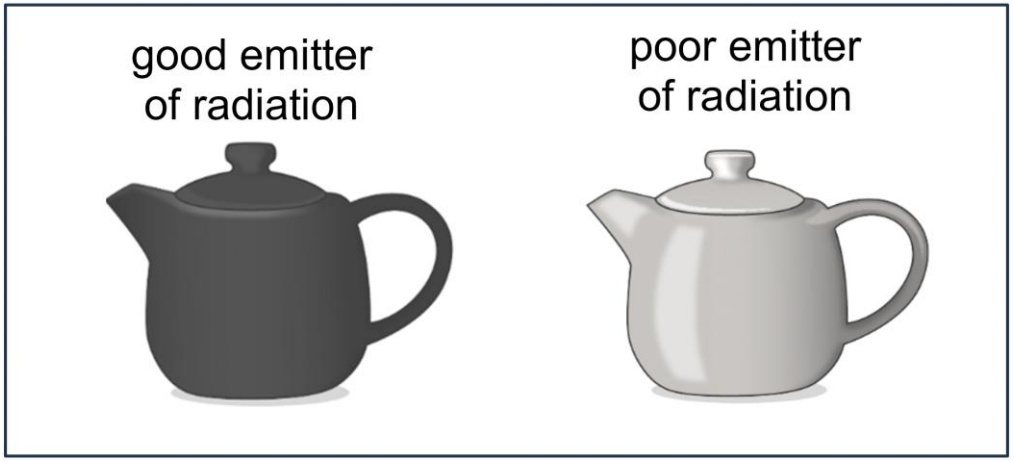
The Transfer of Thermal Energy and its Effects

Radiation

- Examples of applications of radiation:

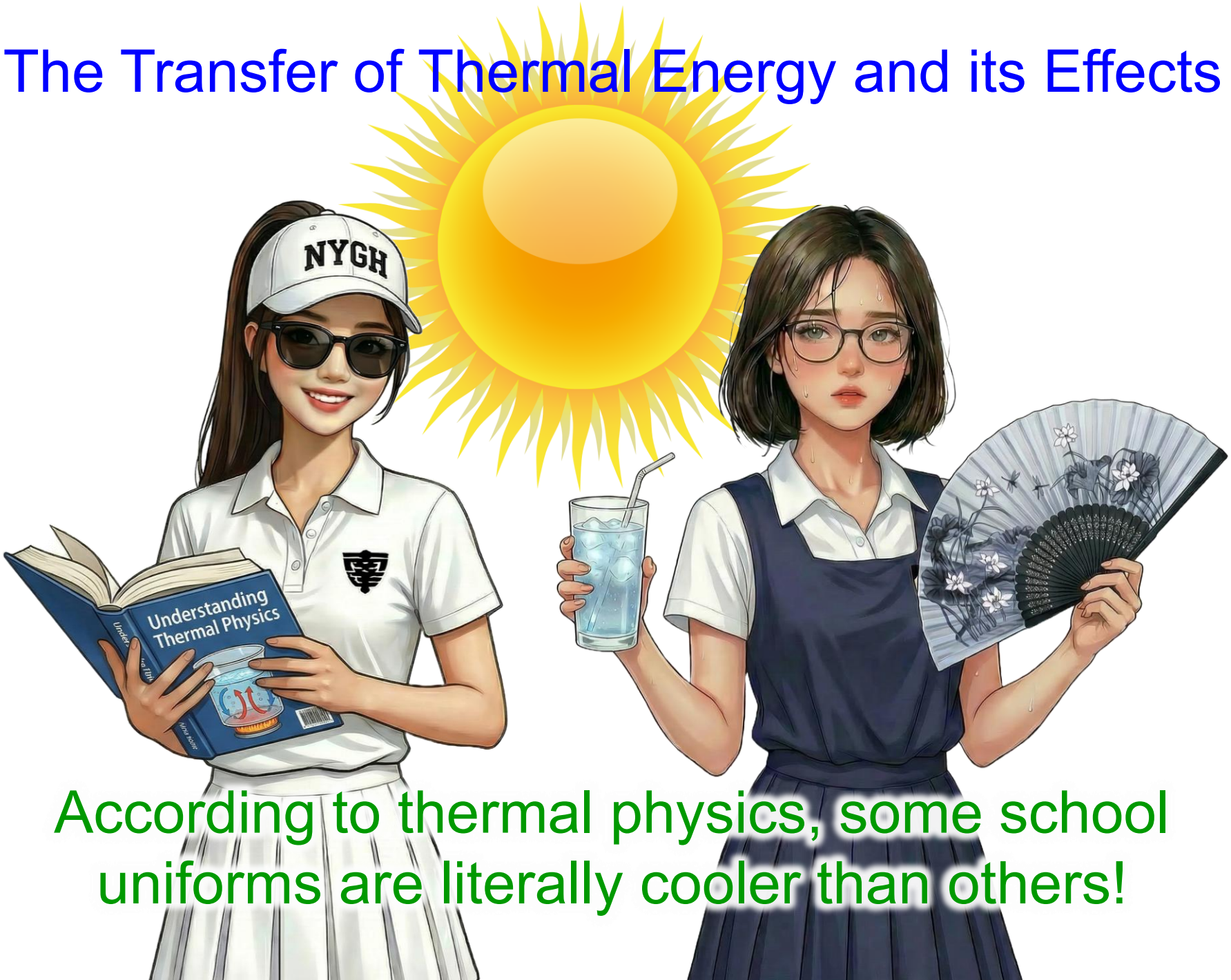
  (a) If we want something to stay hot or stay cold for a longer period of time, we use **shiny, white / silver** and **smooth surfaces**.

Light coloured clothes are poor absorbers of radiation, so they do not become as hot as dark coloured clothing under the sun.



Teapots have white and shiny surfaces so that they are poor emitters of radiation. This helps the hot water inside the teapot to cool down at a slower rate.

The Transfer of Thermal Energy and its Effects



According to thermal physics, some school uniforms are literally cooler than others!

The Transfer of Thermal Energy and its Effects

Radiation

- Examples of applications of radiation:

  (b) If we want something to gain heat or lose heat in a shorter period of time, we use **black**, **dull** and **rough surfaces**.

- Cooling fins for motorbike engines have black and rough surfaces so that they are good emitters of radiation. This helps them lose heat quickly to the surroundings and keeps the engines cooler. They also have large surface areas so that they can transfer heat by radiation at a faster rate.

The Transfer of Thermal Energy and its Effects

Radiation

- Examples of applications of radiation:

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The Transfer of Thermal Energy and its Effects

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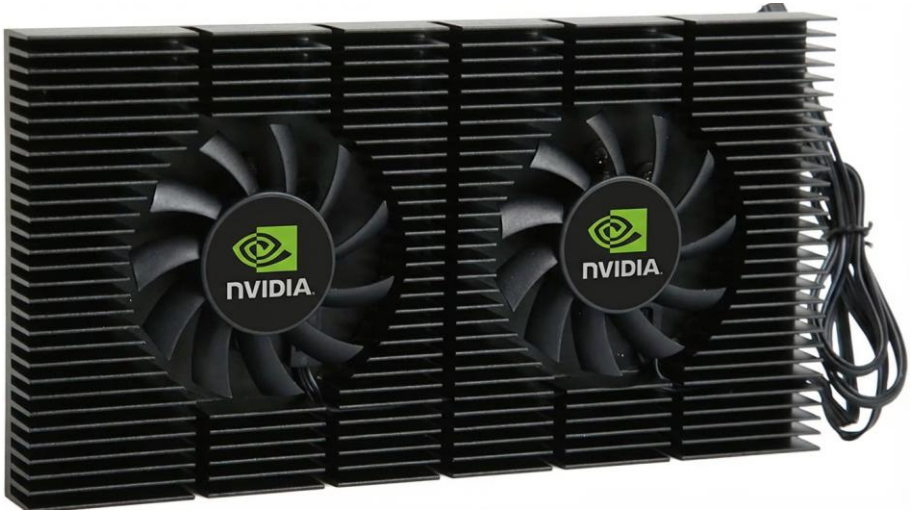


- Cooling fins for heat sinks for computer chips have black and rough surfaces so that they are good emitters of radiation. This helps them lose heat quickly to the surroundings and keep the computer chips cooler. They also have large surface areas so that they can transfer heat by radiation at a faster rate.

The Transfer of Thermal Energy and its Effects

Radiation

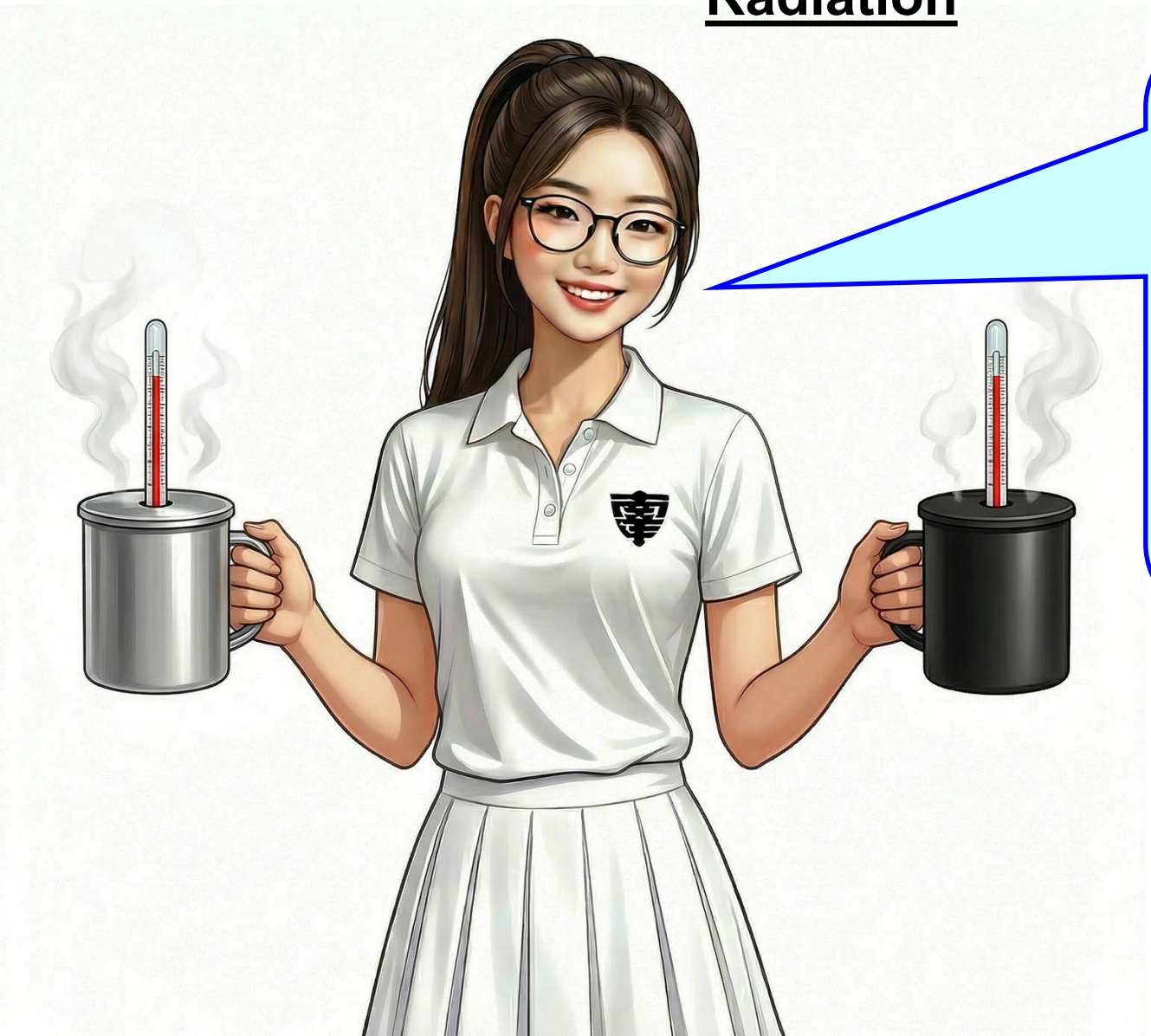
- Examples of applications of radiation:

  (b) If we want something to gain heat or lose heat in a shorter period of time, we use **black**, **dull** and **rough surfaces**.

- Solar heaters (used to heat water) on the roofs of houses are painted black so that they are good absorbers of radiation when placed under the sun. This allows them to get hot quickly as they trap more solar radiation. They also have large surface areas so that they can transfer heat by radiation at a faster rate.

The Transfer of Thermal Energy and its Effects

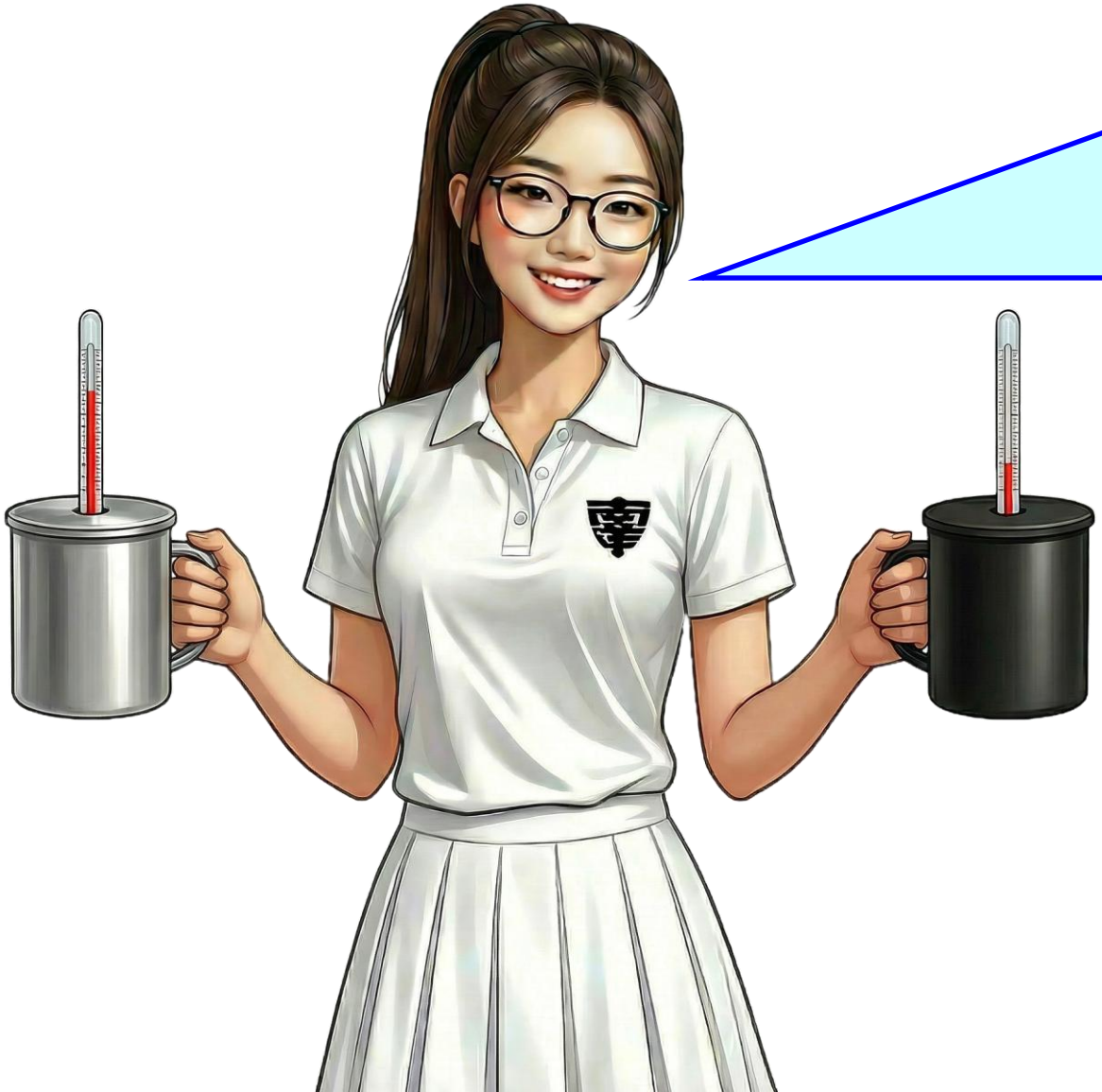
Radiation



The black cup and the silver cup both contain boiling water. Which one will cool down fastest? Why?

The Transfer of Thermal Energy and its Effects

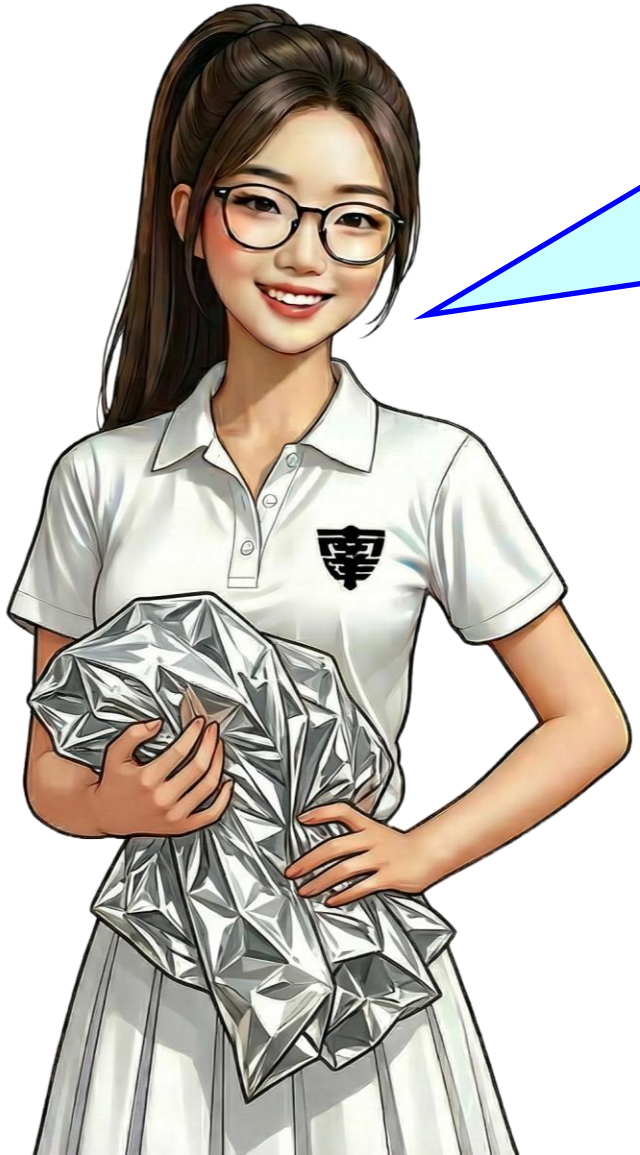
Radiation



The water in the black cup will cool down fastest. Black is a better emitter of thermal energy by radiation than silver.

The Transfer of Thermal Energy and its Effects

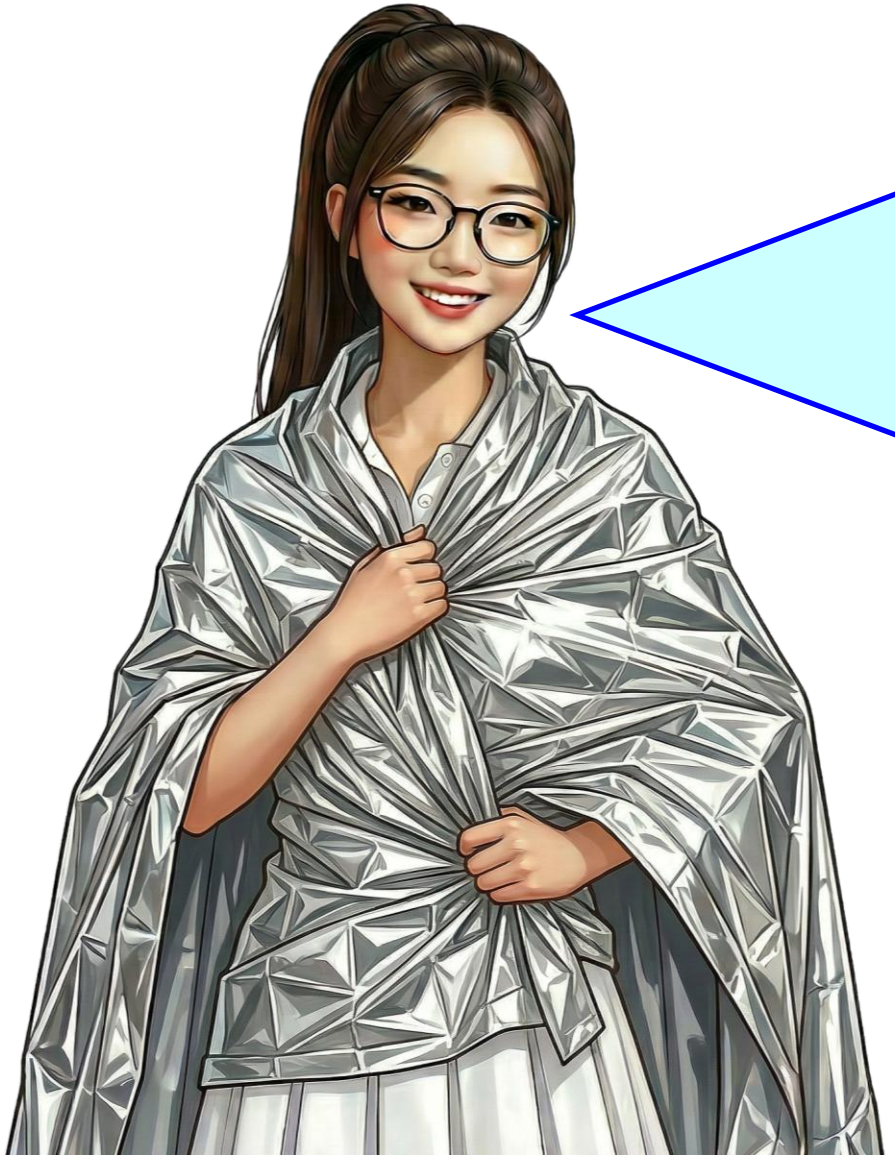
Radiation



At the scene of an accident or mountain rescue, why do emergency services wrap their patients in aluminium foil blankets?

The Transfer of Thermal Energy and its Effects

Radiation



Smooth silver surfaces are poor emitters of thermal energy by radiation. The aluminium foil blanket will reduce the rate at which thermal energy is transferred from the patient's warm body to the colder surroundings, keeping the patient warmer.

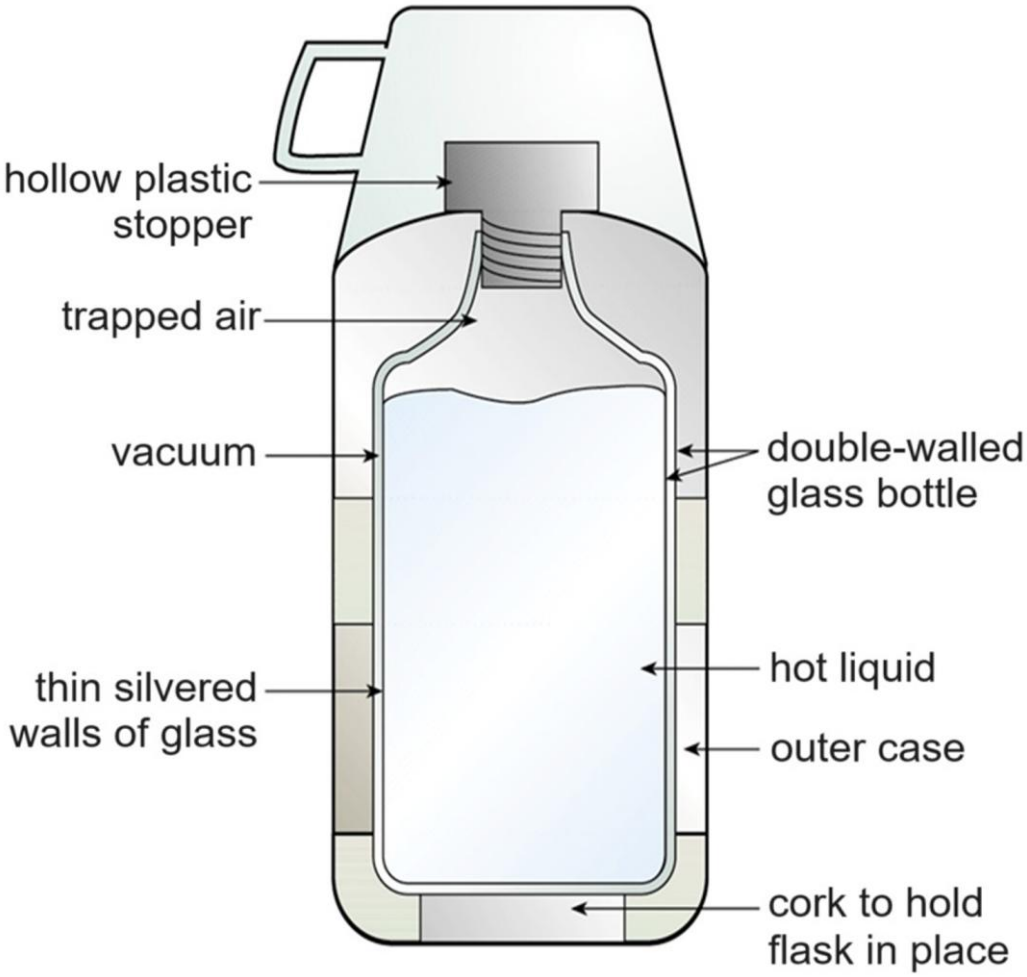
The Transfer of Thermal Energy and its Effects

Radiation

Quick Check 7.

Vacuum flask

The vacuum flask in the diagram is used to maintain the high temperature of the hot liquid. Explain how the various features of a vacuum flask minimise the transfer of thermal energy.



The Transfer of Thermal Energy and its Effects

Radiation

Features	Process of Transfer of Thermal Energy is Prevented
Vacuum between the two glass walls	
Silvery surface between the two glass walls	
Use of glass wall and use of cork to hold flask in place	
Hollow plastic stopper	

The Transfer of Thermal Energy and its Effects

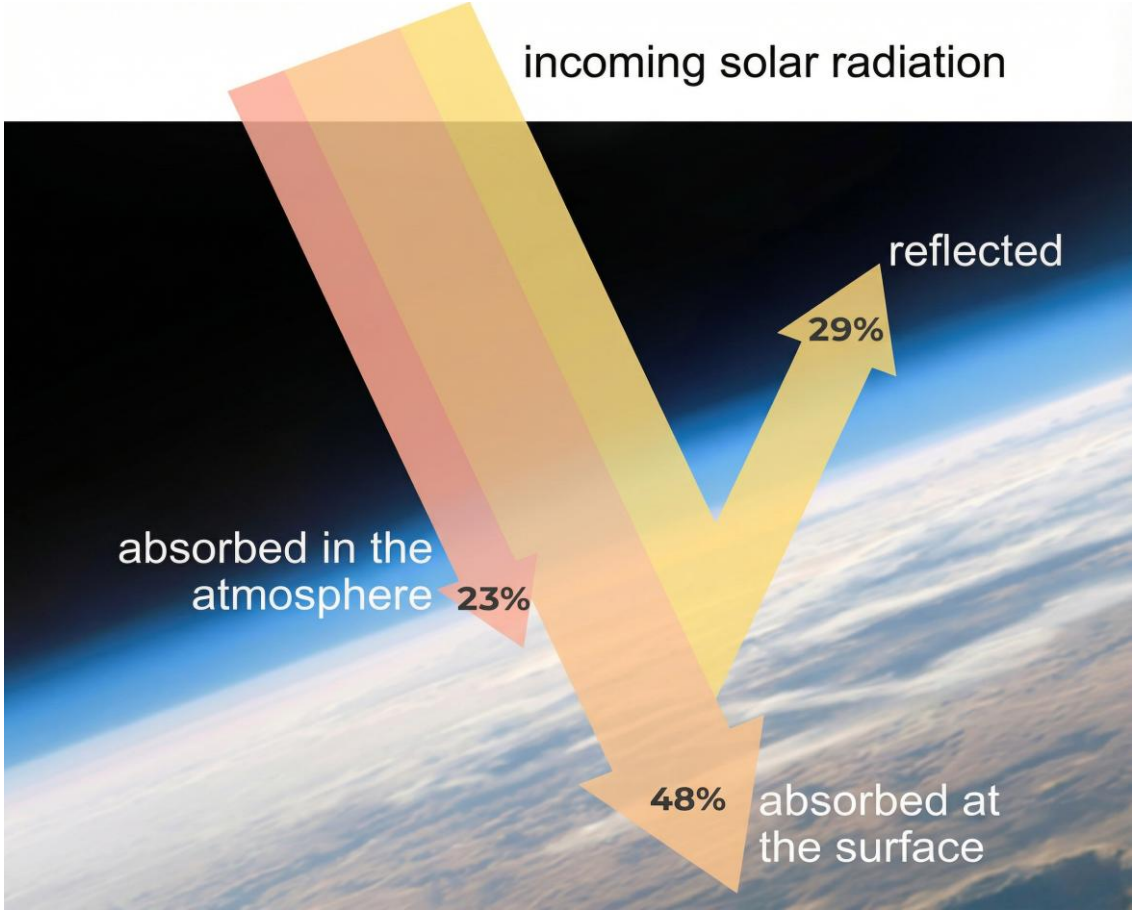
Radiation

Features	Process of Transfer of Thermal Energy is Prevented
Vacuum between the two glass walls	Conduction and convection are both prevented because both processes require a medium to transfer thermal energy.
Silvery surface between the two glass walls	Radiation is reduced because silvery surfaces are poor emitters of radiation.
Use of glass wall and use of cork to hold flask in place	Conduction is reduced because both glass and the cork are poor thermal conductors. They both reduce the rate of transfer of thermal energy from the hot liquid to the surroundings.
Hollow plastic stopper	Conduction is reduced because the plastic stopper is a poor thermal conductor and it reduces the rate at which thermal energy is transferred from the hot liquid to the cooler surroundings. Convection is prevented because keeping the plastic stopper tightly screwed on prevents hot air above the hot liquid from rising into the surroundings. Hence the cooler air in the surroundings is unable to take its place to set up a convection current.

The Transfer of Thermal Energy and its Effects

Radiation

- How does solar radiation from the sun reach the Earth?



The Transfer of Thermal Energy and its Effects

Radiation

- How does solar radiation from the sun reach the Earth?

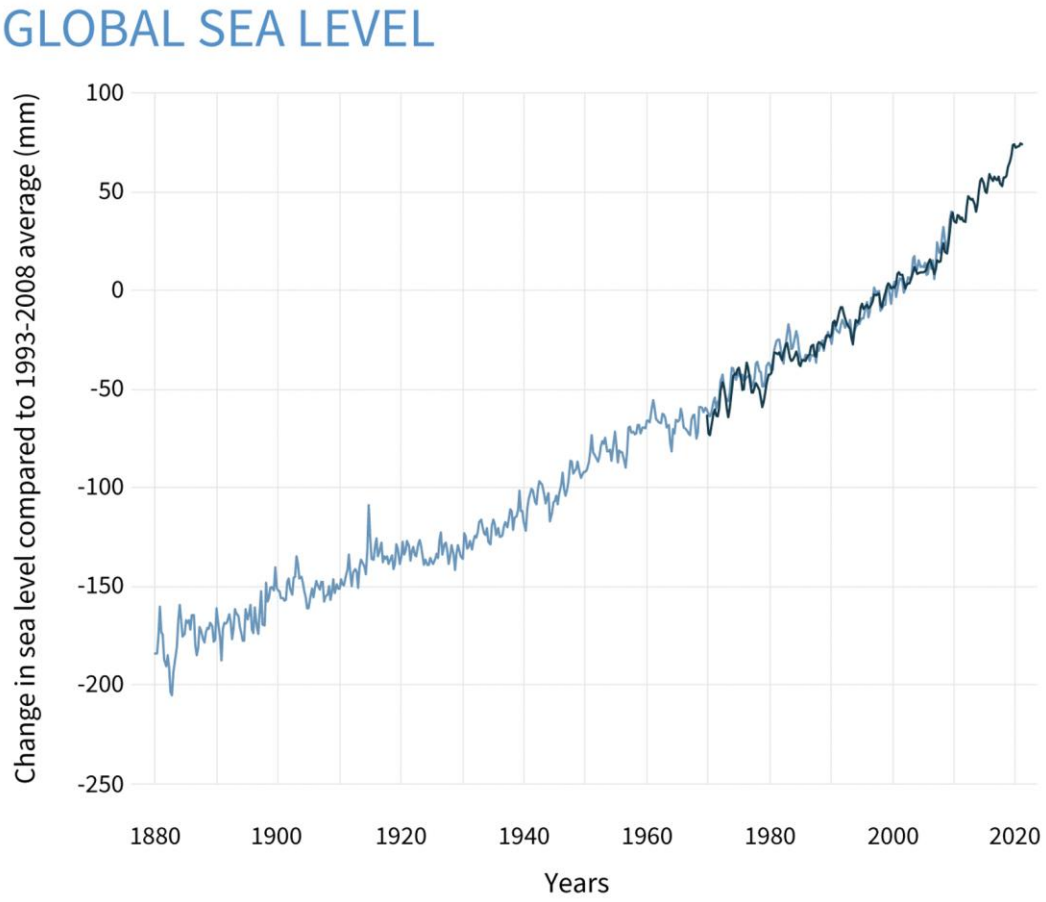
  The sun radiates thermal energy in all directions, but only a small portion reaches the Earth. The atmosphere helps to reflect and absorb part of that thermal energy, otherwise the Earth may become too hot or cold.

  However, in recent years, the greenhouse gases emitted into the atmosphere prevent radiation from leaving the Earth effectively and cause the Earth's atmosphere to increase in temperature. Scientists have observed that the excessive greenhouse effect has led to a sharp increase in the world's temperature over the last decade.

The Transfer of Thermal Energy and its Effects

Radiation

- Climate Change: Global Sea Levels



The Transfer of Thermal Energy and its Effects

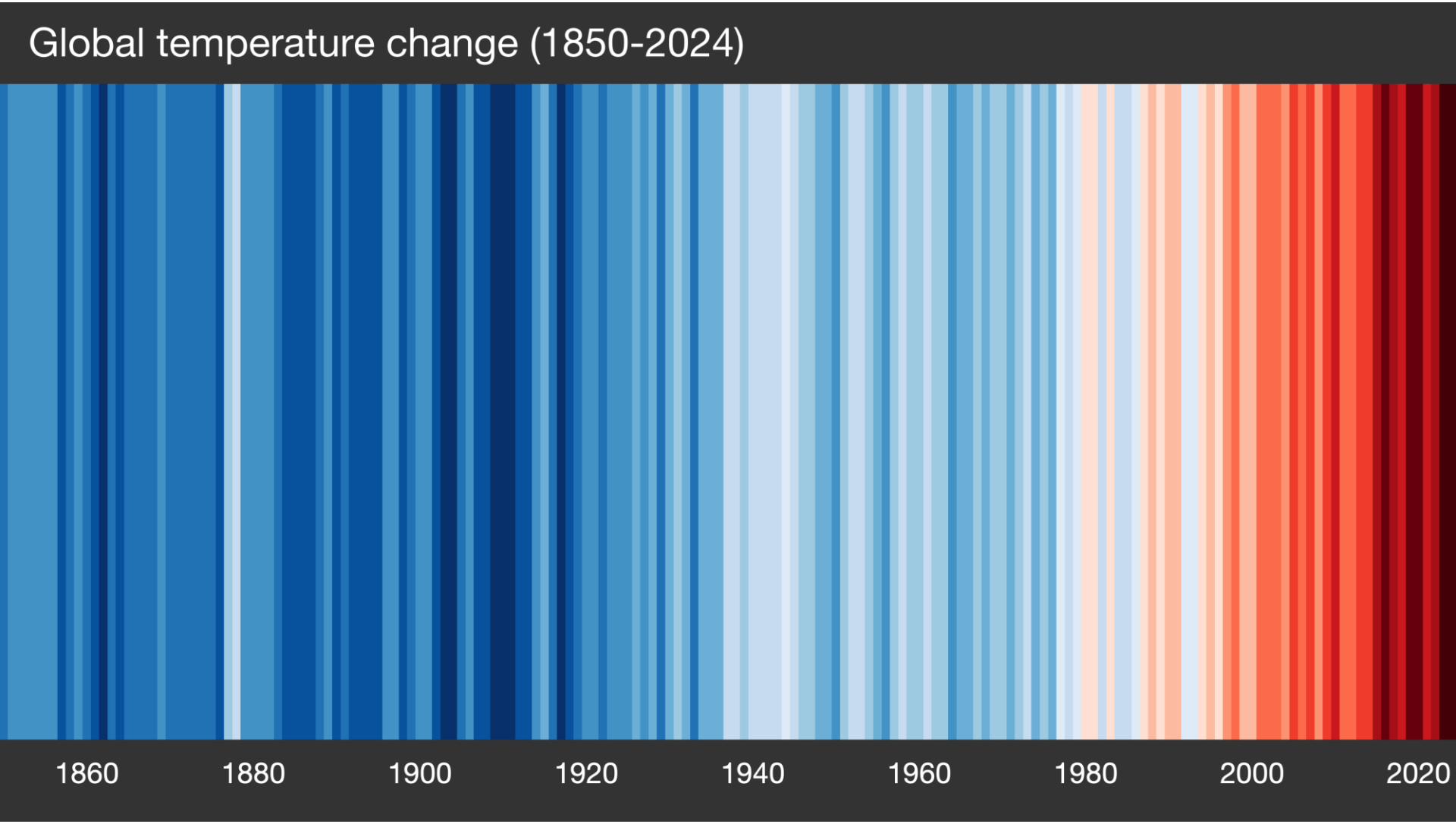
Radiation

- Climate Change: Global Sea Levels

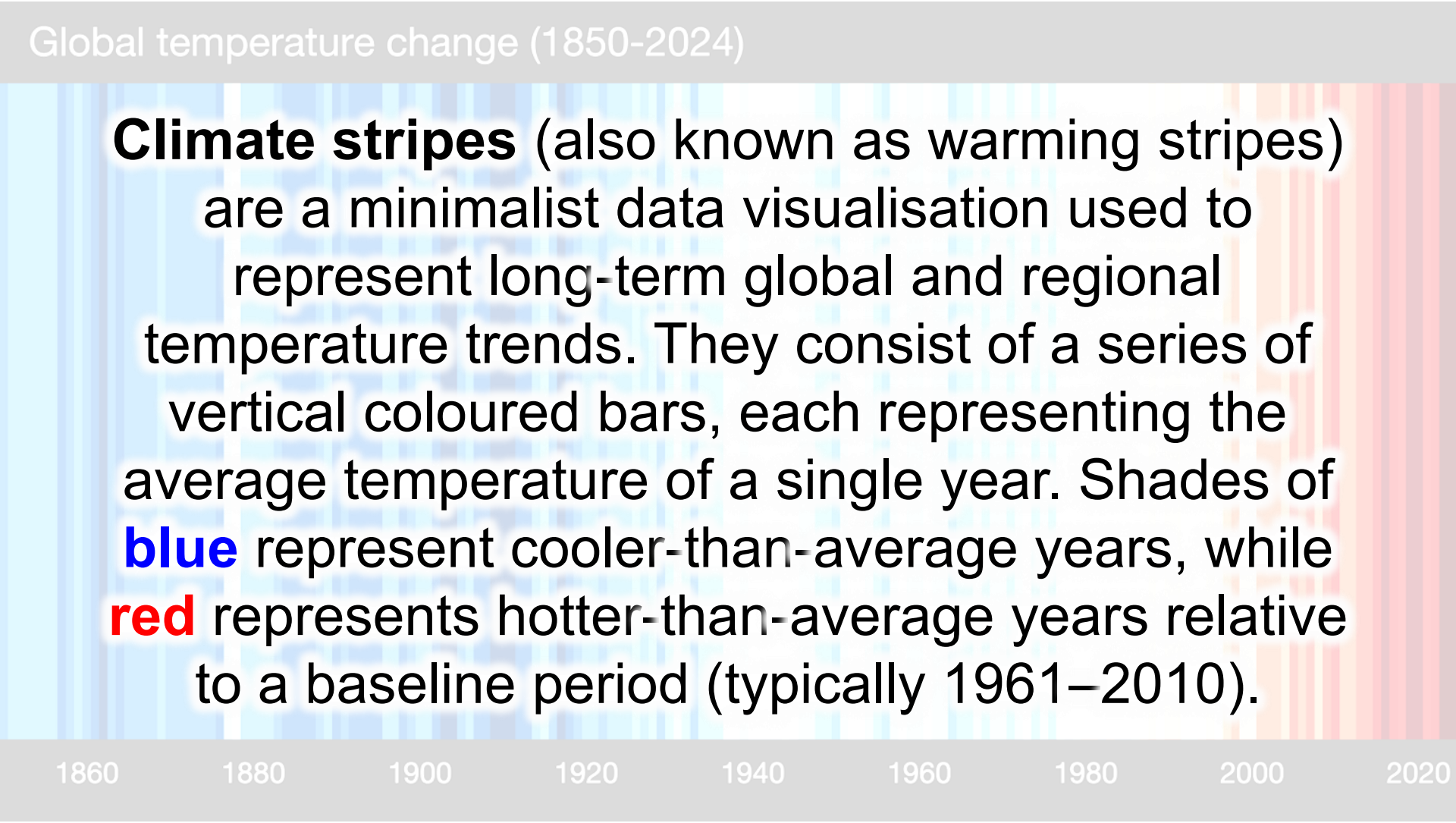
  The warming of Earth is primarily due to accumulation of heat-trapping greenhouse gases, and more than 90 percent of this trapped heat is absorbed by the oceans.

  As this heat is absorbed, ocean temperatures rise and water expands. This thermal expansion of seawater and the melting water from glaciers and ice sheets cause the global sea level to rise.

The Transfer of Thermal Energy and its Effects

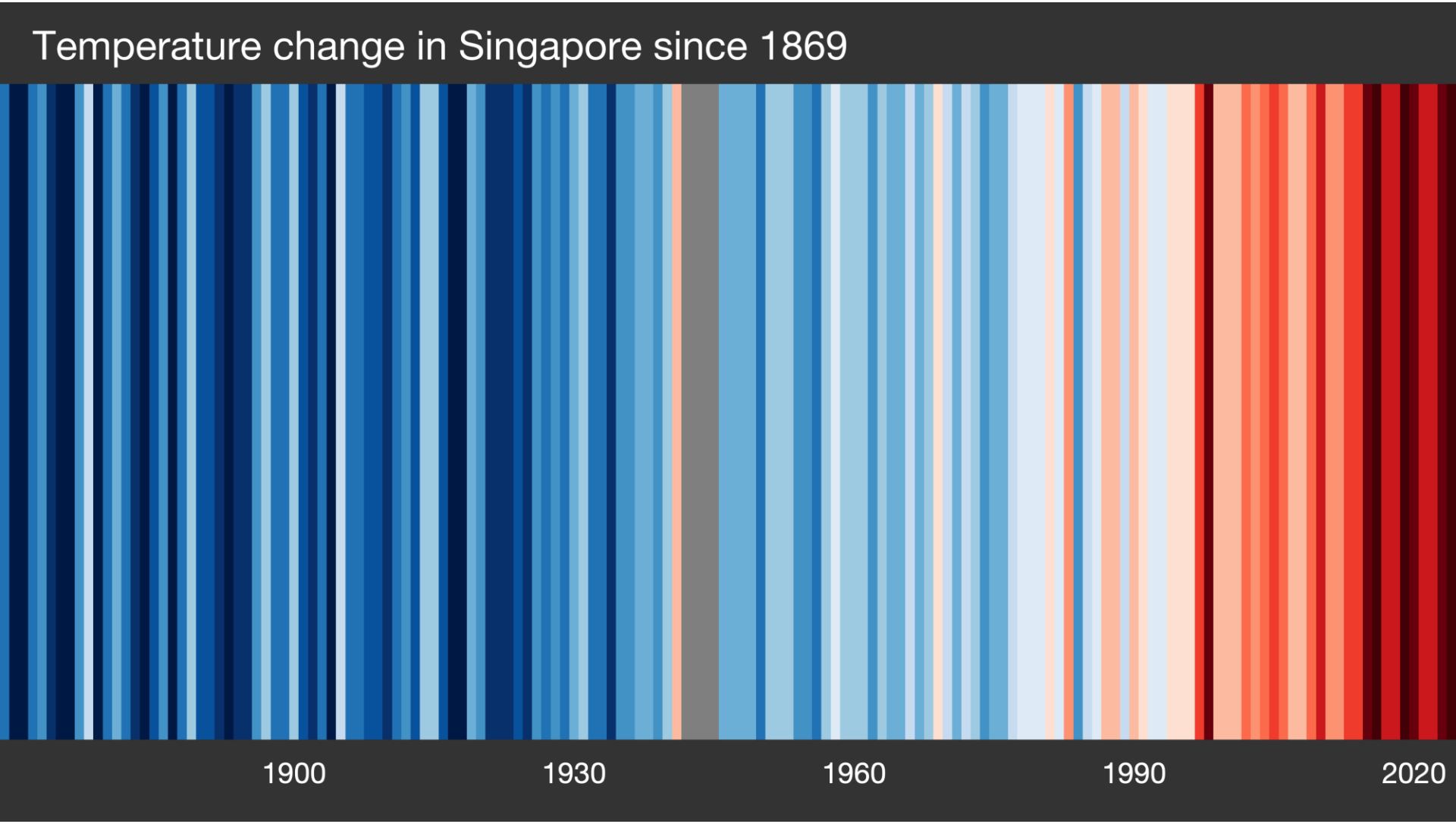


The Transfer of Thermal Energy and its Effects



Climate stripes (also known as warming stripes) are a minimalist data visualisation used to represent long-term global and regional temperature trends. They consist of a series of vertical coloured bars, each representing the average temperature of a single year. Shades of **blue** represent cooler-than-average years, while **red** represents hotter-than-average years relative to a baseline period (typically 1961–2010).

The Transfer of Thermal Energy and its Effects



The Transfer of Thermal Energy and its Effects

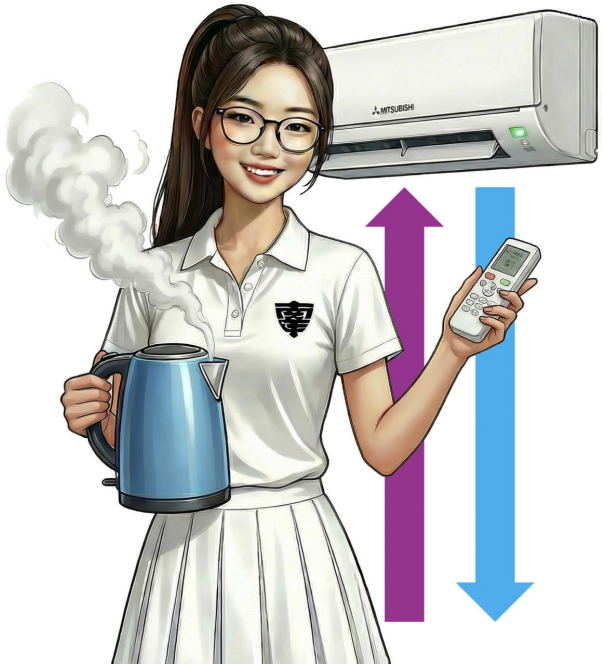
Comparison of Conduction, Convection and Radiation			
	Conduction	**Convection**	**Radiation**
Definition	Conduction is the transfer of thermal energy through a medium without the physical movement of the medium itself.	Convection is the transfer of thermal energy due to the movement of the medium, arising from density differences within the medium.	Radiation is the transfer of thermal energy in the form of infrared radiation without the need of a medium. Can occur in a vacuum.
Where does this take place (solid, liquid, gas)?	Occurs within solid, liquid or gas.	Occurs within liquid or gas (fluid) only.	Occurs anywhere. Presence of solid, liquid or gas are NOT needed.

The Transfer of Thermal Energy and its Effects

Comparison of Conduction, Convection and Radiation			
	Conduction	**Convection**	**Radiation**
What conditions affect this process?	Nature of the medium, good or poor thermal conductors. The packing of the atoms and the presence of free electrons in the medium. These determine whether the medium is a thermal insulator or conductor. *Note that air and water are poor thermal conductors.	The position of the heating / cooling sources. For convection to take place, heating source should be placed at the bottom of the medium. For convection to take place, cooling sources should be placed at the top of the medium.	(1) Temperature of object: The hotter the body of an object, the higher the rate of radiation from the object. (2) Surface area of object: An object with a larger surface area has a higher rate of radiation. (3) Texture and colour of surface (dull / shiny or dark / light coloured or rough / smooth): Black / dull surfaces are good absorbers of radiation. Black / dull surfaces are good emitters of radiation. White / Shiny surfaces are poor absorbers of radiation. White / Shiny surfaces are poor emitters of radiation.

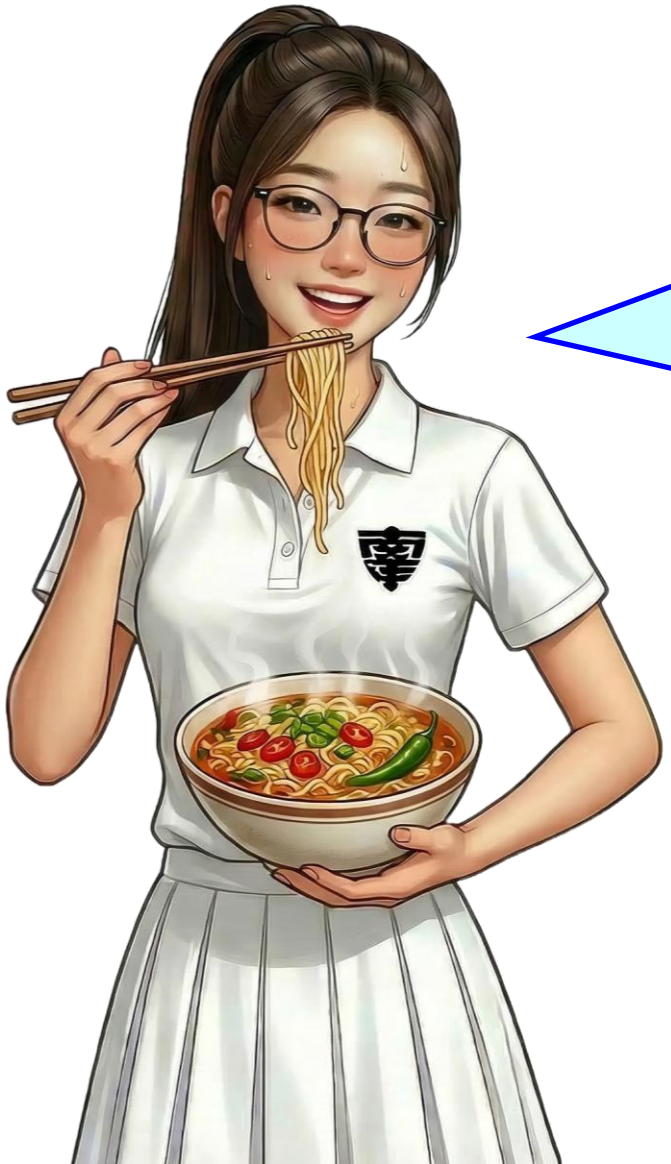
The Transfer of Thermal Energy and its Effects

End of Presentation



The Transfer of Thermal Energy and its Effects

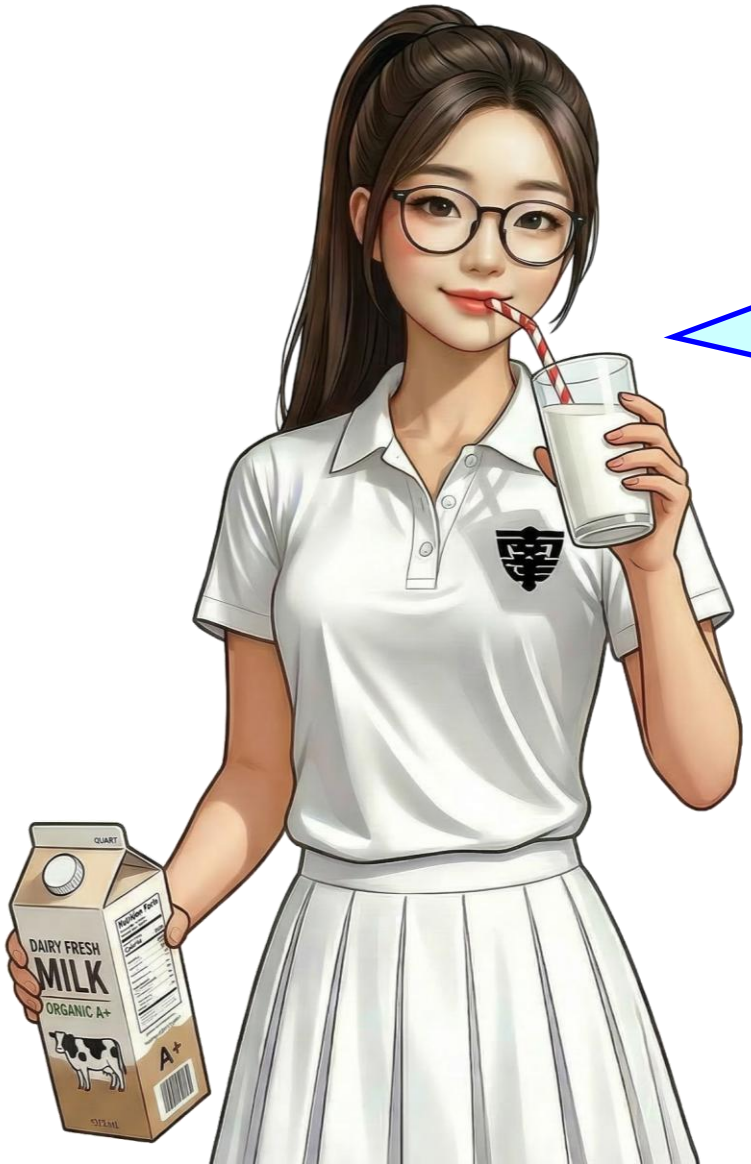
Postscript



Food made hot with red and green chilis, or wasabi, is not *thermally hot*. The heat felt from eating chili peppers is a sensory illusion caused by a chemical compound called *capsaicin*.

The Transfer of Thermal Energy and its Effects

Postscript



Capsaicin binds to receptors on your tongue which are designed to detect real heat. This sends a signal to your brain that your mouth is burning. This is called a *thermogenic effect*. The effect can be eased by *drinking milk*.