

Thermal Energy Transfers

Convection



Conduction



Radiation



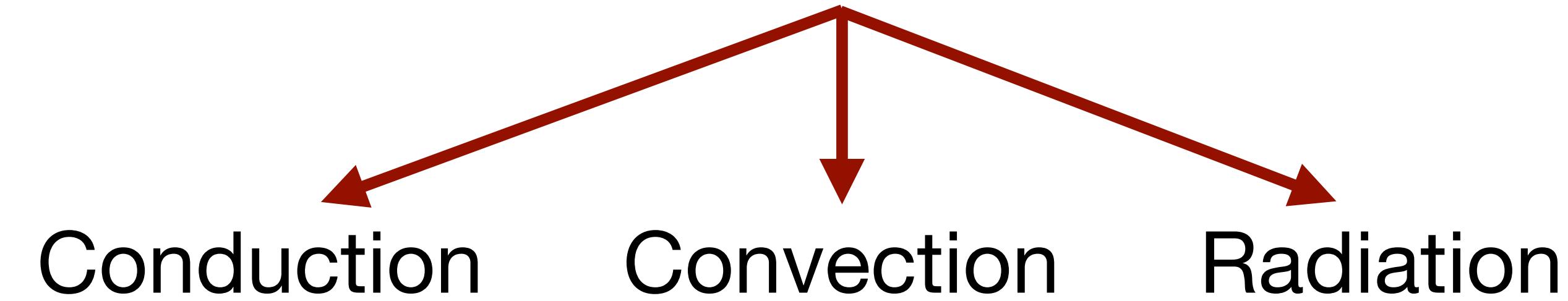
New Words

Conductor Insulator lattice mechanism convection radiation
current cavity absorb emit reflect dull/matte malleable
polyethylene draught
jelly vacuum flask

Thermal Energy Transfer

→ Higher temperature  Thermal energy transfers  Lower temperature

→ So, temperature difference → thermal energy transfer



Conduction

- Pick up a **metal** and a **wooden** spoon in turn, do you feel any difference?



Conduction: direct contact



Thermal conductor

A substance that conducts thermal energy



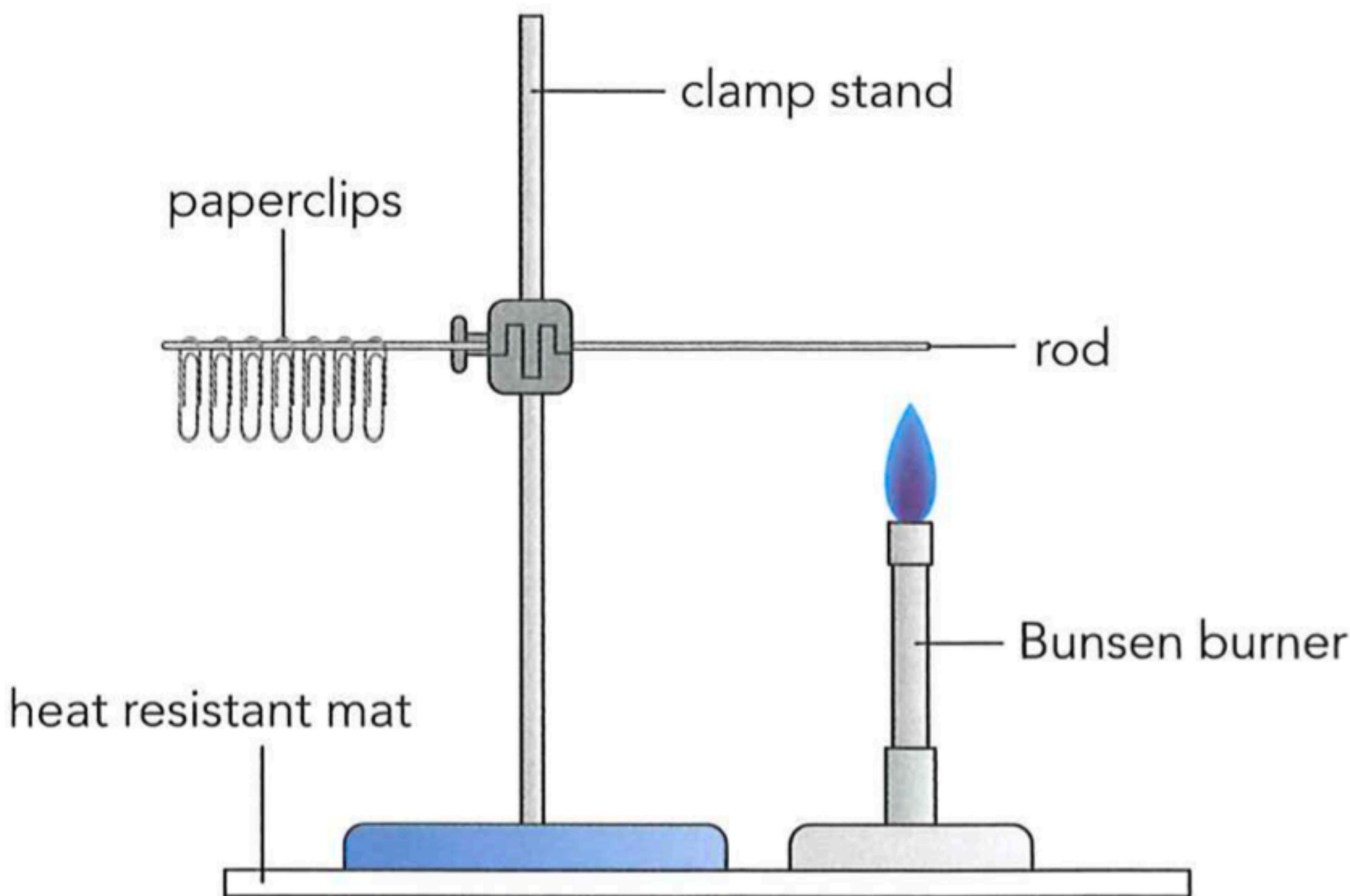
Thermal insulator

A substance that conducts very little thermal energy

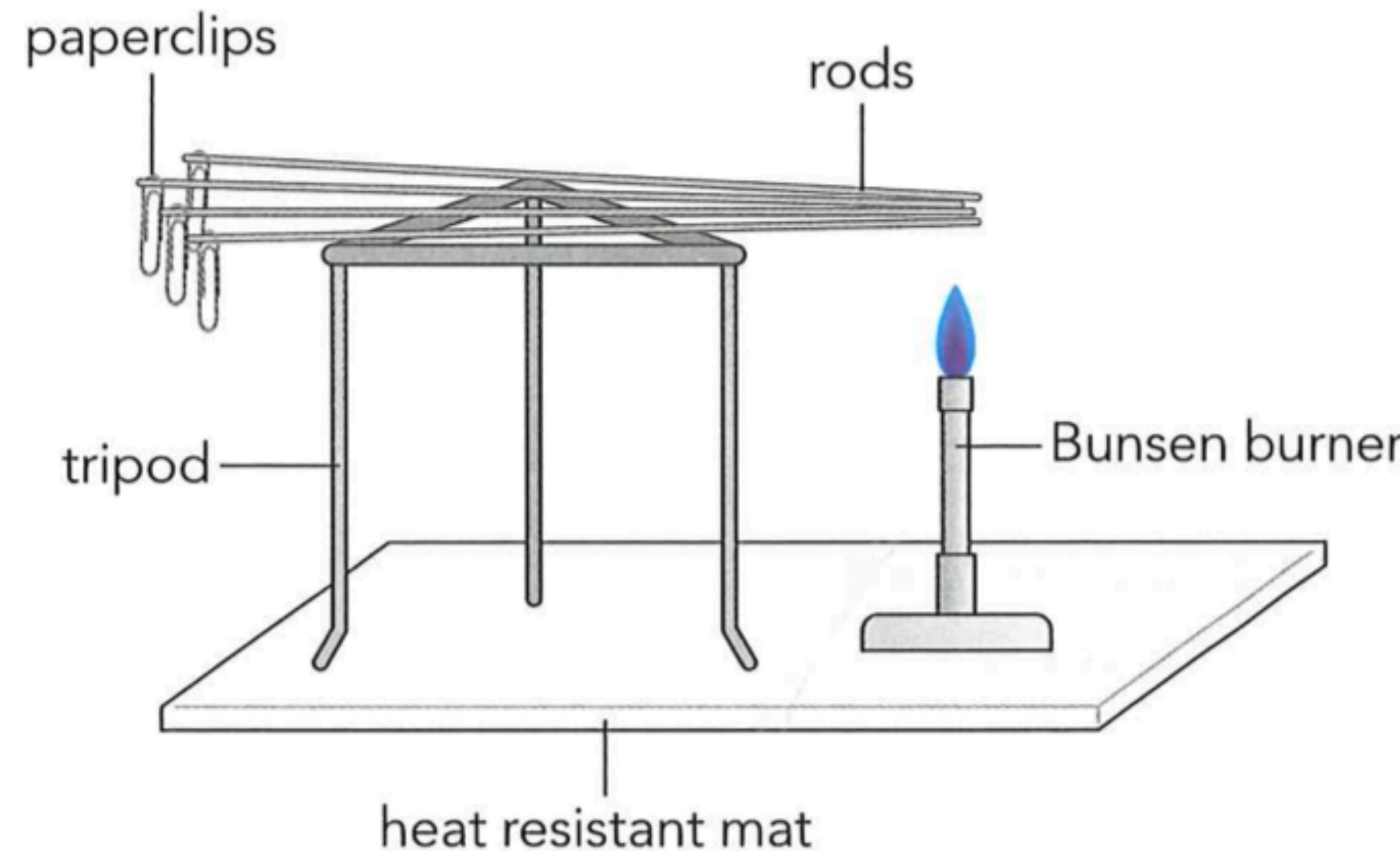
Note that, a good thermal conductor -> a bad thermal insulator

Binary opposition (二元对立), e.g. 最亮的, 最不暗的

How is thermal energy conducted along a metal bar?

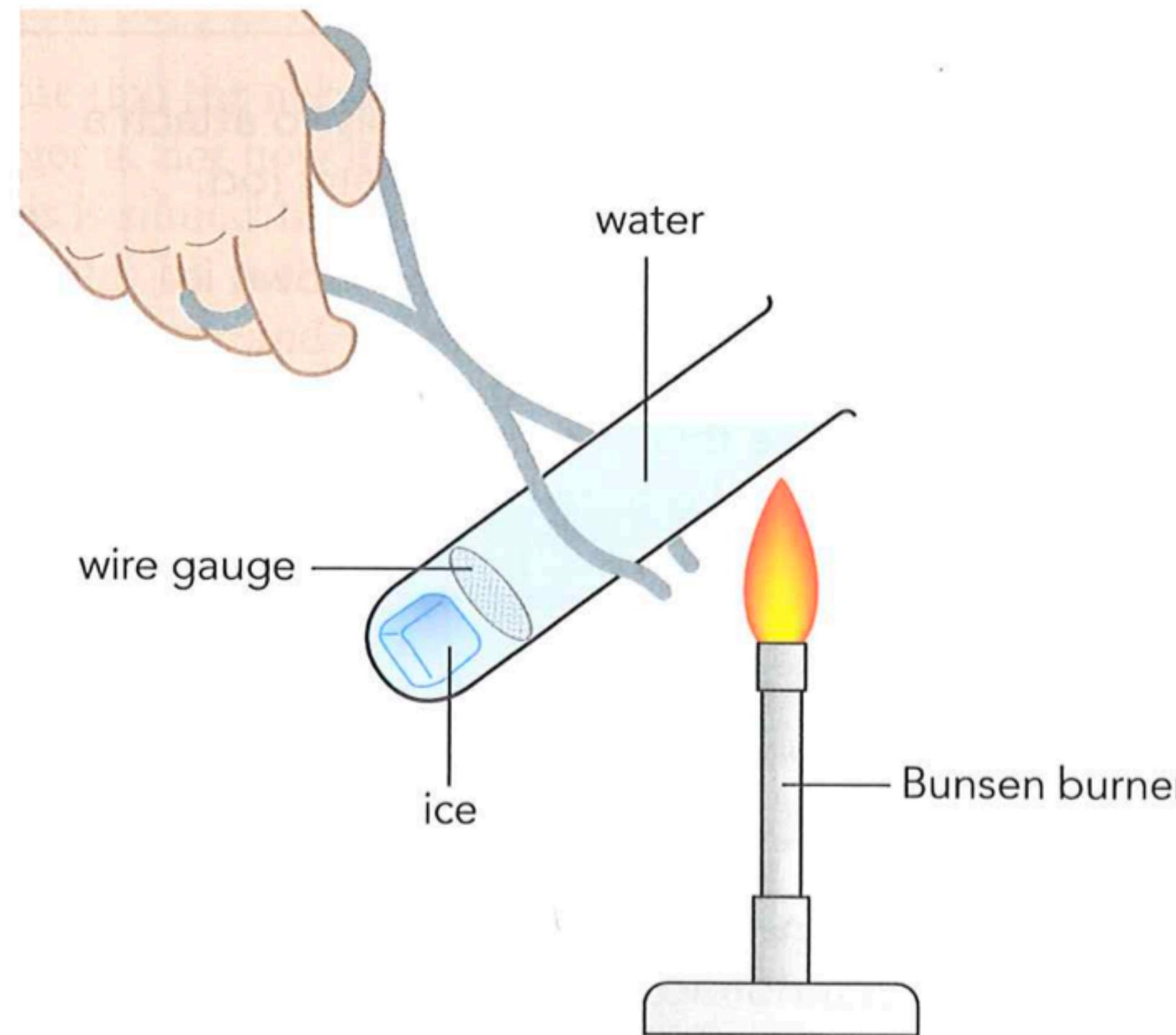


Which metal is the best conductor?



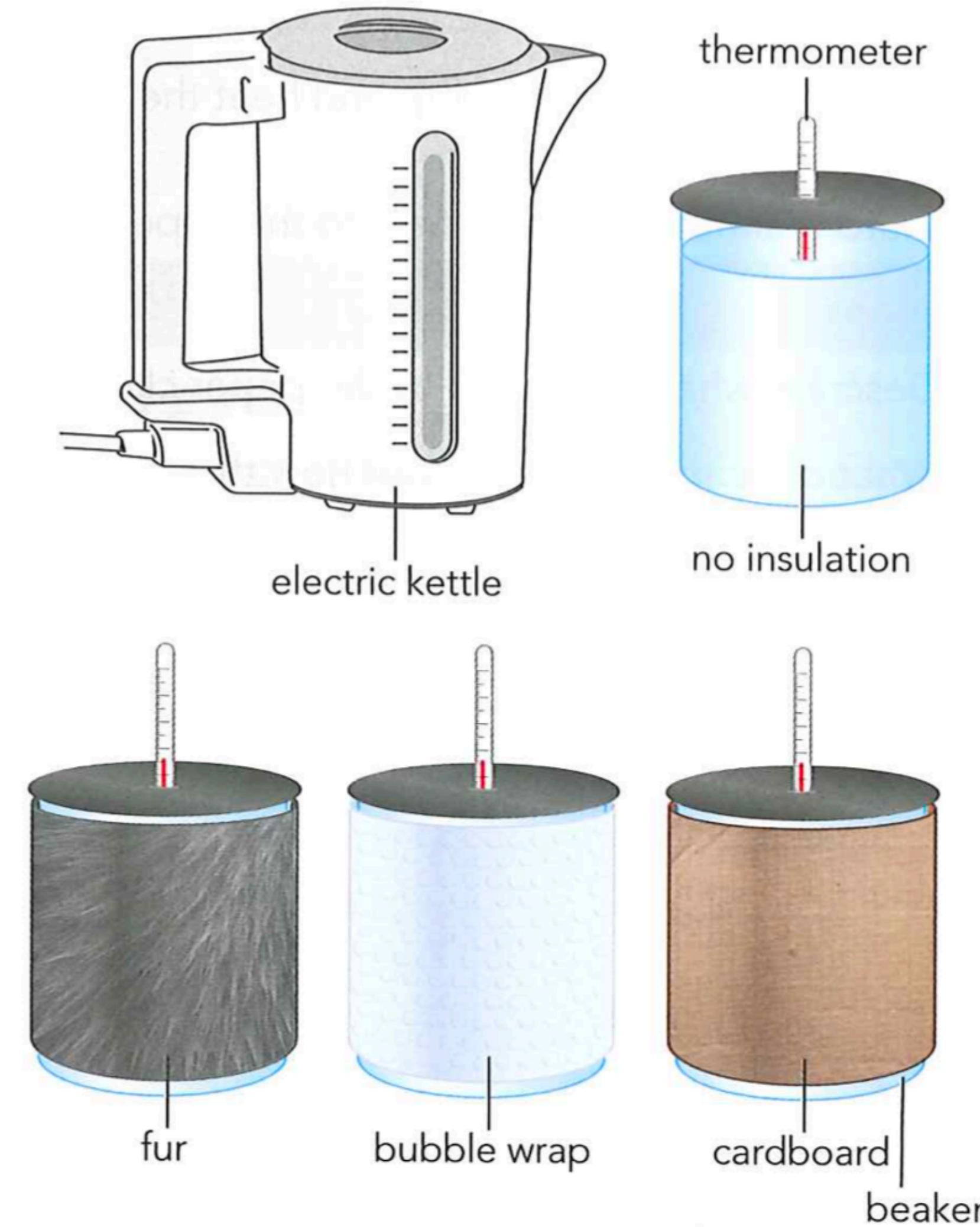
- https://igexams.com/physics_exp_video/heat-conduction-in-metal-rods/
- What might be the source of experimental error?

Is water a good conductor of thermal energy?



- What might be your expected observations?
- Why do you expect that?

What materials make good insulators?



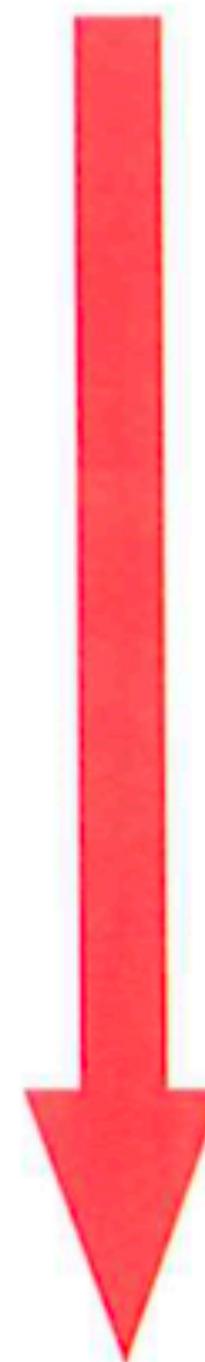
Good /bad conductors

In general,

- metals are **good conductors** of thermal energy, non-metal are **poor conductors**.
- Gas and liquid are **very poor conductors**.
- Conductivity: **Metal> non-metal solid >fluid**

Good /bad conductors

best conductor



worst conductor

diamond
silver, copper
aluminum, steel
lead
ice, marble, glass
Polyethene, nylon
rubber, wood
polystyrene
glass wool

worst insulator

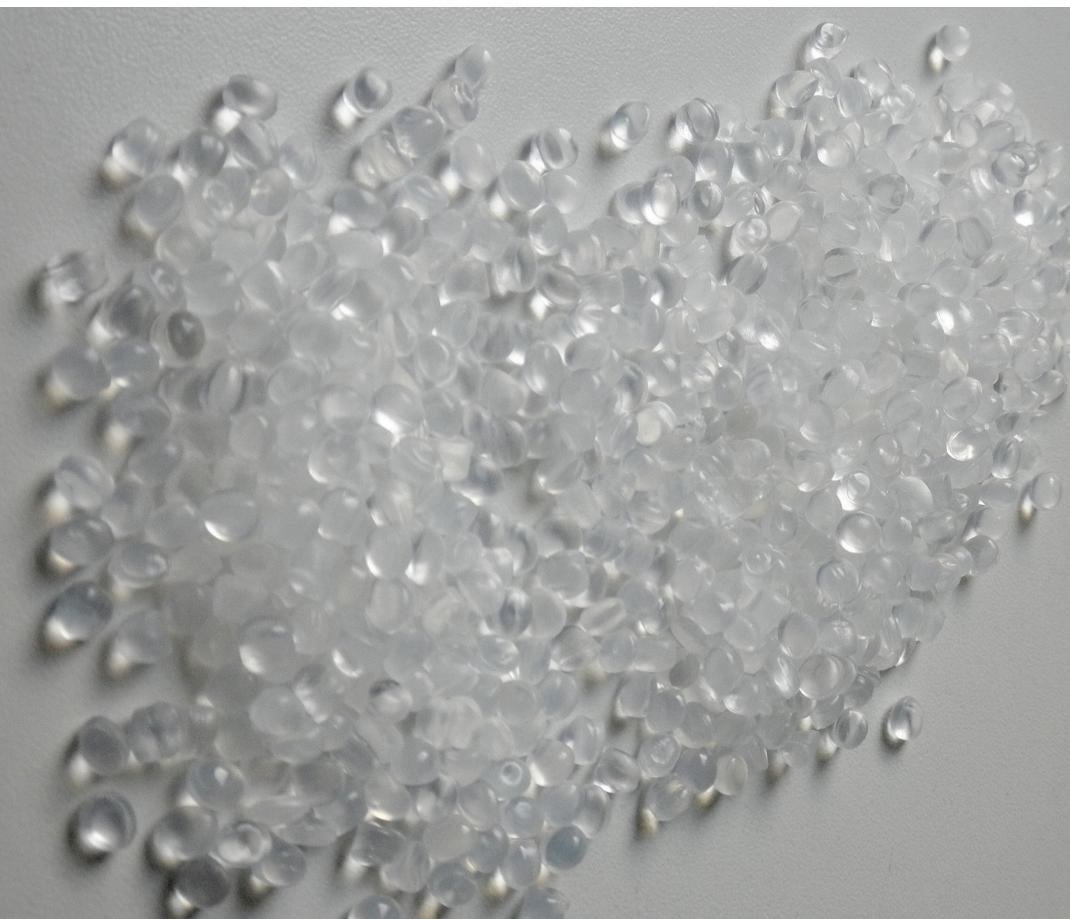


best insulator

Conduction

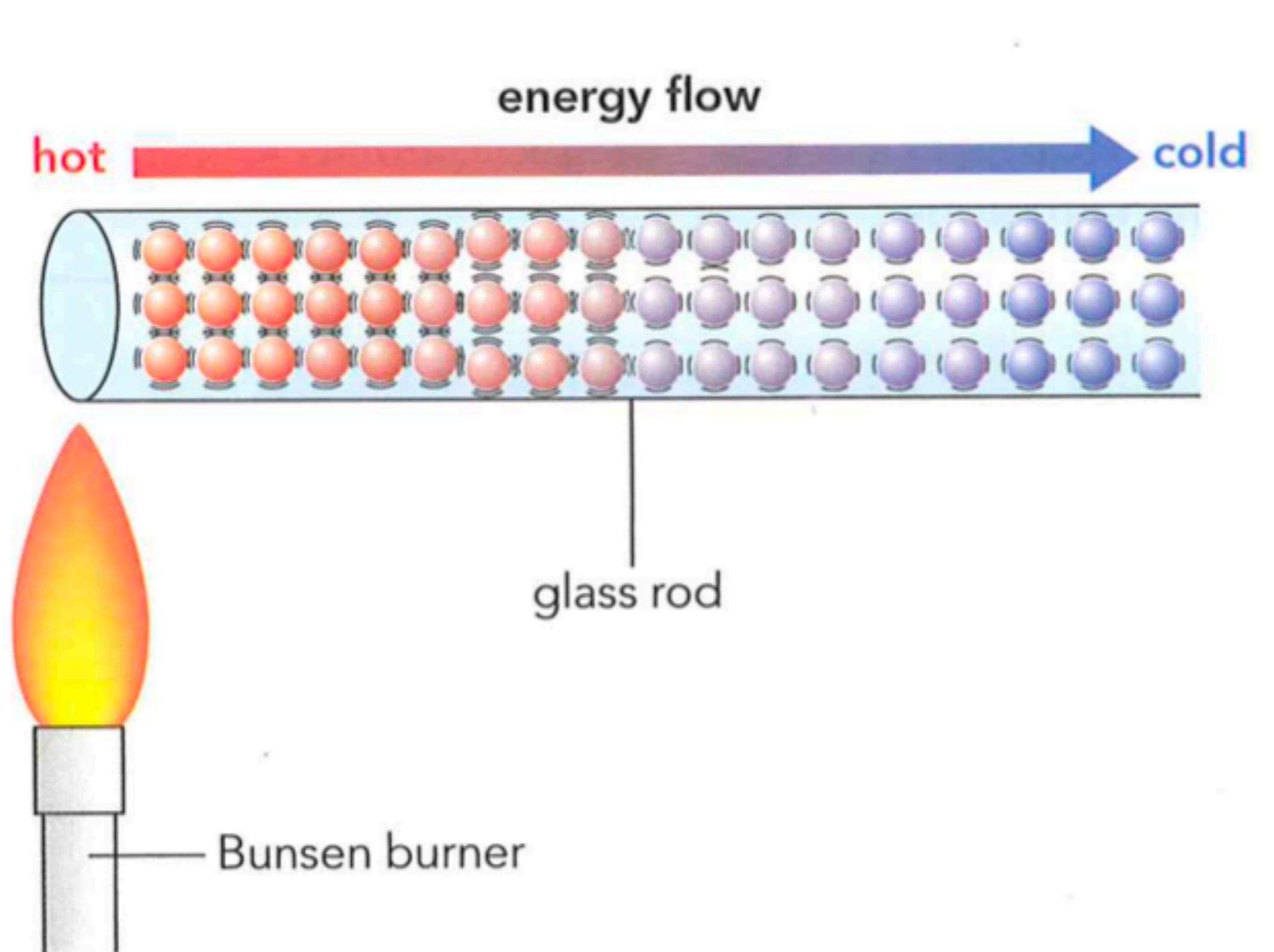
- Which of the following are good conductors?

- A. polyethylene 聚乙烯
- B. copper
- C. iron
- D. rubber
- E. silicon
- F. glass
- G. water
- H. aluminium
- I. wood
- J. glass wool 玻璃棉
- K. polystyrene 聚苯乙烯 (热塑塑料)



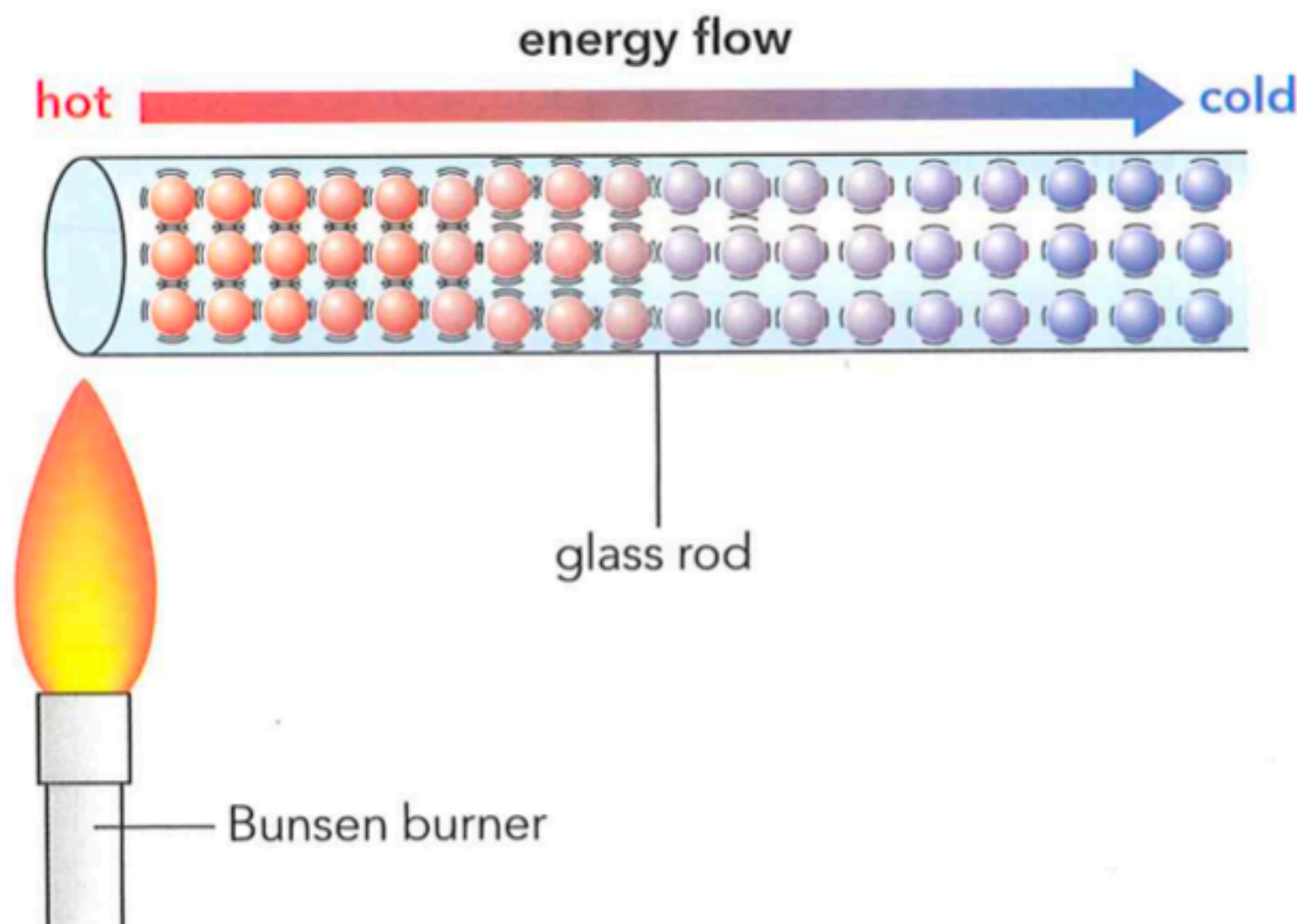
Explain conduction

- Non-metal



Explain conduction

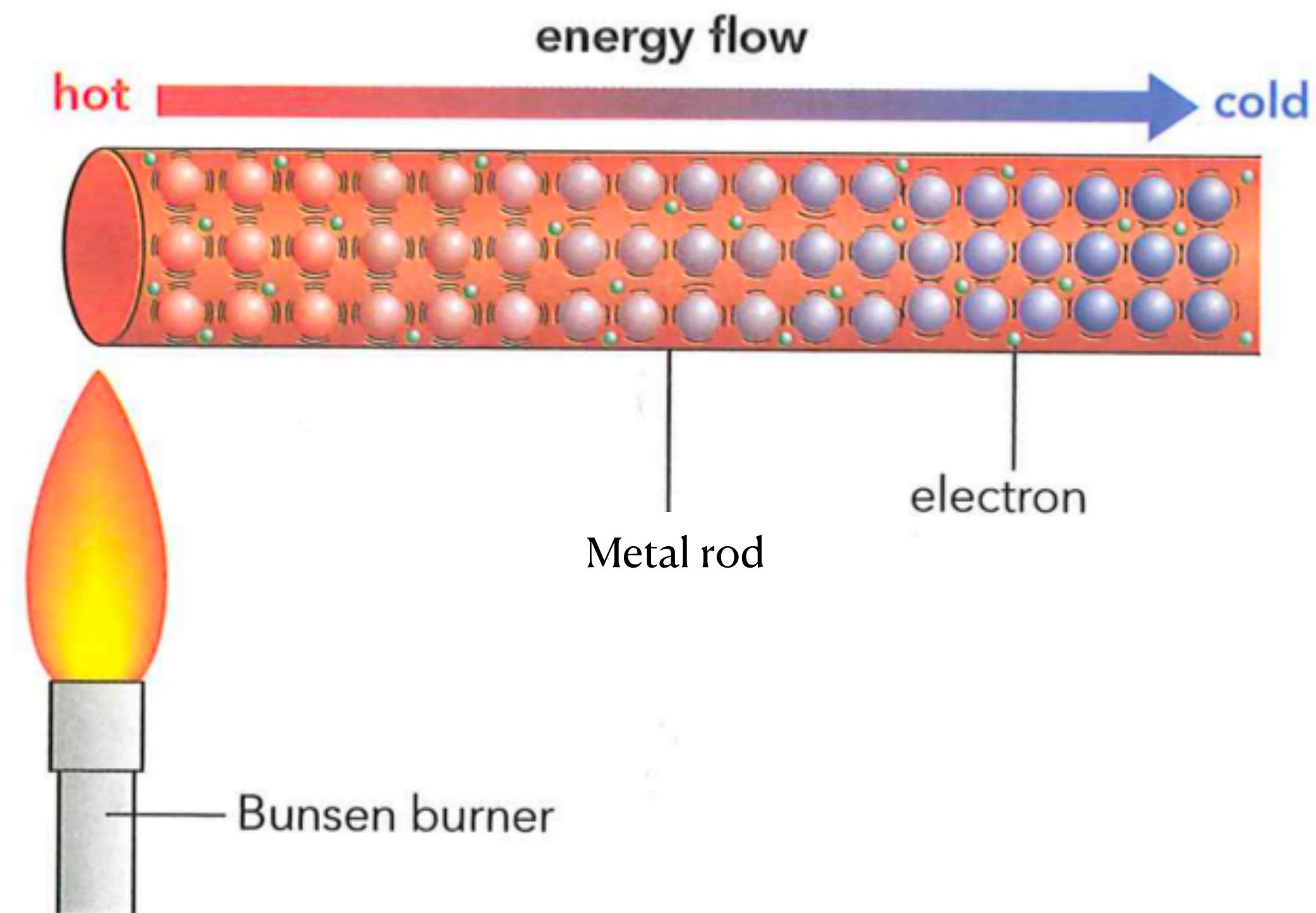
- Non-metal



At hot end, the atoms **vibrate more**, collide with their neighbors, transfer its energy to neighbors.

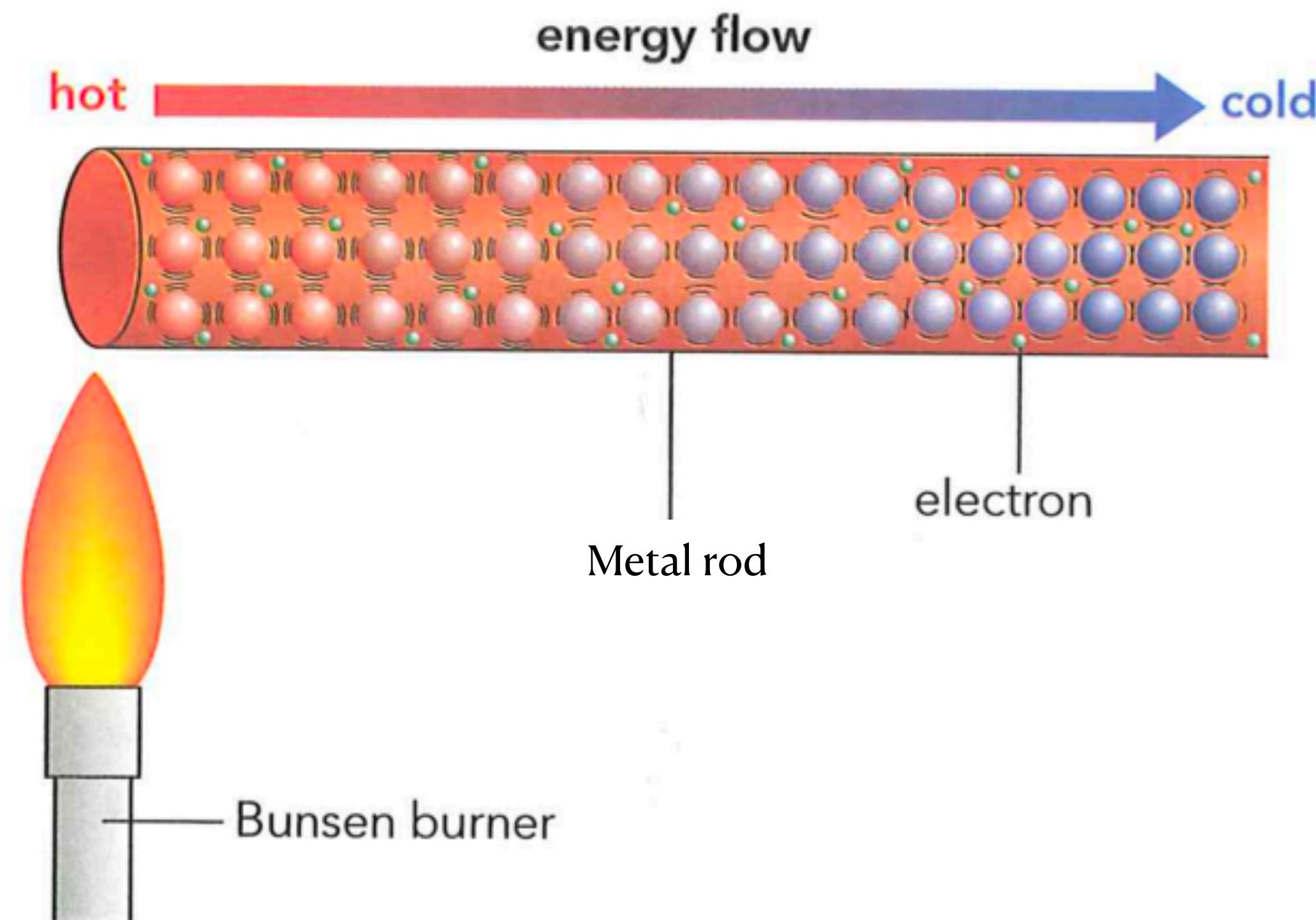
Explaining conduction

- Metal



Explaining conduction

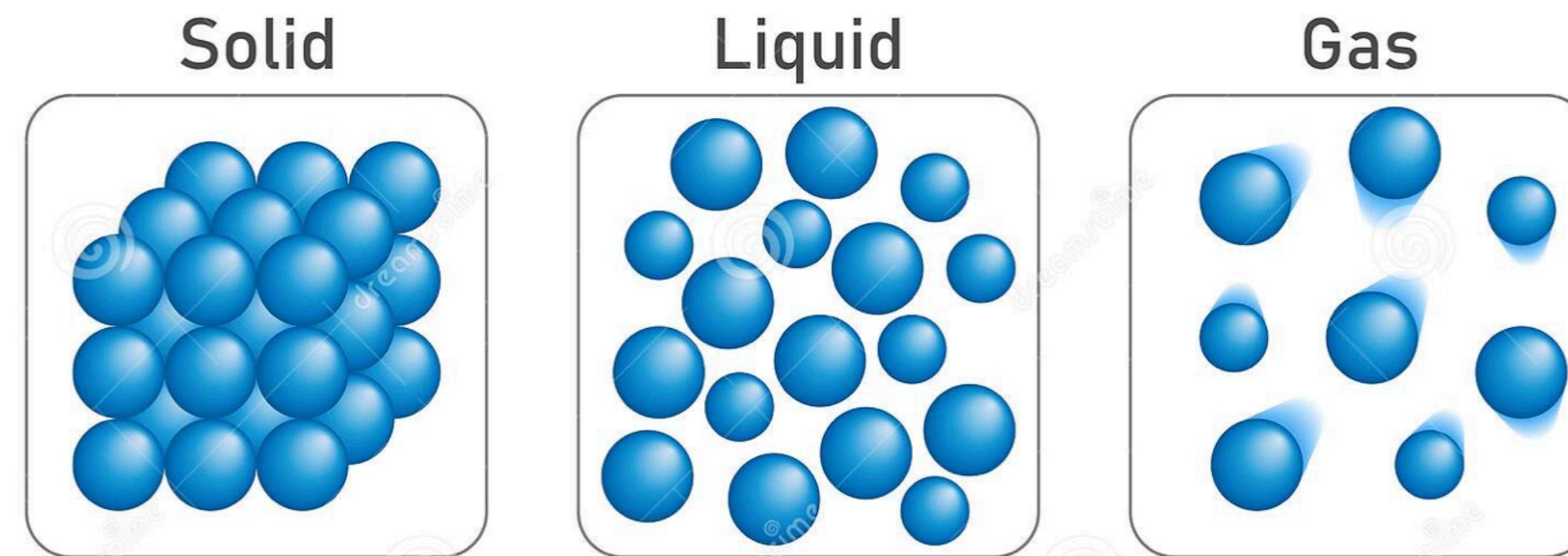
- Metal



(Main) at hot end, **electrons move faster**, strike atoms, carry energy through metal
(Minor) atoms **vibrate more**, collide with neighbors transfer energy

Explain conduction

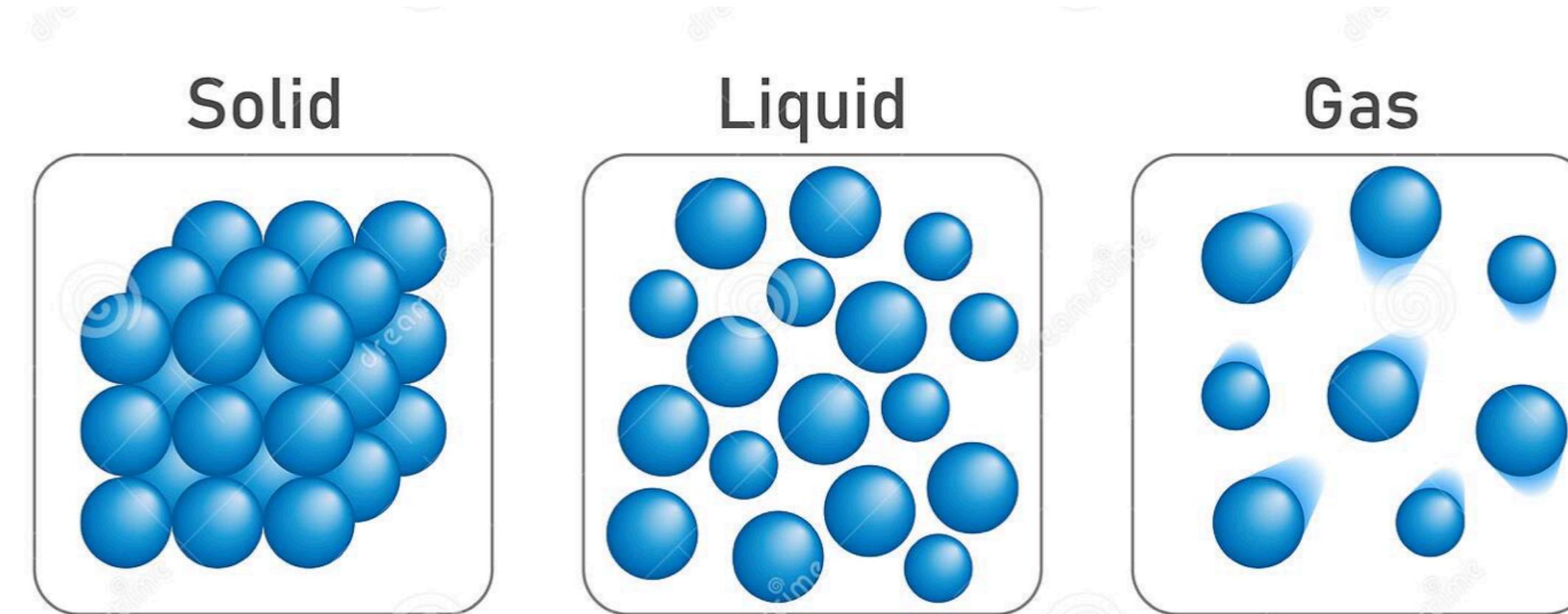
Fluid (liquid + gas)



Explain conduction

Fluid (liquid + gas)

Particles free to move, separate more -> vibrations not easily passed -> bad conductors



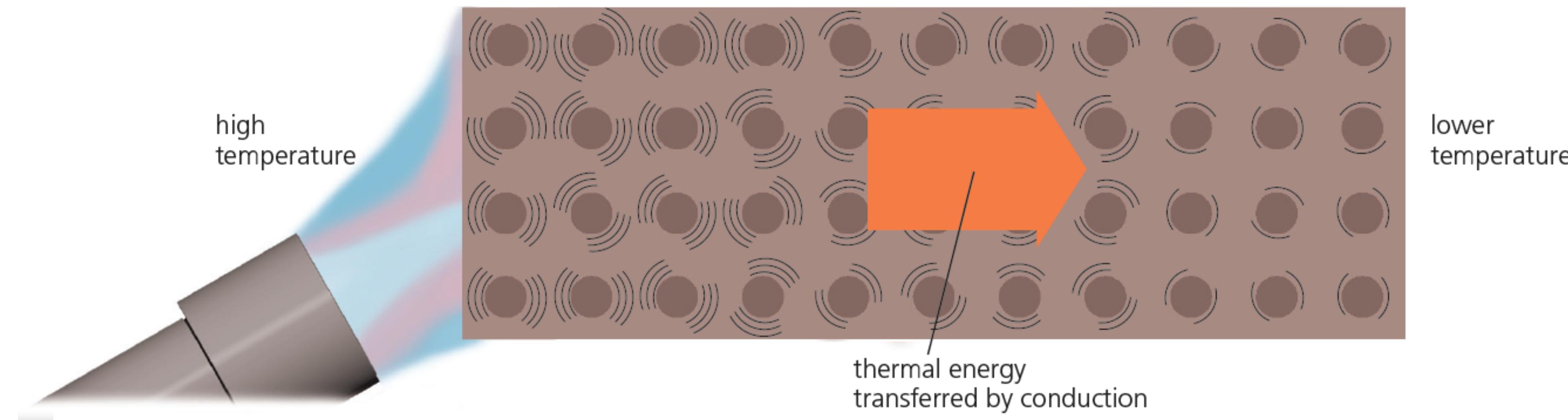
Summary

- Temperature difference -> thermal transfer
- Conduction is a type of thermal transfer; Conduction is most significant heat transfer in solids.
- **Conduction ability: metal > non-metal > fluid.** This is due to their different micro-structure.

Non-metal: at hot end, the atoms **vibrate more**, collide with their neighbors, transfer its energy to neighbors.

Metal: at hot end, **electrons move faster**, strike atoms, carry energy through metal atoms **vibrate more**, collide with neighbors transfer energy

How to get greater conduction rate?



- The **temperature difference** across the ends of the bar is increased
- The **cross-sectional ('end-on') area** of the bar is increased
- The length of the bar is reduced

Conduction in real life



Questions

1. Conduction happens mostly in **{solids/liquids/gases}**. Thermal energy flows from the **{hotter/cooler}** parts of an object to the **{hotter/cooler}** parts. A material which does not conduct thermal energy well is called **{a conductor/ an insulator/ a resistor}**. An example is **{copper/ polystyrene/ gold}**.

Questions

1. Conduction happens mostly in **{solids/liquids/gases}**. Thermal energy flows from the **{hotter/cooler}** parts of an object to the **{hotter/cooler}** parts. A material which does not conduct thermal energy well is called **{a conductor/ an insulator/ a resistor}**. An example is **{copper/ polystyrene/ gold}**.

Questions

2. Explain why a **wooden** spoon is better than a **metal** one to stir a saucepan of hot soup.



Questions

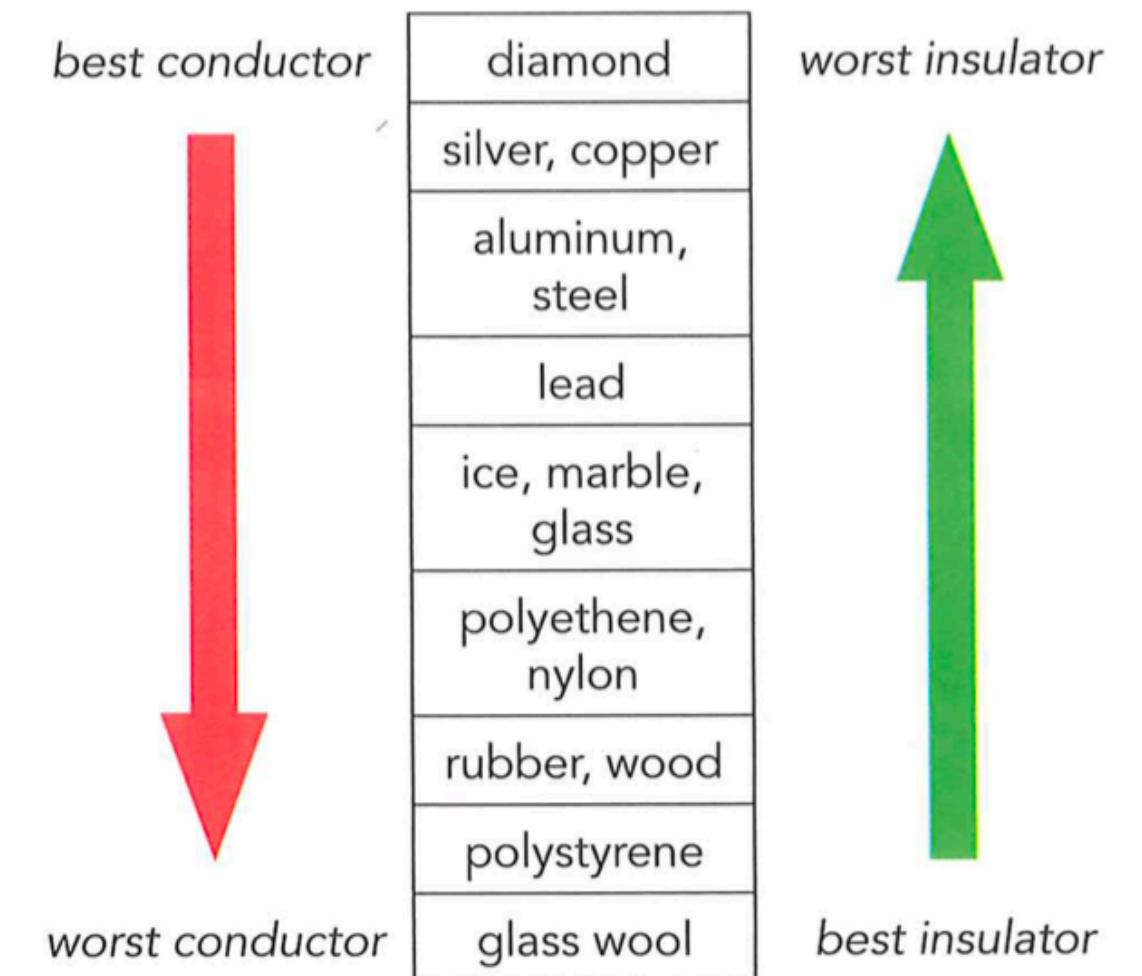
2. Explain why a **wooden** spoon is better than a **metal** one to stir a saucepan of hot soup.

Metal is a good conductor, so a metal spoon will **conduct thermal energy** from the food to your hand;
Wood is an insulator, so the wooden spoon **does not conduct much thermal energy**, so stays cool and easy to hold.



Questions

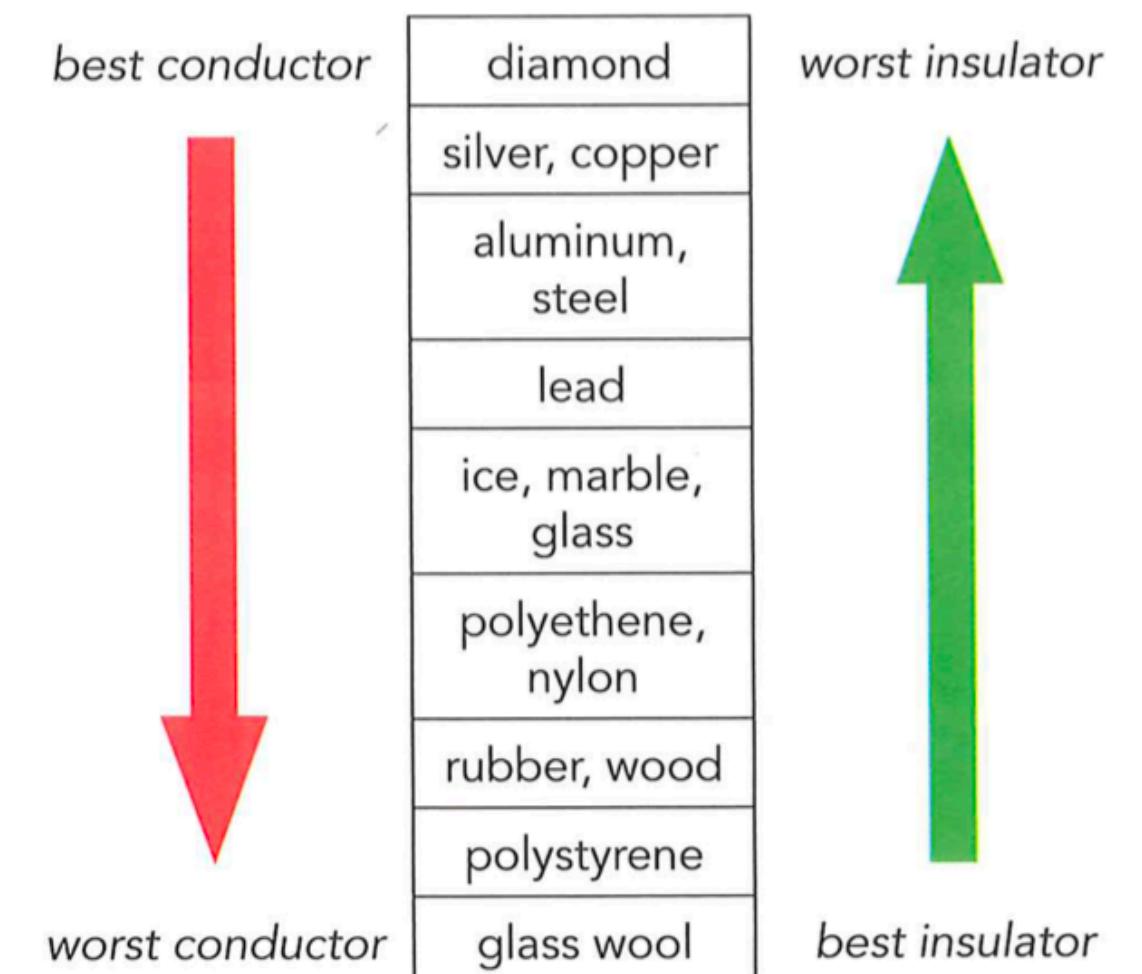
3. Use the information in the right table to explain why walking on a marble floor in bare feet would feel colder than walking on a wooden floor.



Questions

3. Use the information in the right table to explain why walking on a marble floor in bare feet would feel colder than walking on a wooden floor.

Mable is a good **conductor** than wood so more thermal energy would flow from your feet to the marble, **cooling your feet down**.



Questions

4. Explain why two thin layers of clothing are often warmer than one thick layer.

Questions

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Air is a **very poor conductor**. The layer of air trapped between the clothes will reduce the loss of thermal energy from the body.

Questions

5.Explain why:

- a. Copper is a better conductor than wood
- b. Wood is a better conductor than air.

Questions

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- a. Copper is a better conductor than wood
- b. Wood is a better conductor than air.

- a. Copper is a metal and so contains **free electrons** which move very fast carry thermal energy through the metal.
- b. Wood is a solid so the particles are close and in fixed position which allows vibrations to be passes on. Air is a gas, so its particles are far apart and do not pass on thermal energy.

Exam-style Questions

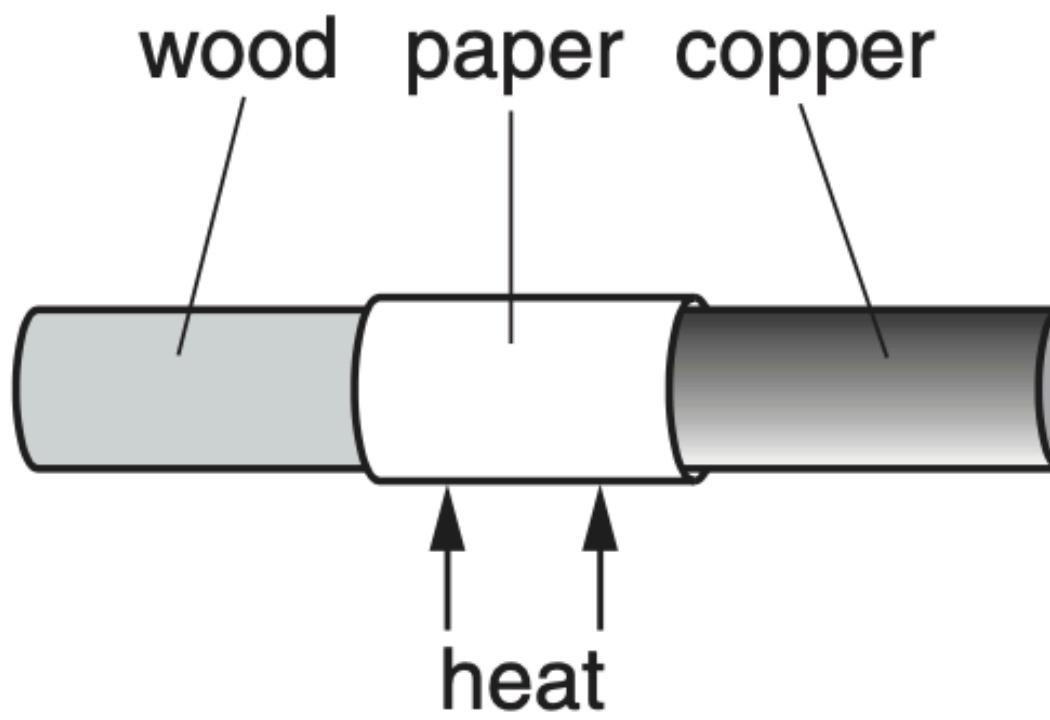
A person holds a glass beaker in one hand and fills it quickly with hot water. It takes several seconds before his hand starts to feel the heat.

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.

A bar made of half wood and half copper has a piece of paper wrapped tightly round it.

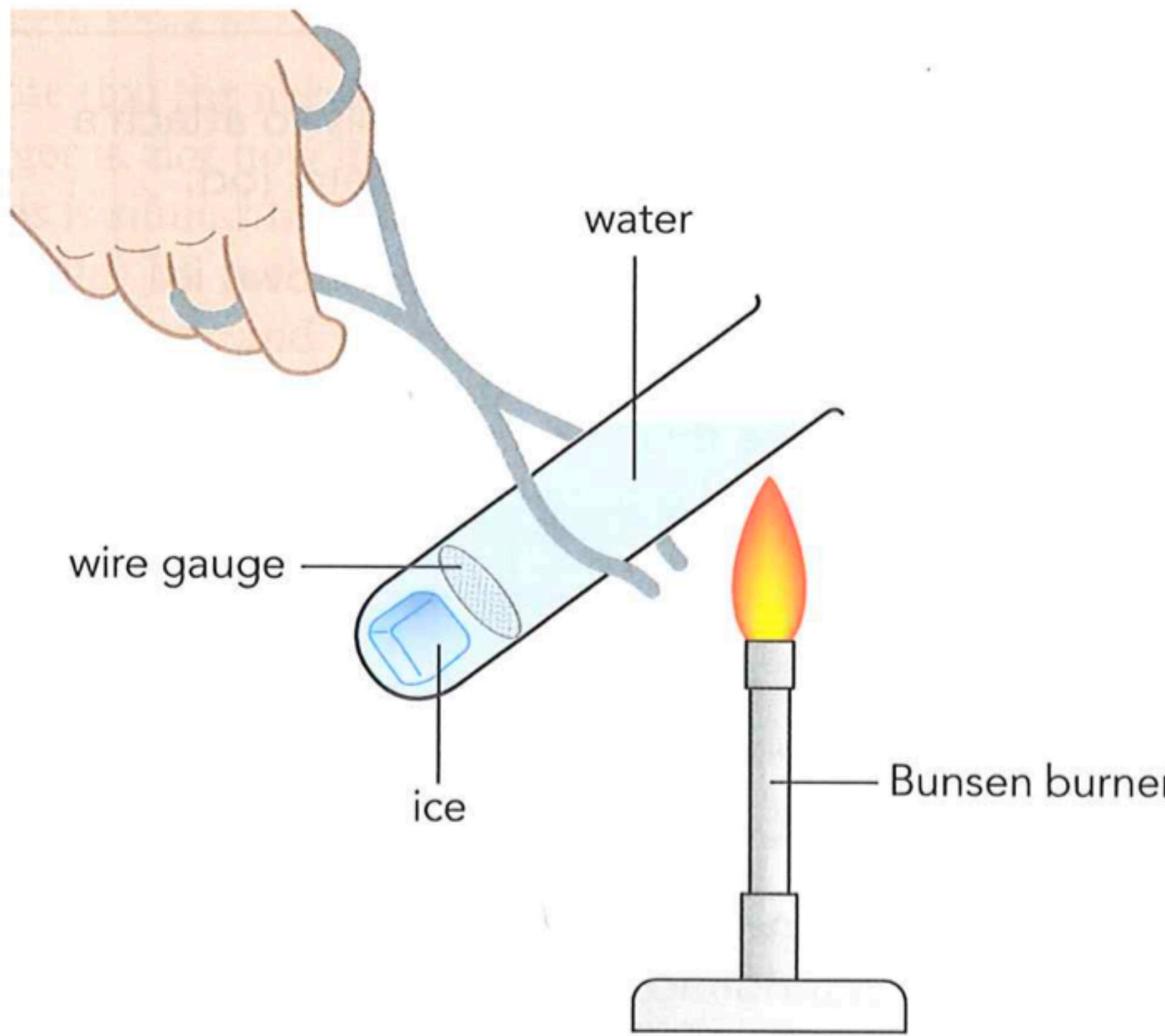
The bar is heated strongly at the centre for a short time, and the paper goes brown on one side only.



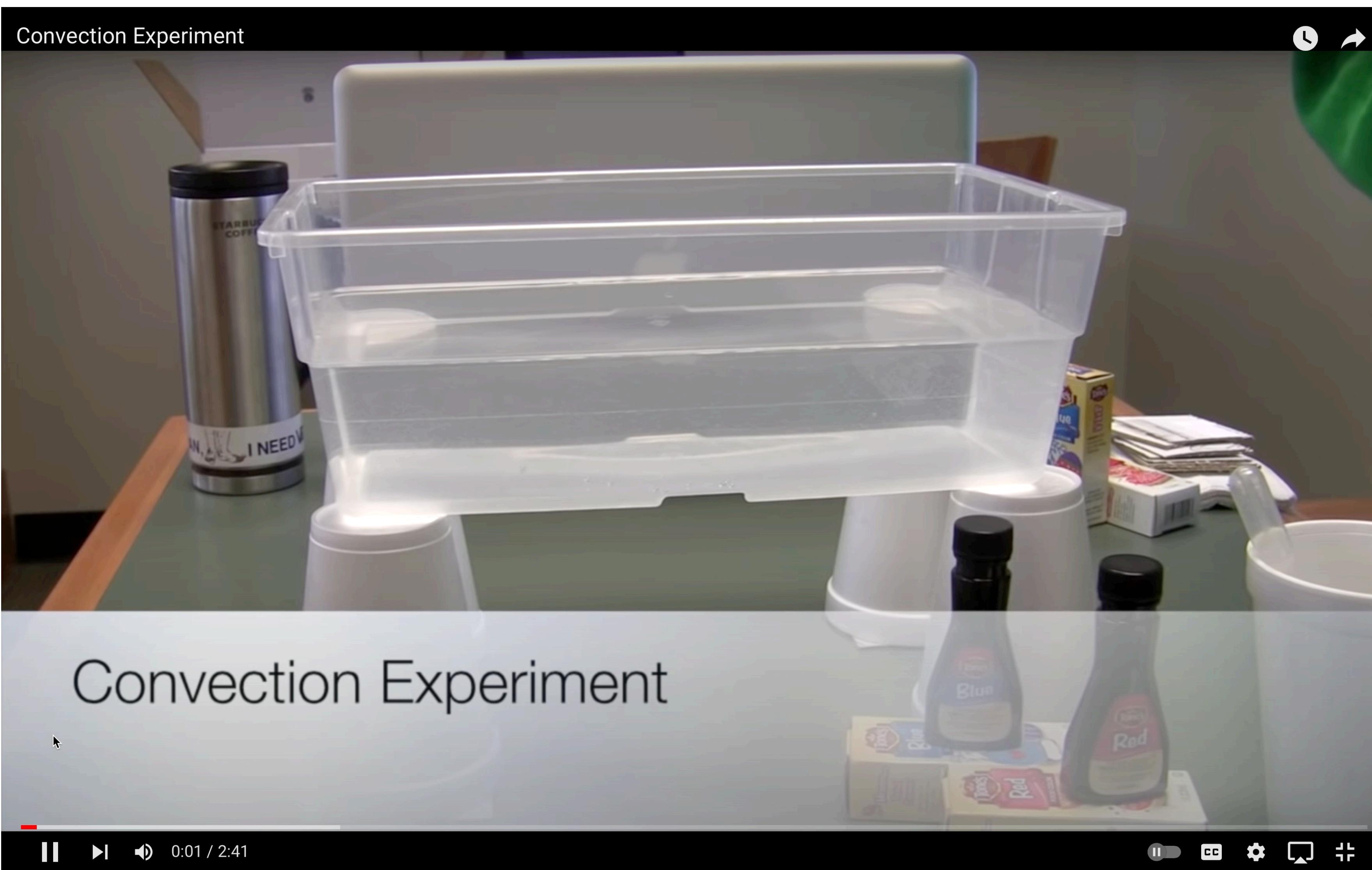
Which side goes brown, and what does this show about wood and copper?

	brown side	wood	copper
A	copper	conductor	insulator
B	copper	insulator	conductor
C	wood	conductor	insulator
D	wood	insulator	conductor

How does water get heated?



How does water get heated?



Convection

Definition : transfer of thermal energy through a material by **the movement of the material** itself



"hot air rises"

Explanation: when heated, fluids
expands so their density
decreases, warm fluid rises.

Happens only in **fluids**(a material that can flow: liquid/gas), not in solid

Convection

- **Convection current** : a movement of a fluid that carries energy from a warmer place to a cooler one
- **Key difference:**

Convection: energy transfer through movement of material itself

Conduction: without material itself moving

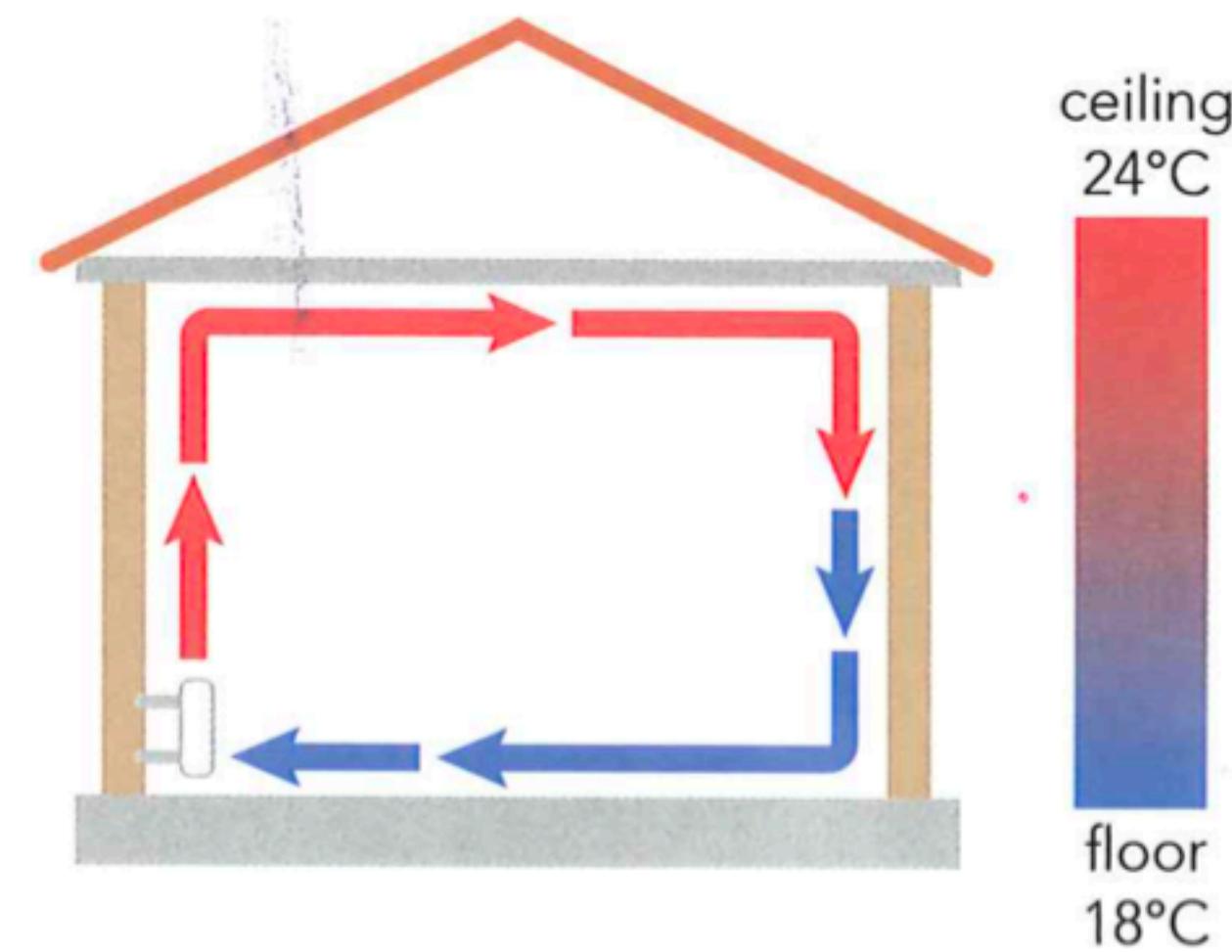


Convection current at work

- What do convection current do? **Share energy between warm and cold places**

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- Heater in the room

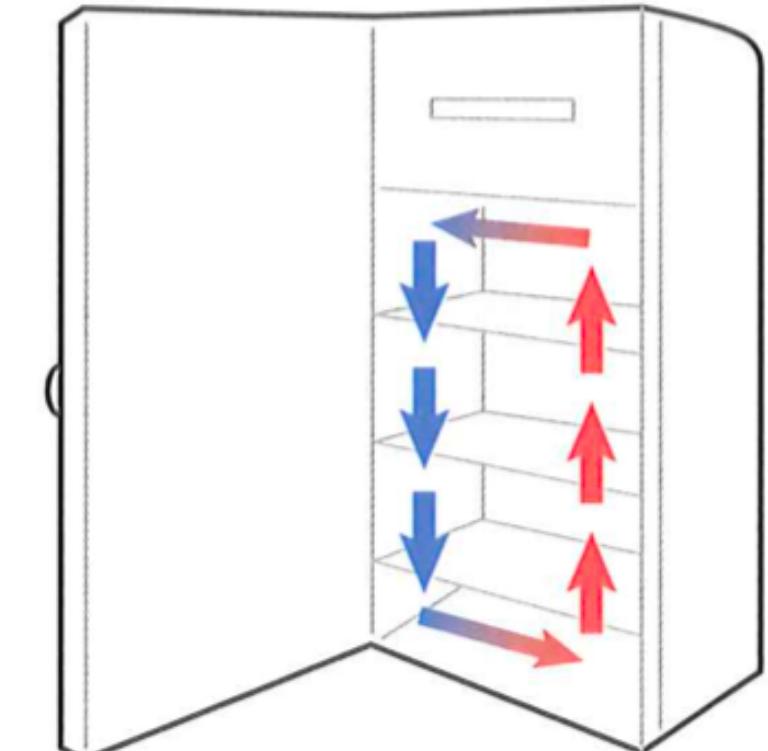


A fun fact about bed bug



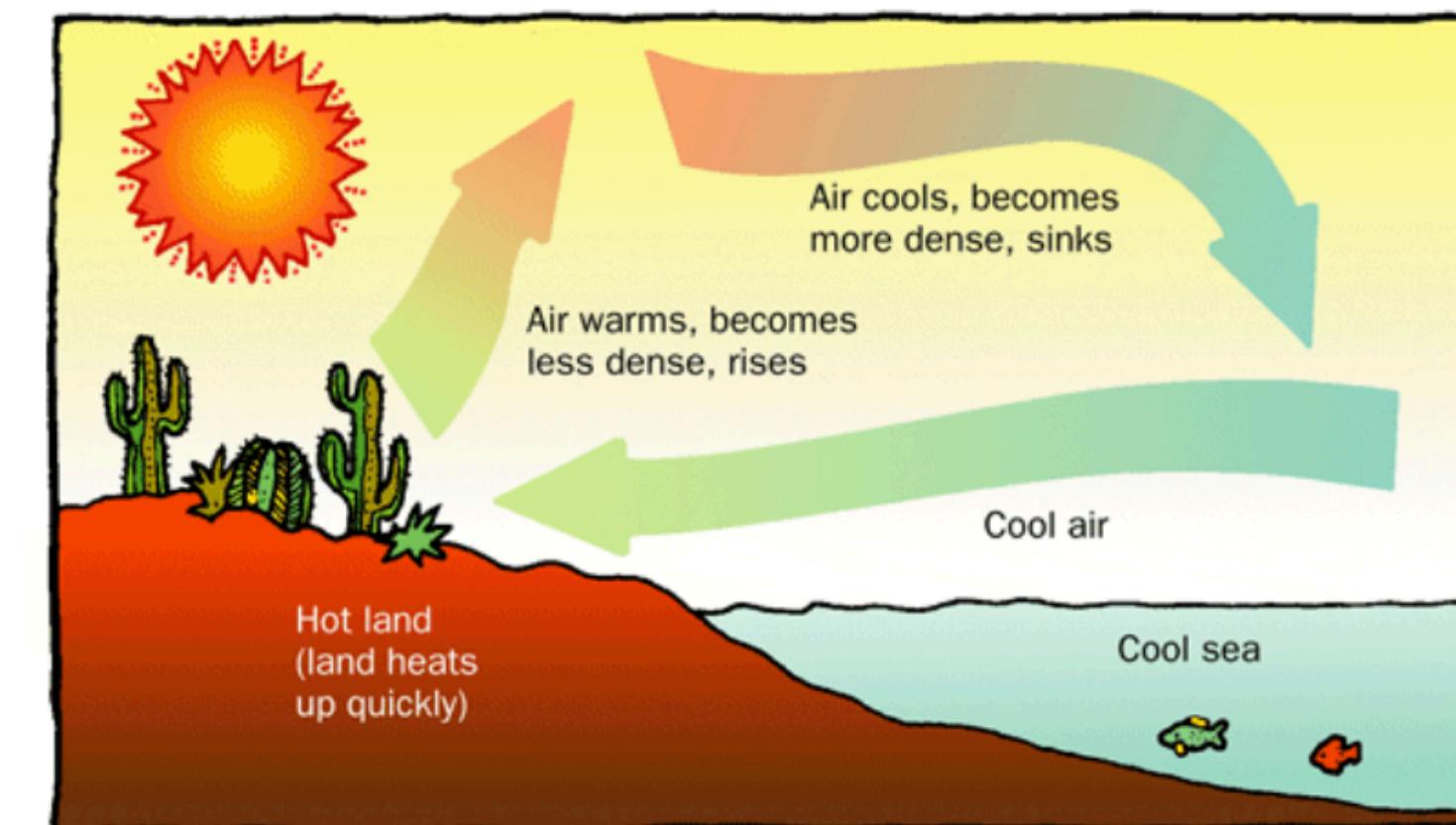
Convection current at work

- What do convection current do? Share energy between warm and cold places
- Heater in the room
- Refrigerator: where is the freezing surface

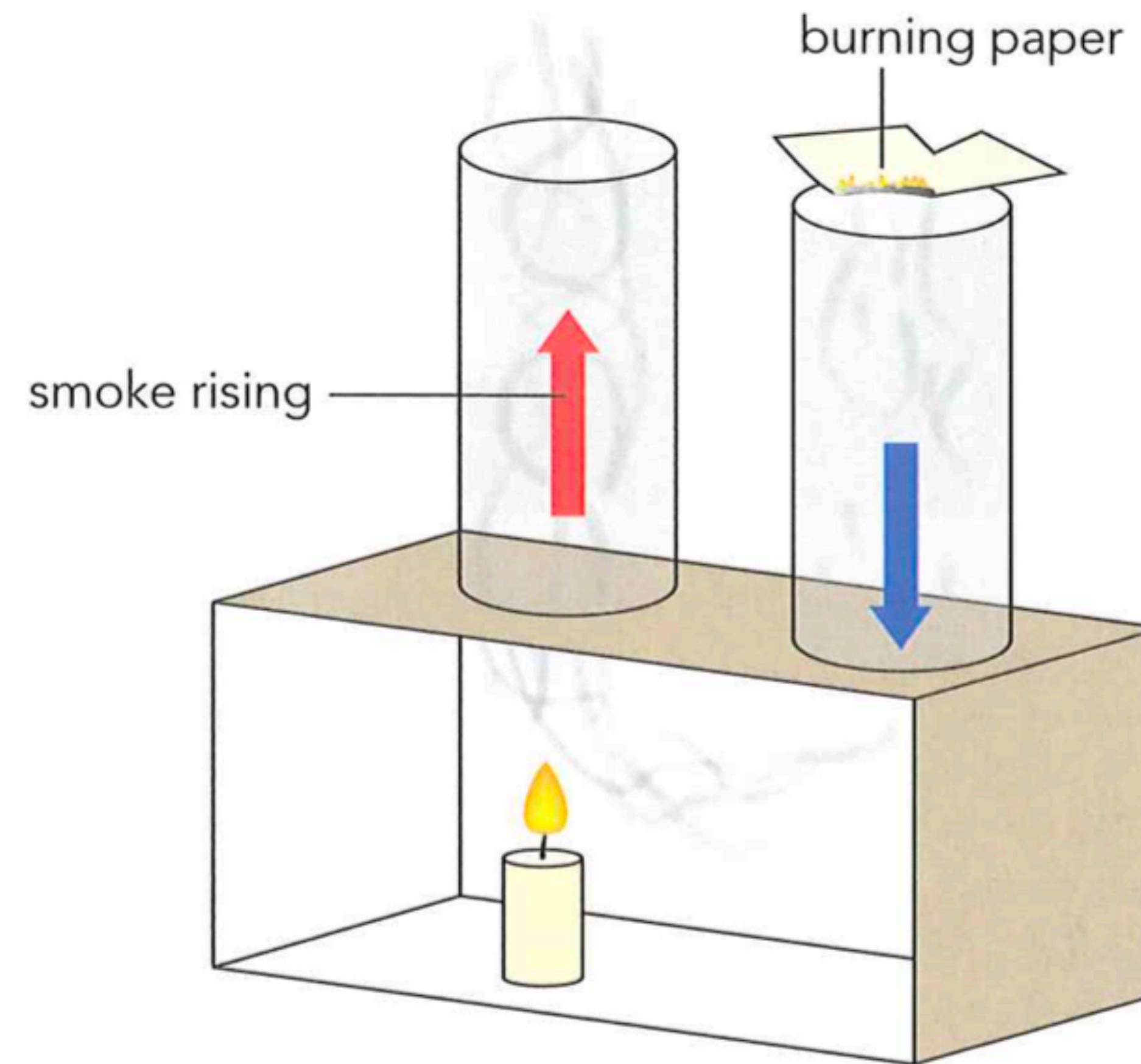


Convection current at work

- What do convection current do? Share energy between warm and cold places
- Heater in the room
- Refrigerator: where is the freezing surface
- Wind



Convection: smoke demo



Convection Smoke Chimney



0:20 / 1:36



Questions

- 1. An inventor makes an electric kettle with the heating element at the top. Explain why it will not work.

Questions

- 1. An inventor makes an electric kettle with the heating element at the top. Explain why it will not work.

The water at the top will heat up and become less dense so it will stay at the top and the water in the bottom will stay cold .

Questions

- Explain why convection does not happen in solids.

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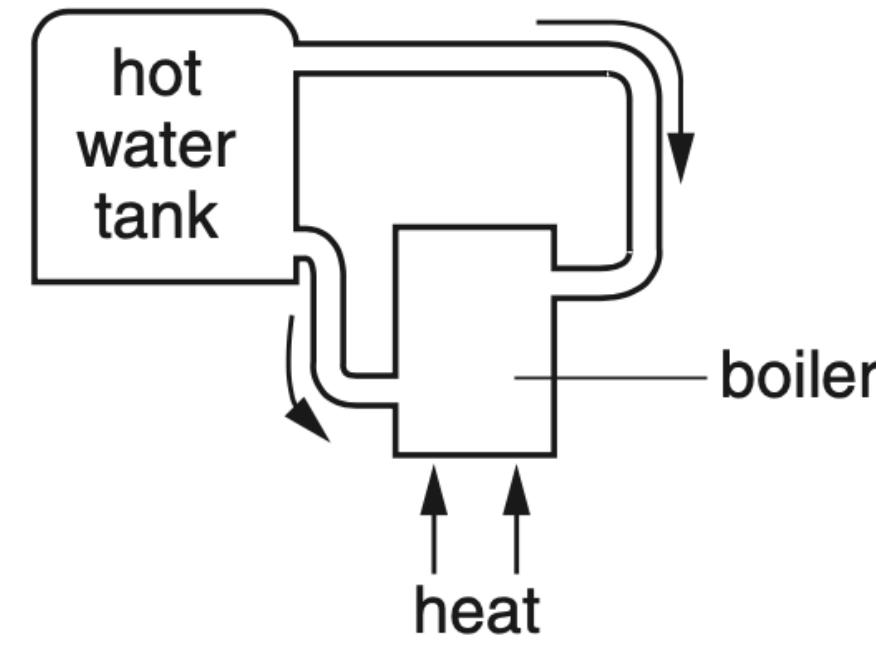
Convection cannot happen in a solid because the particles are **not free to move**

Exam-style Questions

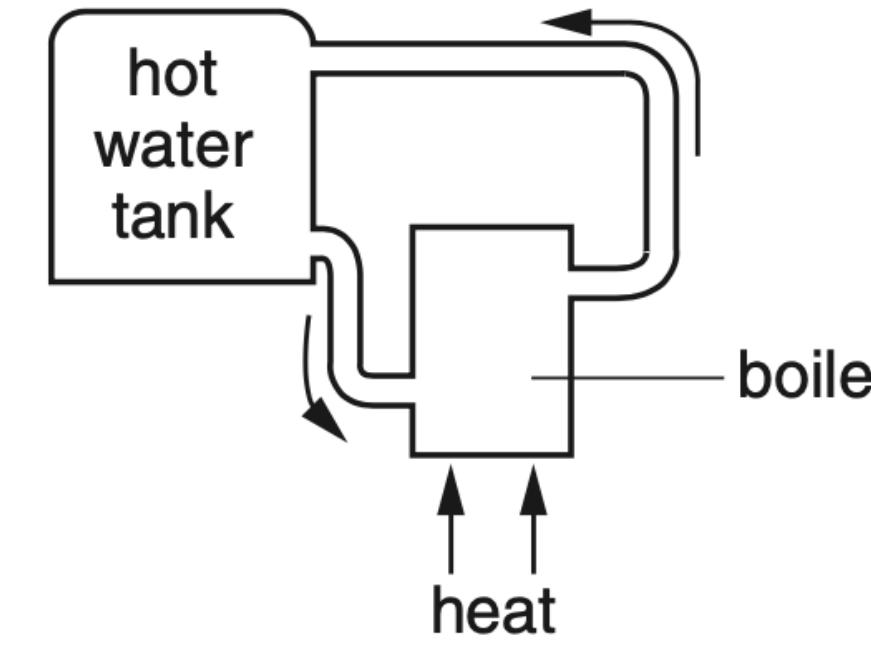
The diagrams show part of a water-heating system which is working by convection.

Which diagram shows the most likely flow of water in the system?

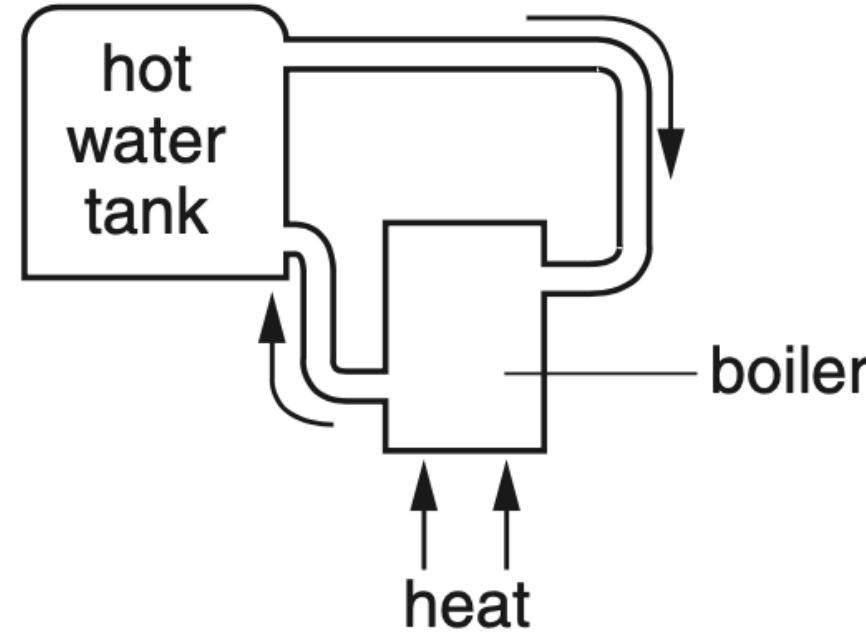
A



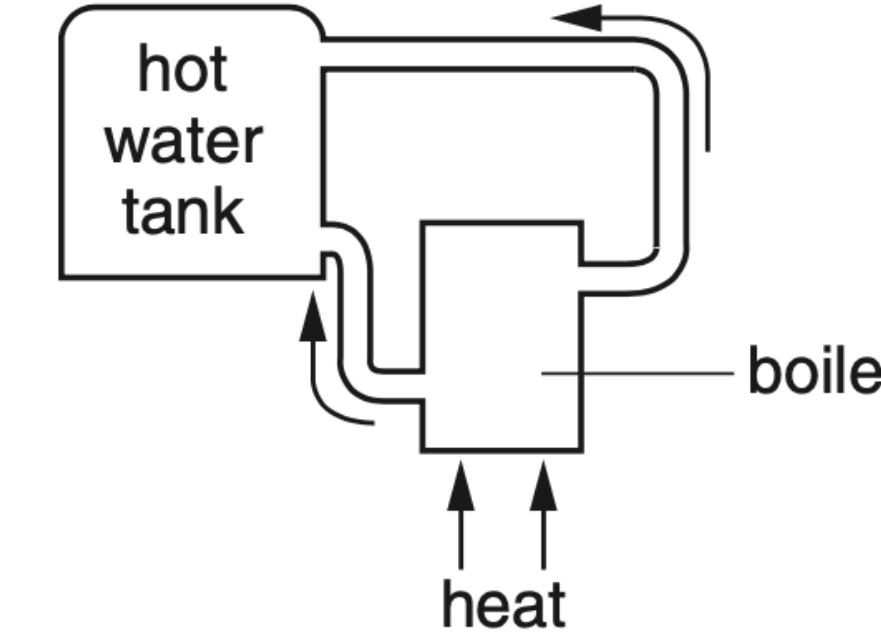
B



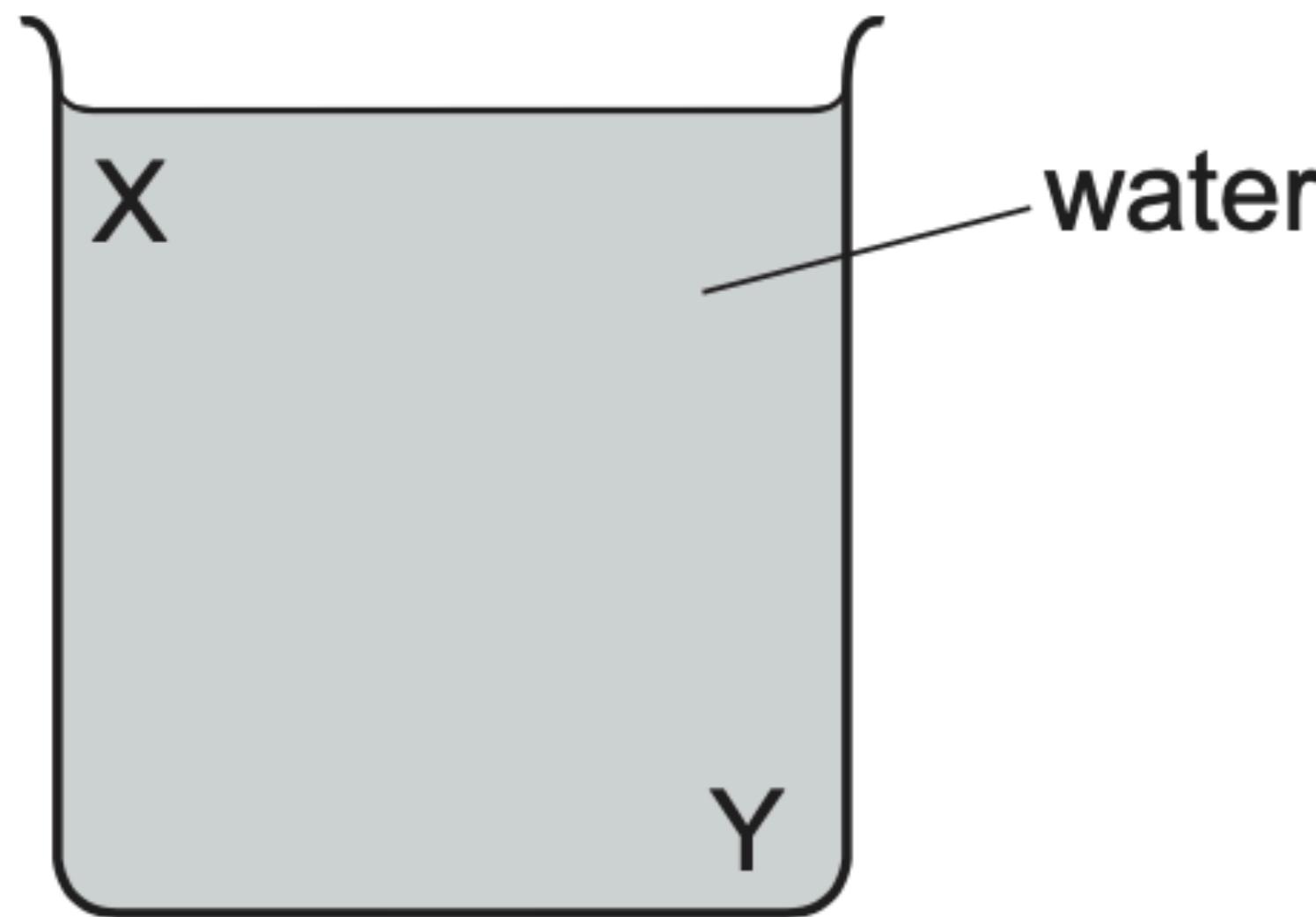
C



D



A beaker contains water at room temperature.

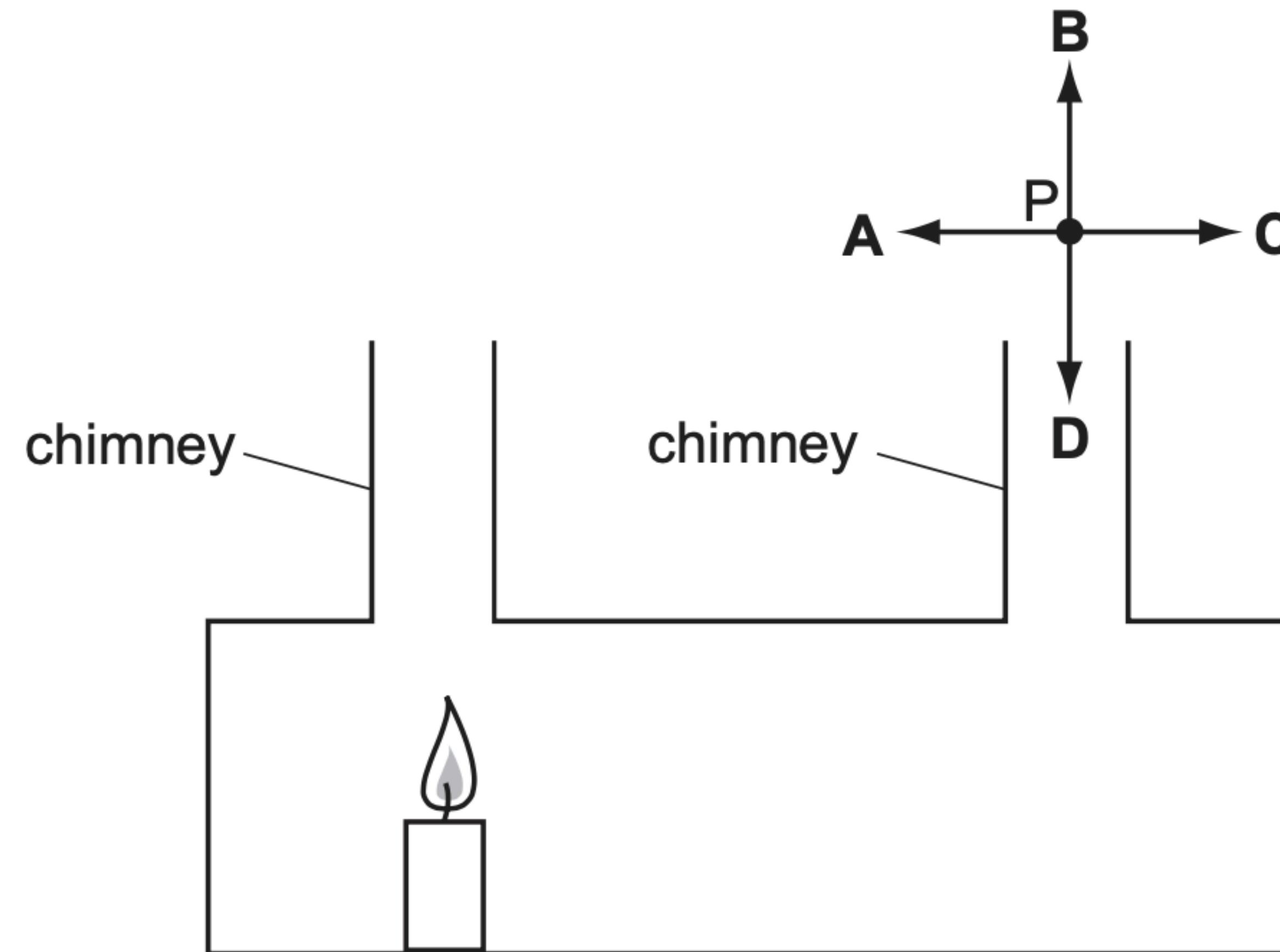


How could a convection current be set up in the water?

- A** cool the water at X
- B** cool the water at Y
- C** stir the water at X
- D** stir the water at Y

A teacher demonstrates convection currents using a box with two chimneys and a lighted candle. She holds a smoking taper at point P.

In which direction does the convection current cause the smoke to move?



Summary

- Convection is a type of thermal transfer, but only happens in fluids.
- Convection: transfer of thermal energy through a material by the movement of the material itself
- Convection: “**hot air rises**”; Convection current: a movement of a fluid that carries energy from a warmer place to a cooler one

Radiation

- Do you see further during the daytime or at night?

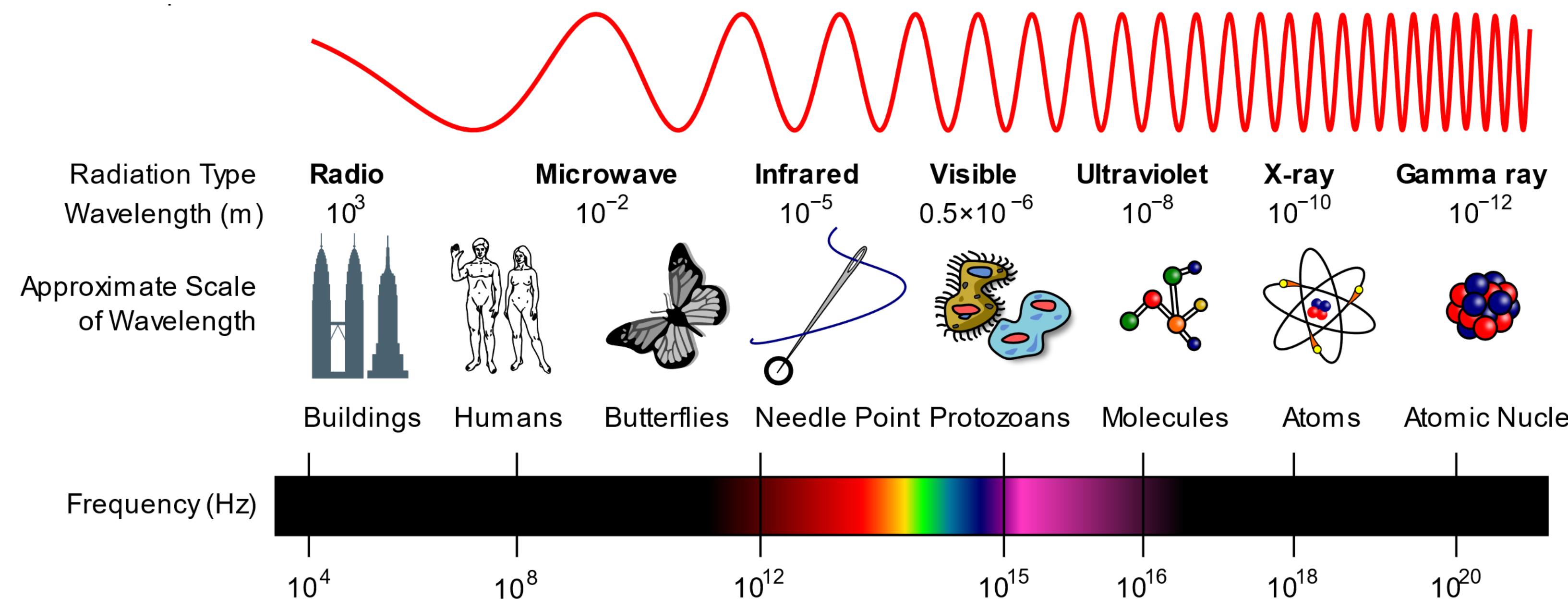
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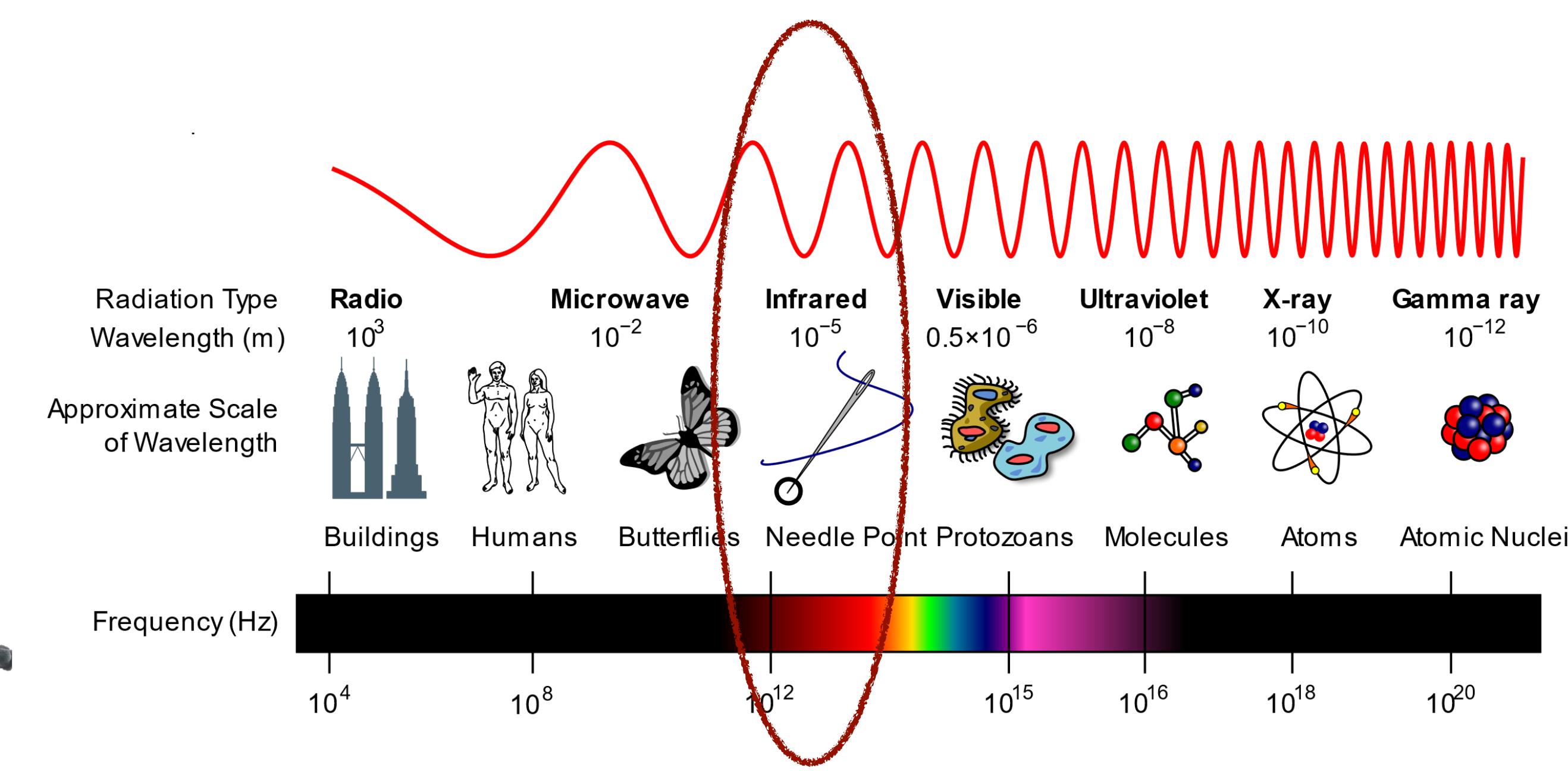
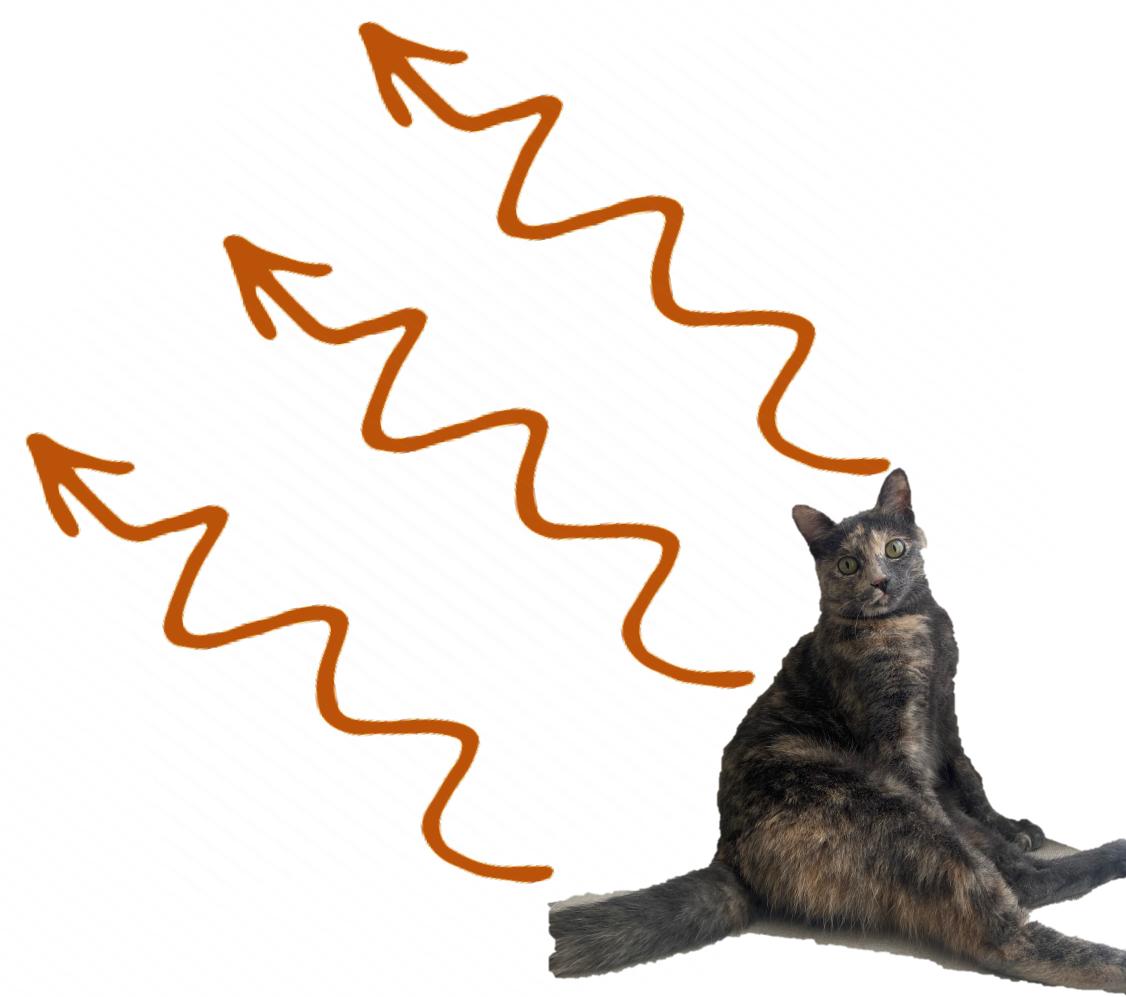
Radiation

- Heat can travel on a wave, **Electromagnetic Wave(EM wave)**.
- **EM wave:** 1. Can travel through a vacuum (Sun -> Earth)
2. In vacuum, $v = \text{speed of light}$



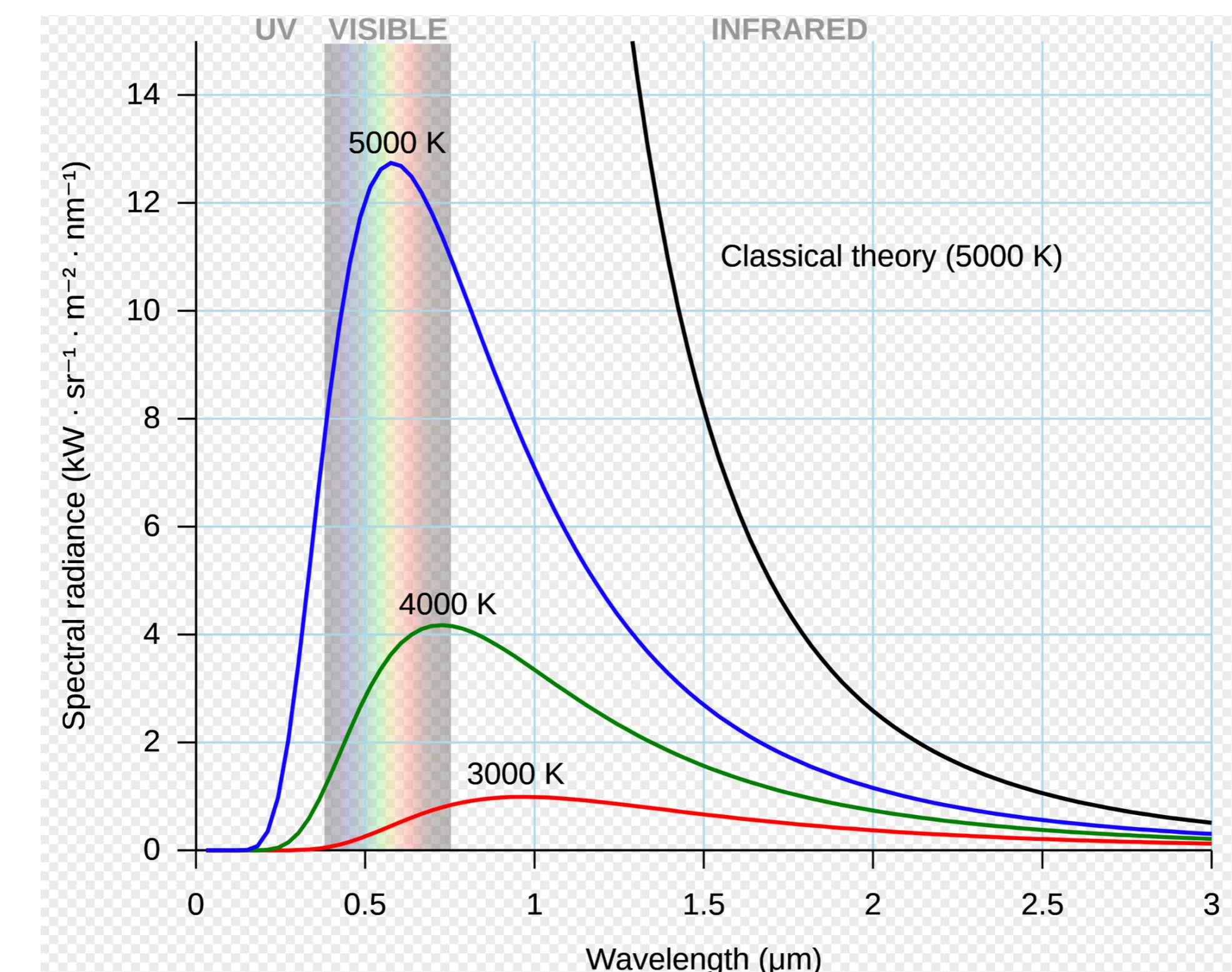
Infrared radiation

- All objects emit electromagnetic radiation – for warm object infrared radiation is most dominant
- Infrared radiation/ thermal(energy) radiation



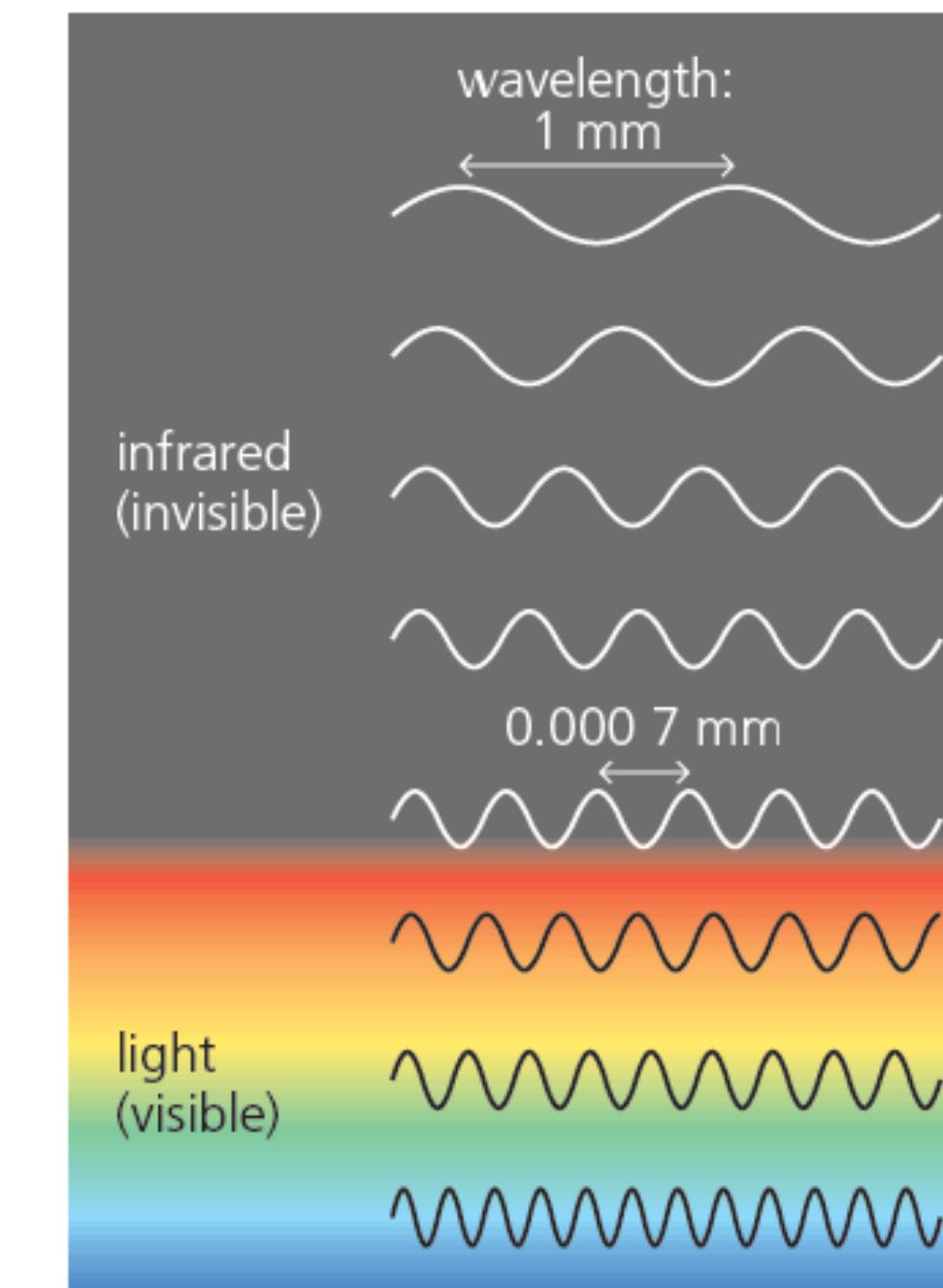
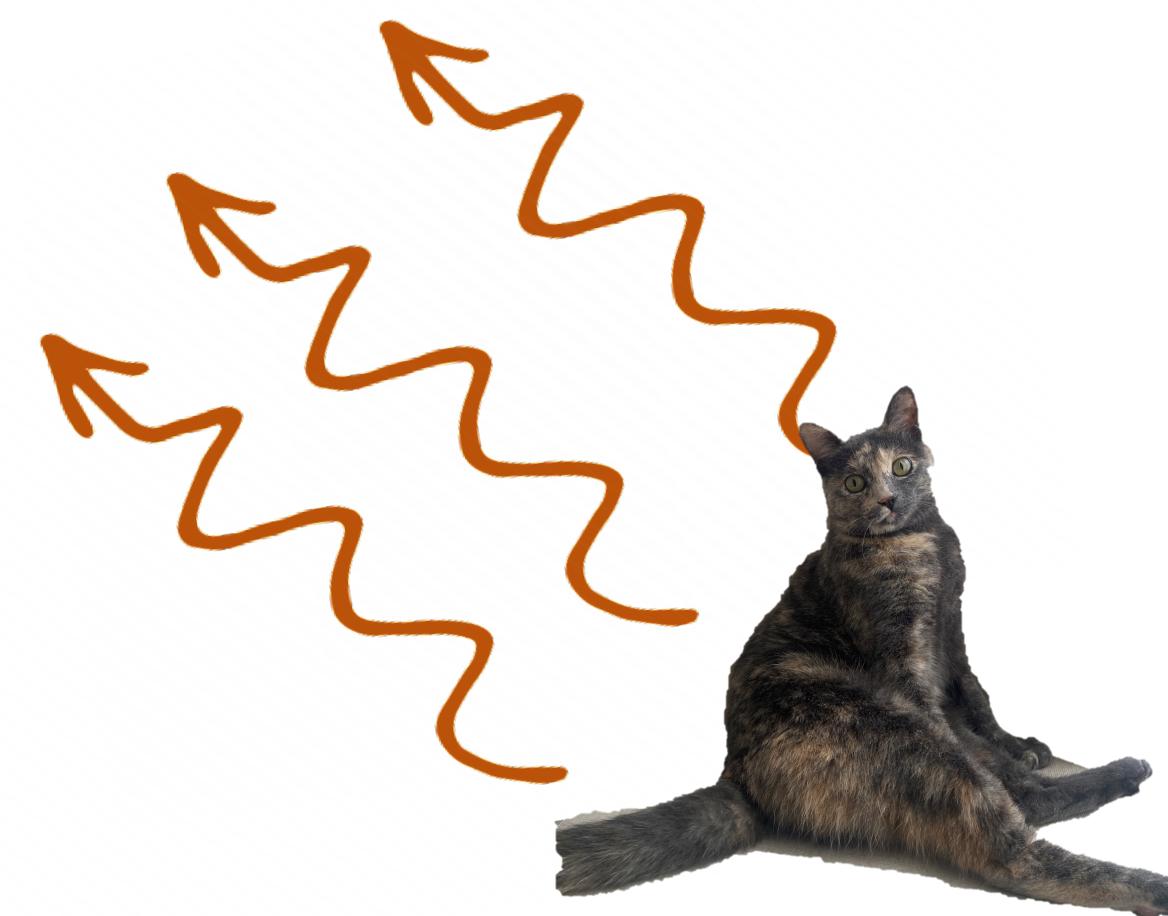
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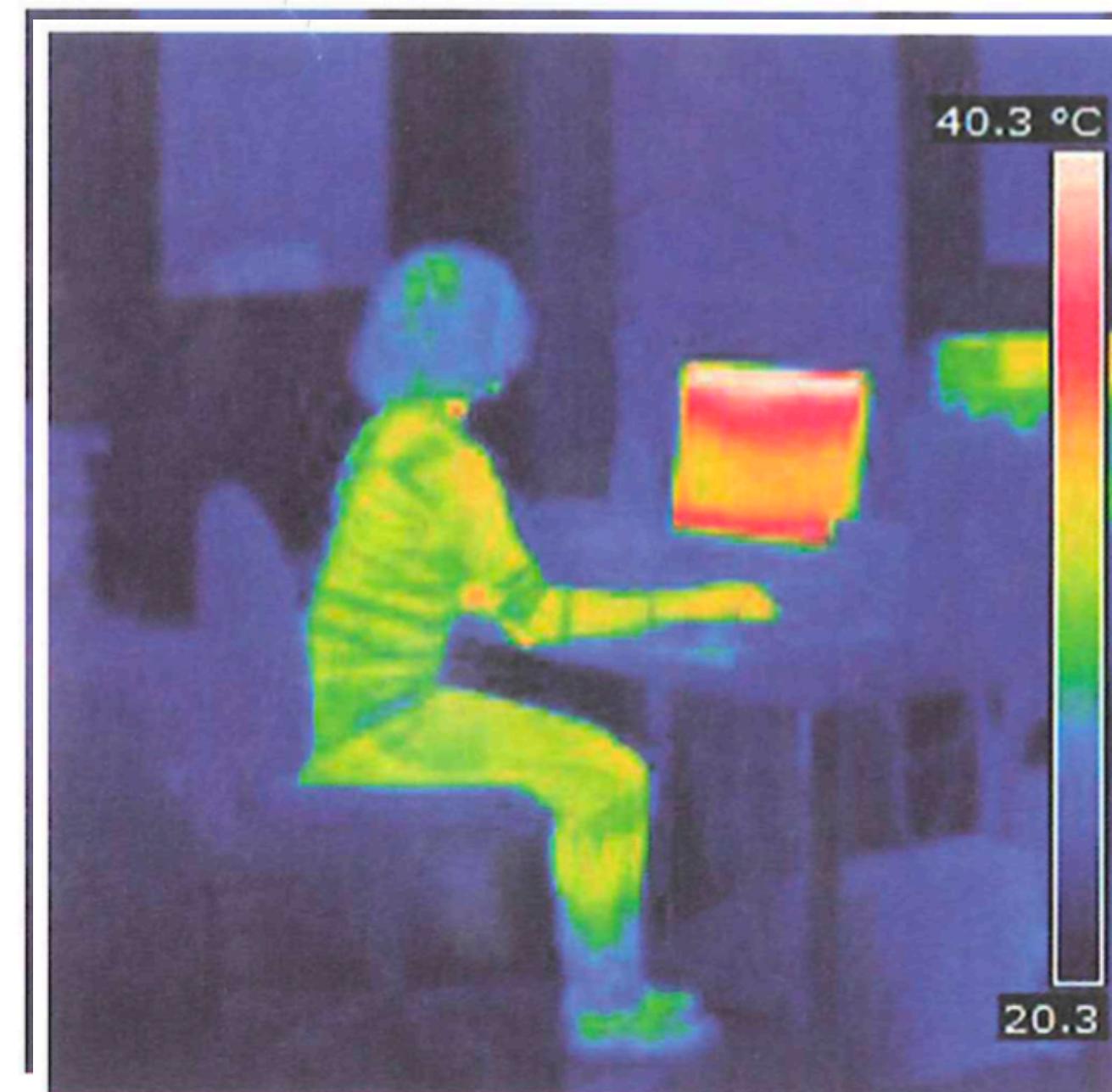
Infrared radiation

- All objects emit electromagnetic radiation – for warm object infrared radiation is most dominant
- Infrared radiation/ thermal(energy) radiation
 - 1. Higher T -> more radiation energy
 - 2. Very hot objects may emit light.
- Only form of thermal energy transfer that doesn't involve the motion of particles

Detecting Infrared radiation

1. Skin nerve cells

2. Temperature sensitive camera



Summary on infrared radiation

1. Is a form of EM, invisible to the naked eye
2. Produced by warm or hot objects
3. Warms the objects that absorbs it
4. Can travel through empty space and medium

Only form of thermal energy transfer that doesn't involve the motion of particles

5. Travel in straight line
6. Can be detected by nerve cells in the skin (close to a thermal source)

Questions

- Explain why thermal energy from the Sun can only reach us by radiation , not conduction or convection.

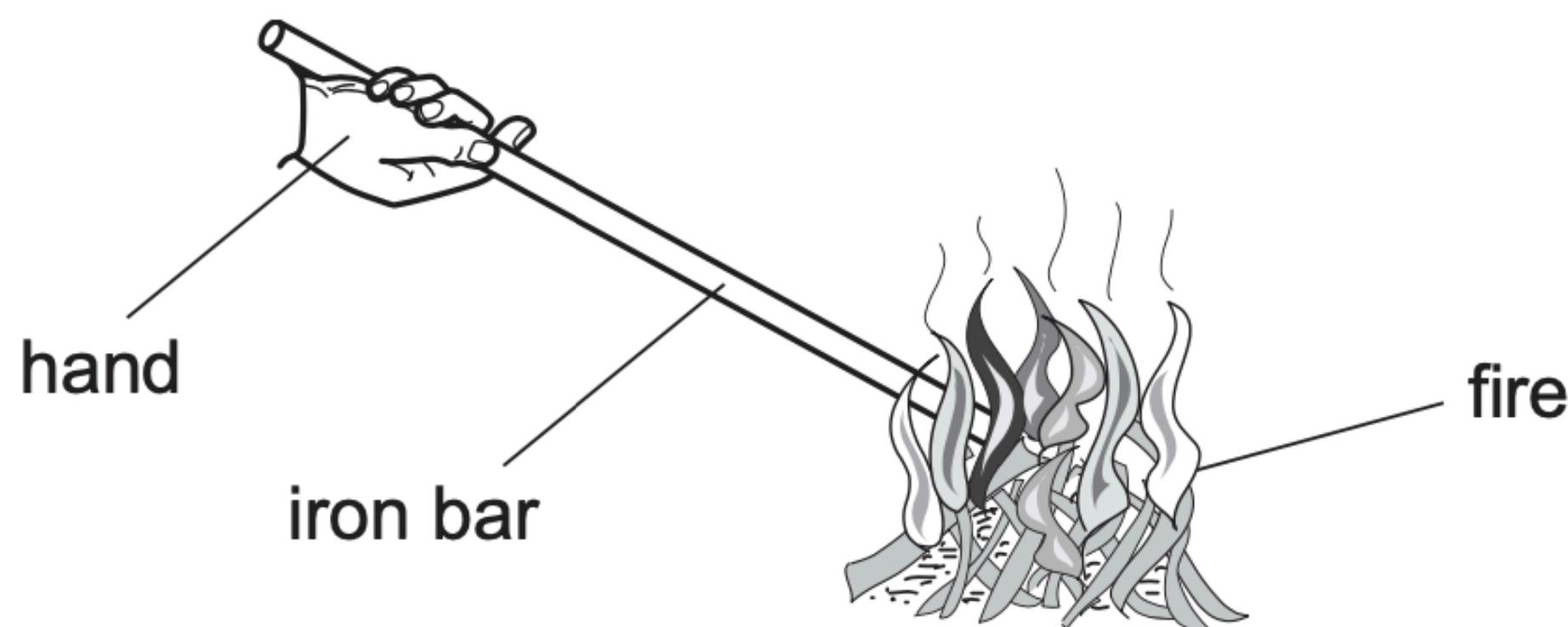
Questions

Which statement about infrared radiation is true?

- a. Infrared radiation travels slower than light
- b. Infrared radiation cannot be reflected
- c. Infrared radiation can travel through a vacuum
- d. Infrared radiation is transferred by the movement of particles

Questions

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

Questions

- What evidence is there in this infrared photograph to suggest that the car has only just broken down?



Good absorbers, good emitters

→ **Surface** determines whether reflect/absorb

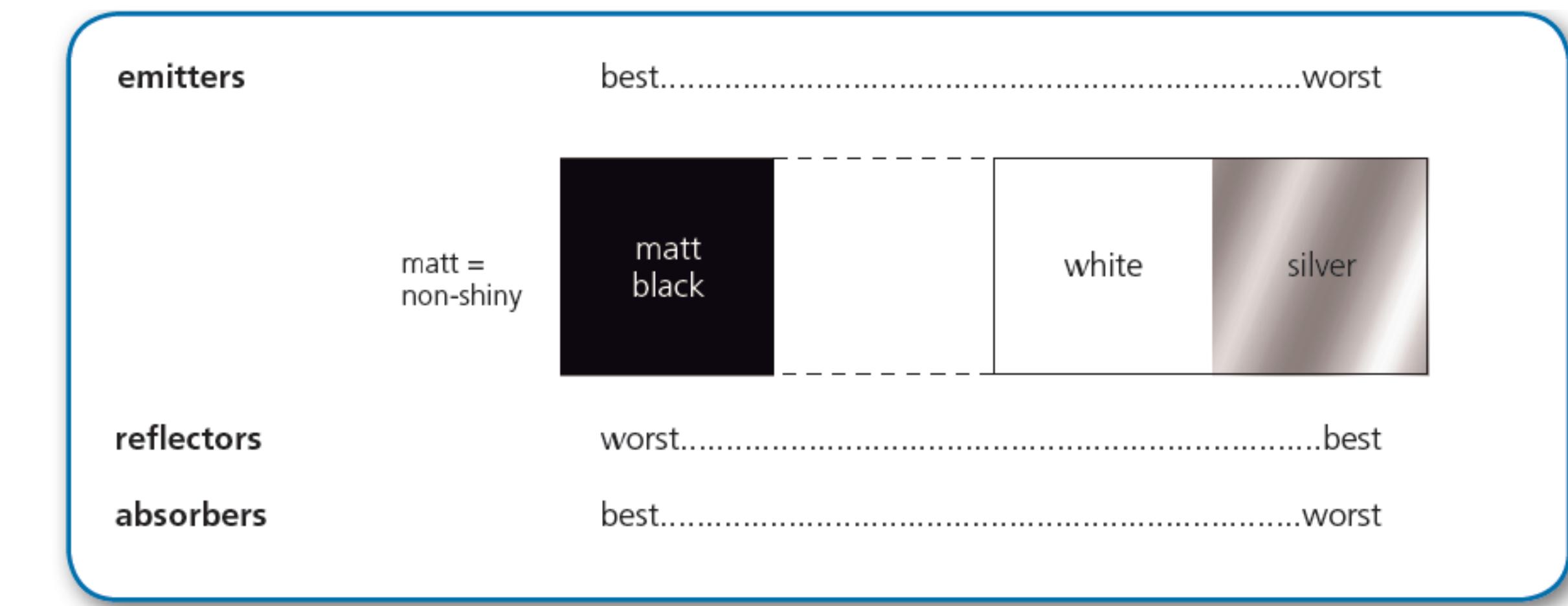
→ Some surfaces **absorb** heat better.

- Dark

Some surfaces **reflect** more heat.

- Light

Dark surfaces also **emit** heat faster.



Good absorbers, good emitters

- **Shiny or white** surface are the best **reflectors** (the worst absorbers) *of thermal radiation*
- **Matte black** surface are the best **absorbers**(the worst reflectors)*of thermal radiation*
- **Matte black** surface are the best **emitters** *of thermal radiation*

Solar panels

Some solar panels absorb heat to heat up water.

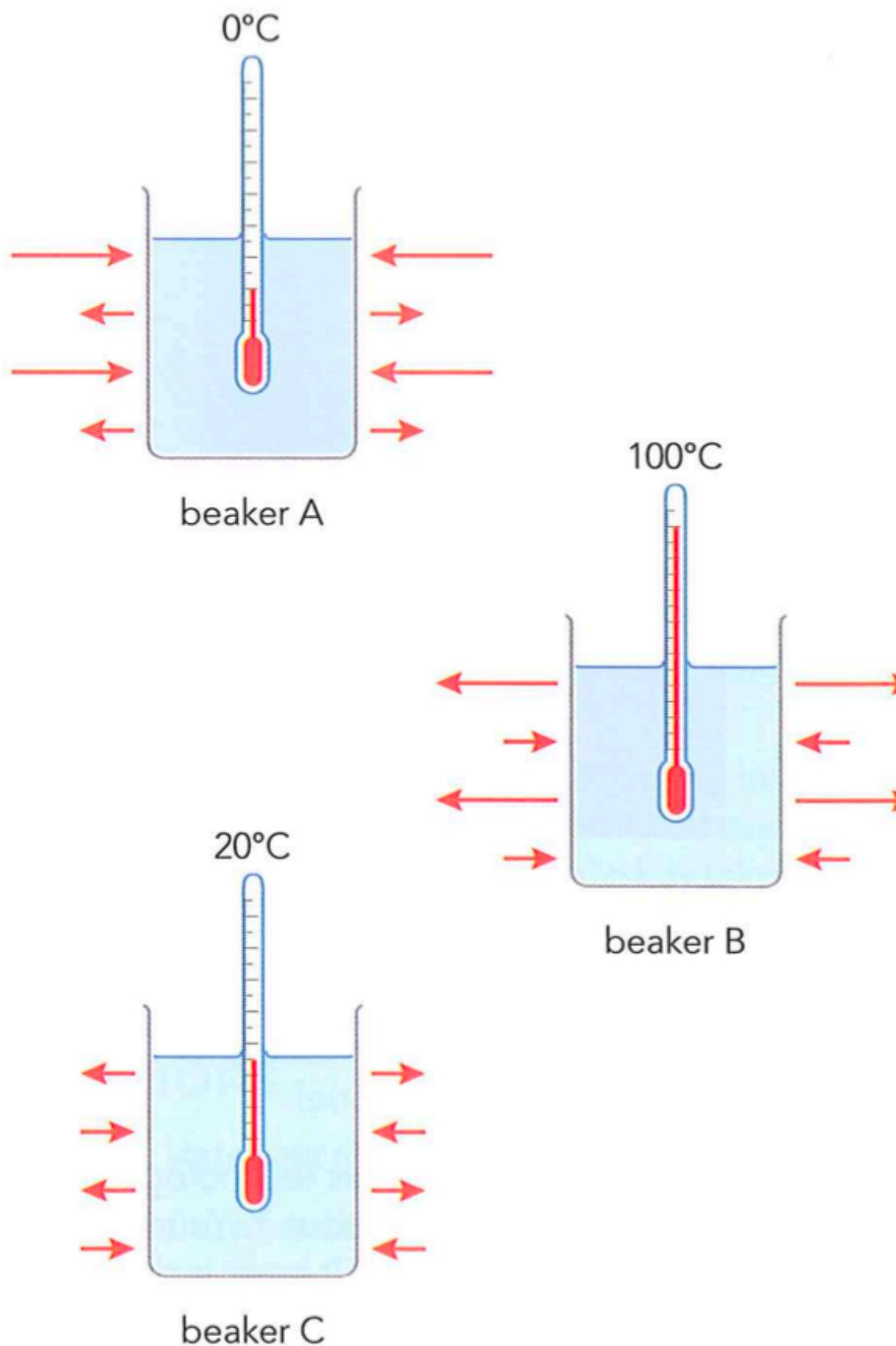
These panels should be dark.



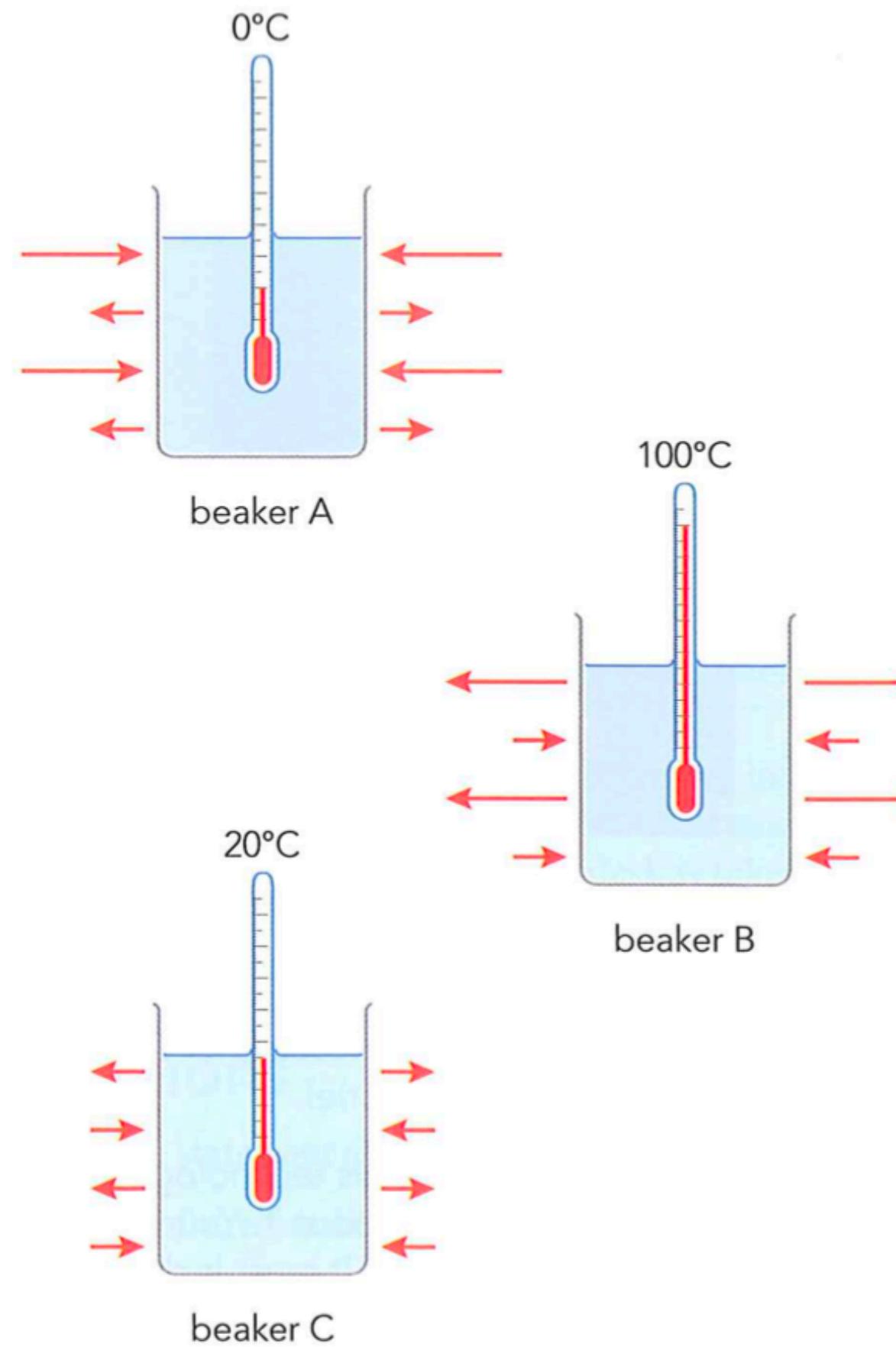
Question

- Which will stay hot longer: tea in a shiny silver teapot or tea in dark brown one?
Explain why.

Factors affecting infrared radiation

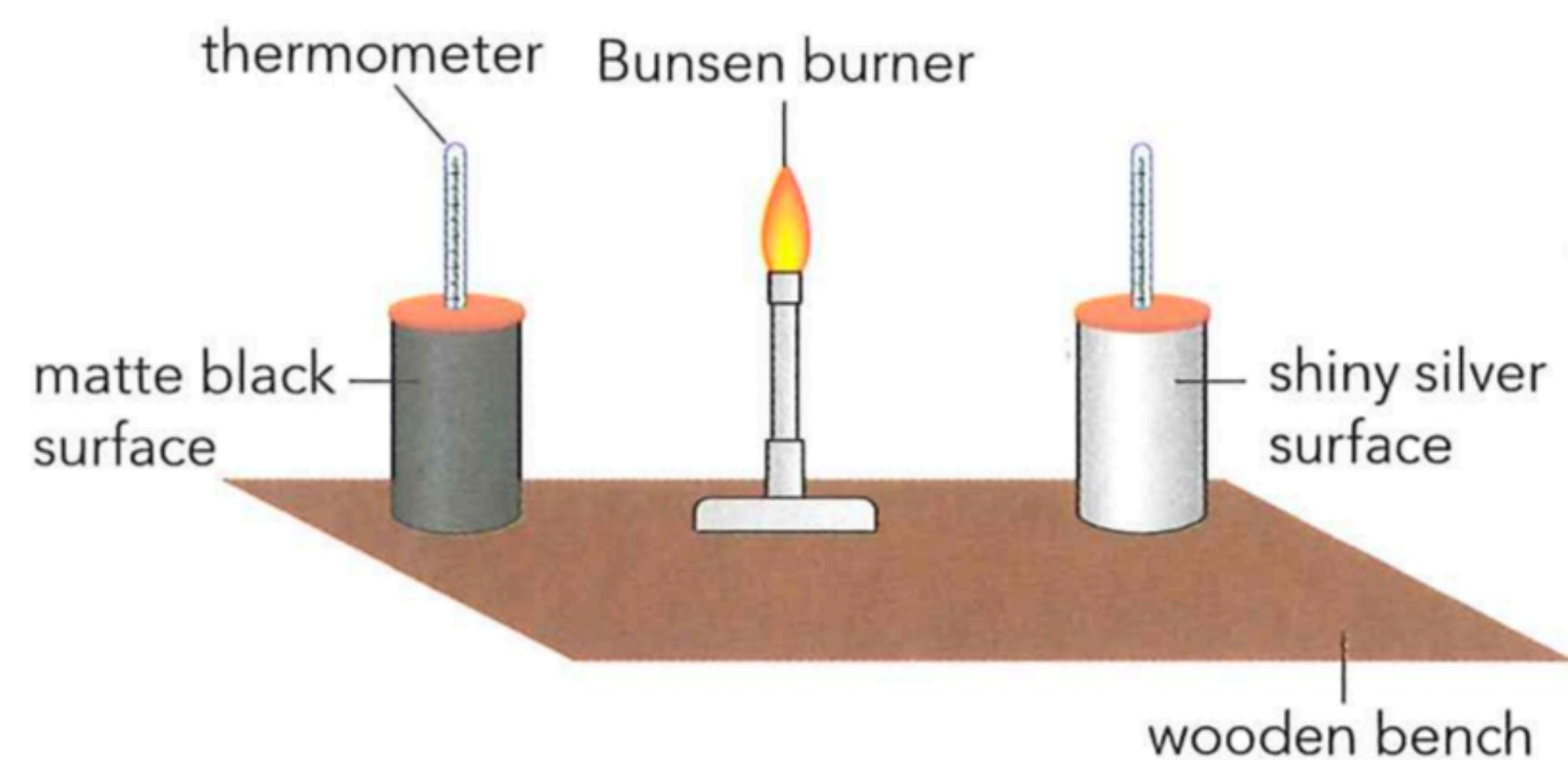
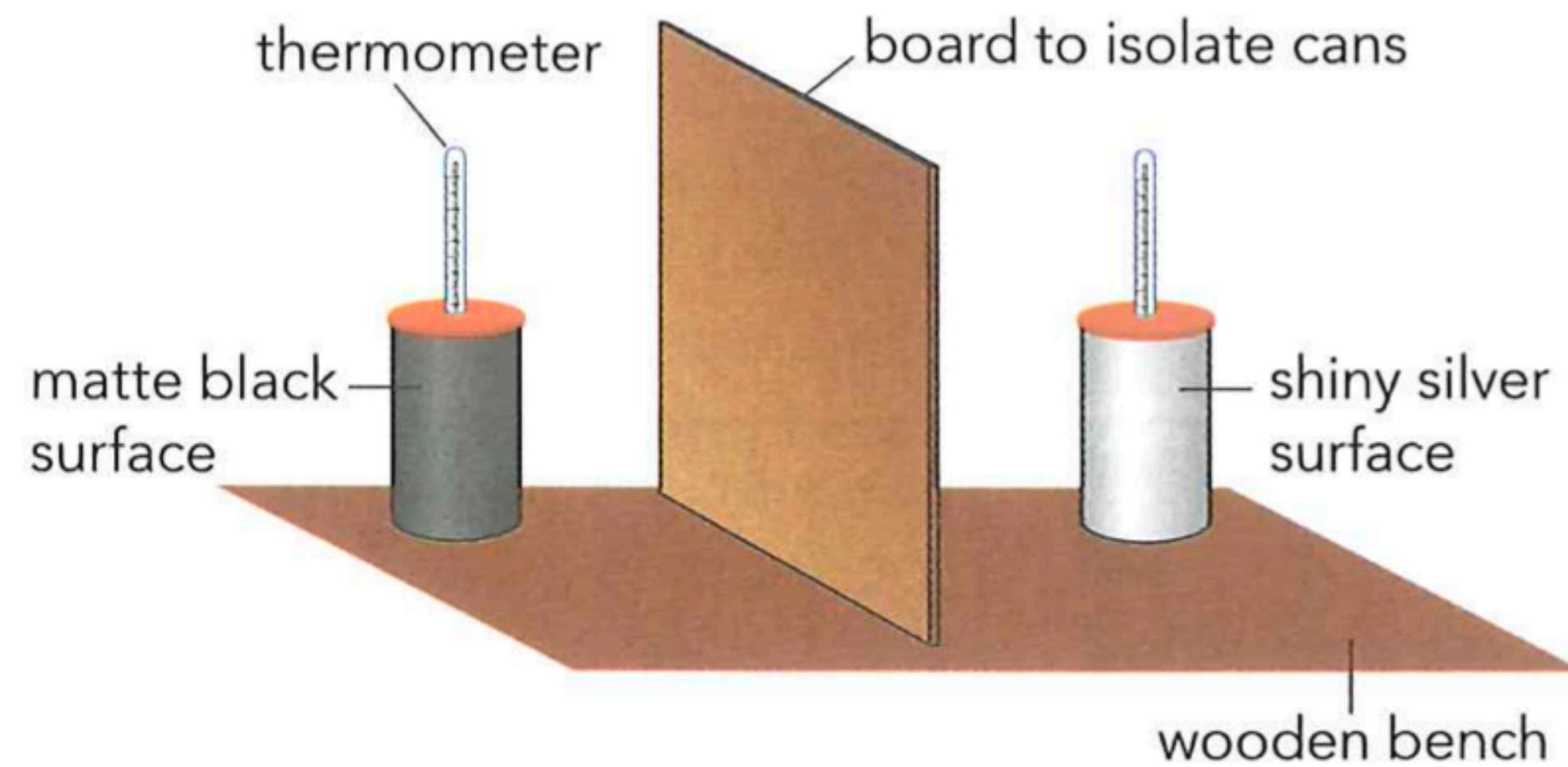


Factors affecting infrared radiation



- Surface temperature
- Surface area
- Surface texture

Experiment: good emitters & good absorbers



Summary

- All objects emits infrared radiation. **Warmer objects emits more.**
- Infrared radiation is a type of EM radiation, so can travel in **vacuum**(doesn't need medium)
- Dark & dull surface => good absorber + good emitter
light & shiny surface => good reflector

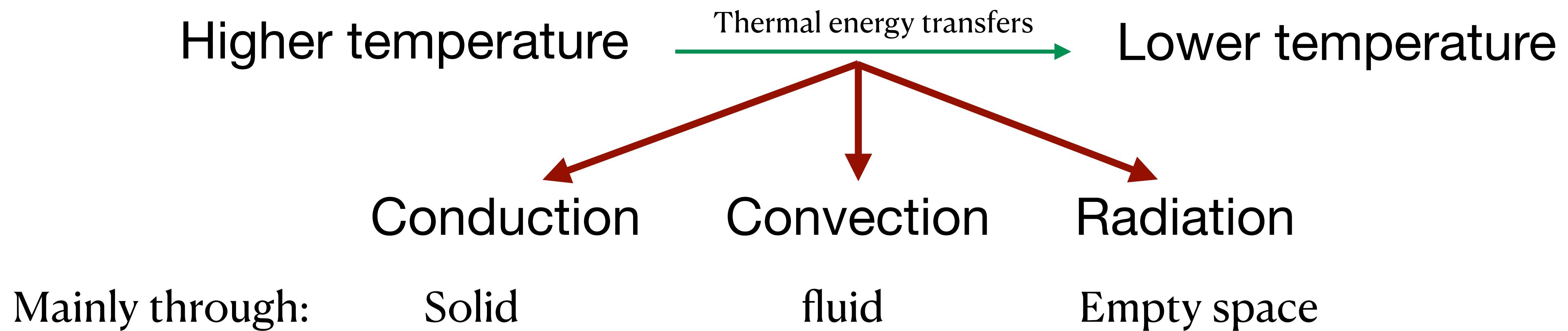
Conduction	Mainly in solid
Convection	Only in fluid
Radiation	Empty space & transparent medium(air)

Questions

How does heat from the Sun reach the Earth?

- A** conduction only
- B** convection only
- C** radiation only
- D** conduction, convection and radiation

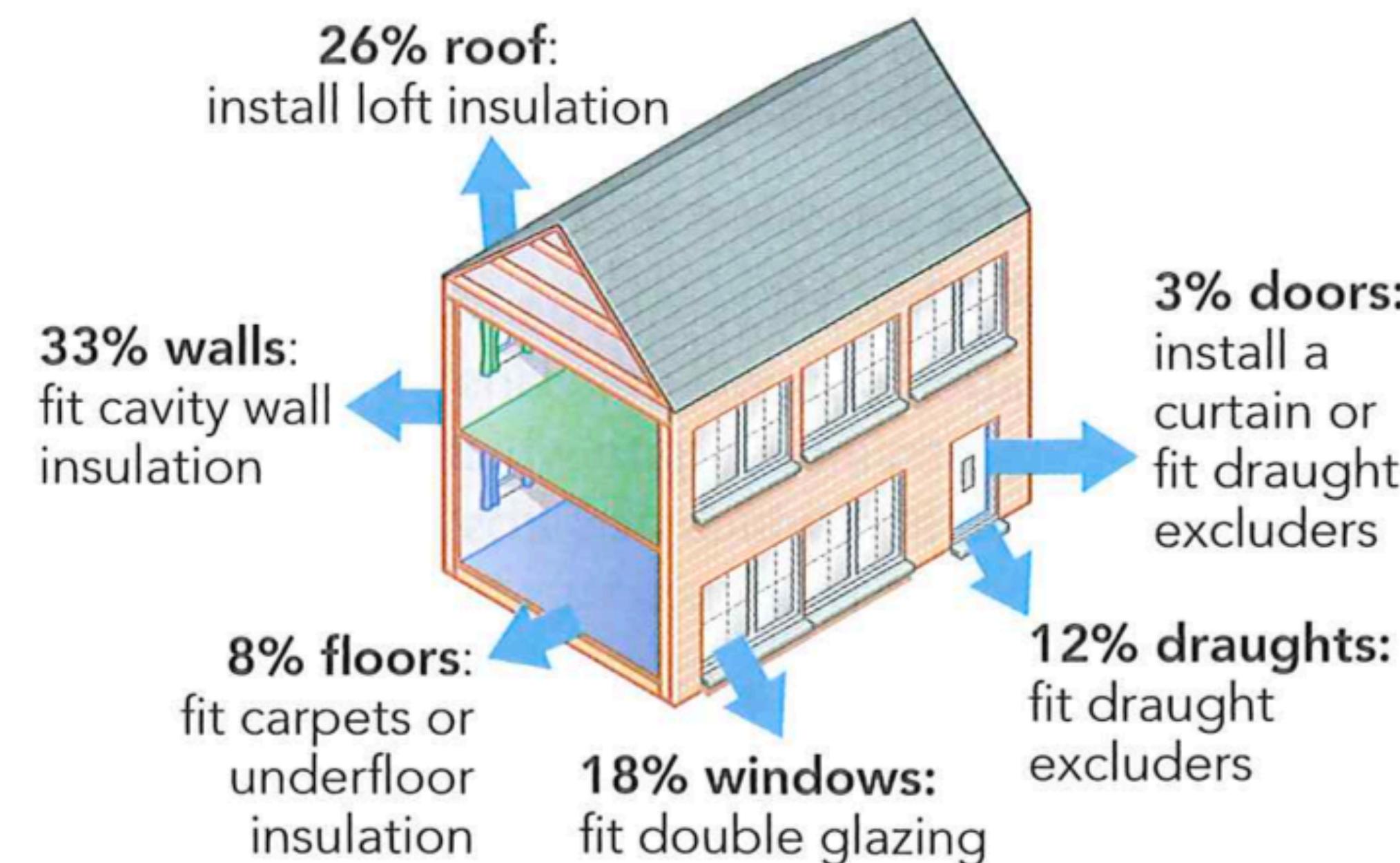
Consequences of thermal energy transfer



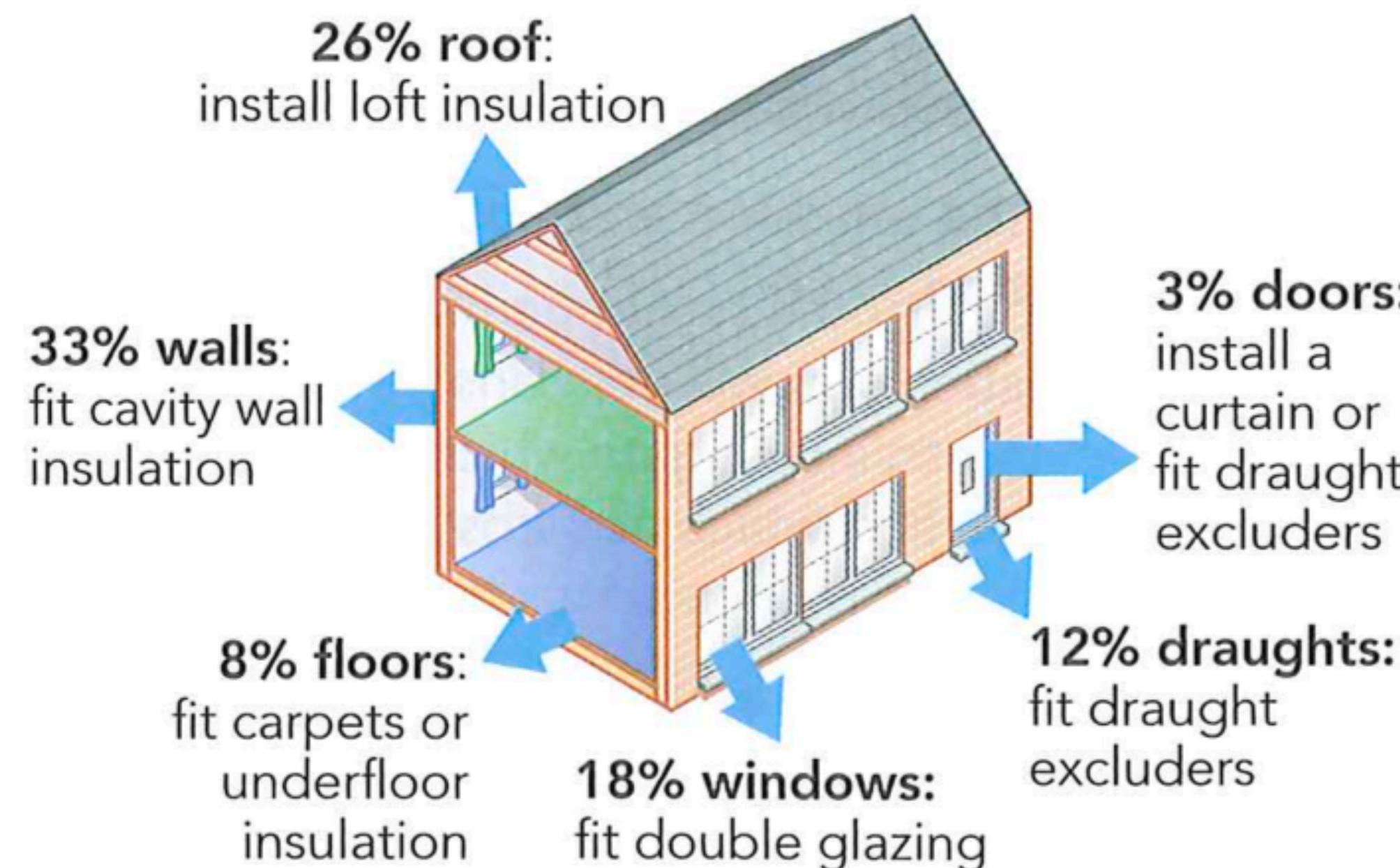
Why do we need to turn on heater for
the most of time during winter?

→ Energy loss → Waste → Better insulation

Home insulation



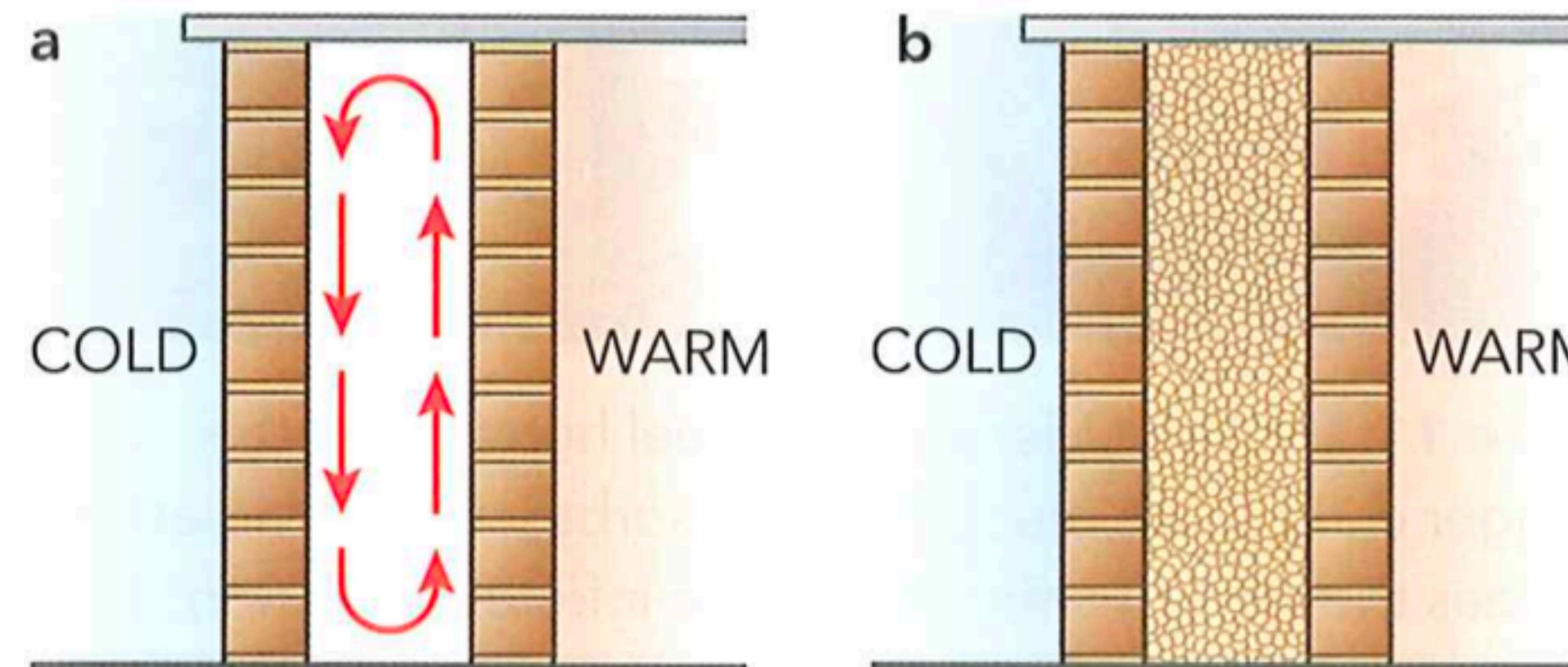
Home insulation



Method	Why it works
thick curtains, draught excluders	stops convection currents, and so prevents thermal energy transfer
loft and underfloor insulating materials	prevents conduction of thermal energy through floors and ceilings
double and triple glazing of windows	vacuum between glass panes cuts out losses or gains by conduction and convection
cavity walls	reduces thermal energy loss or gain by conduction
foam or rockwool in wall cavity	further reduces thermal energy transfer by convection

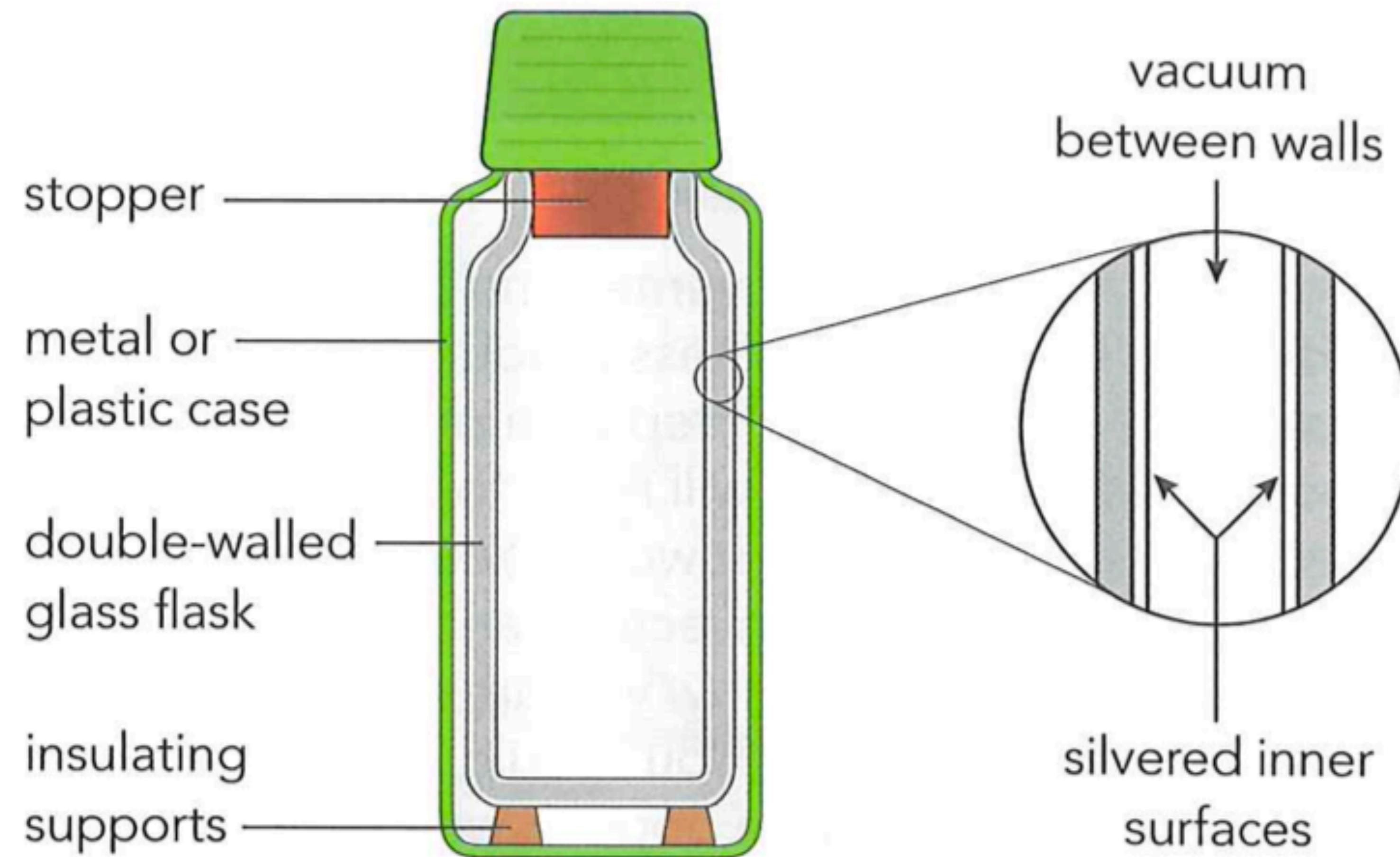
Why?

Cavity wall



Keeping cool

Vacuum flask: keep drinks hot/cool



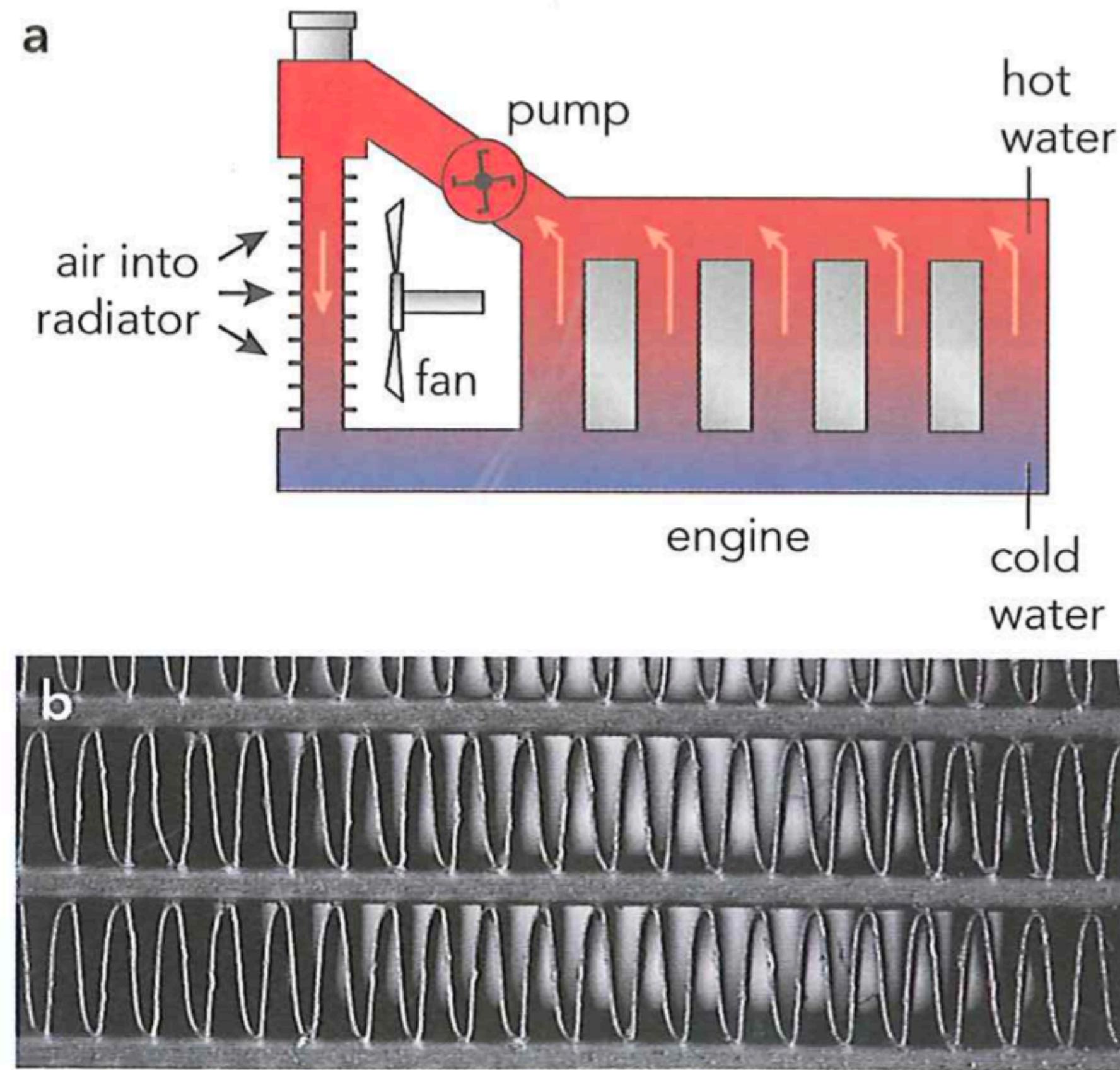
Questions

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

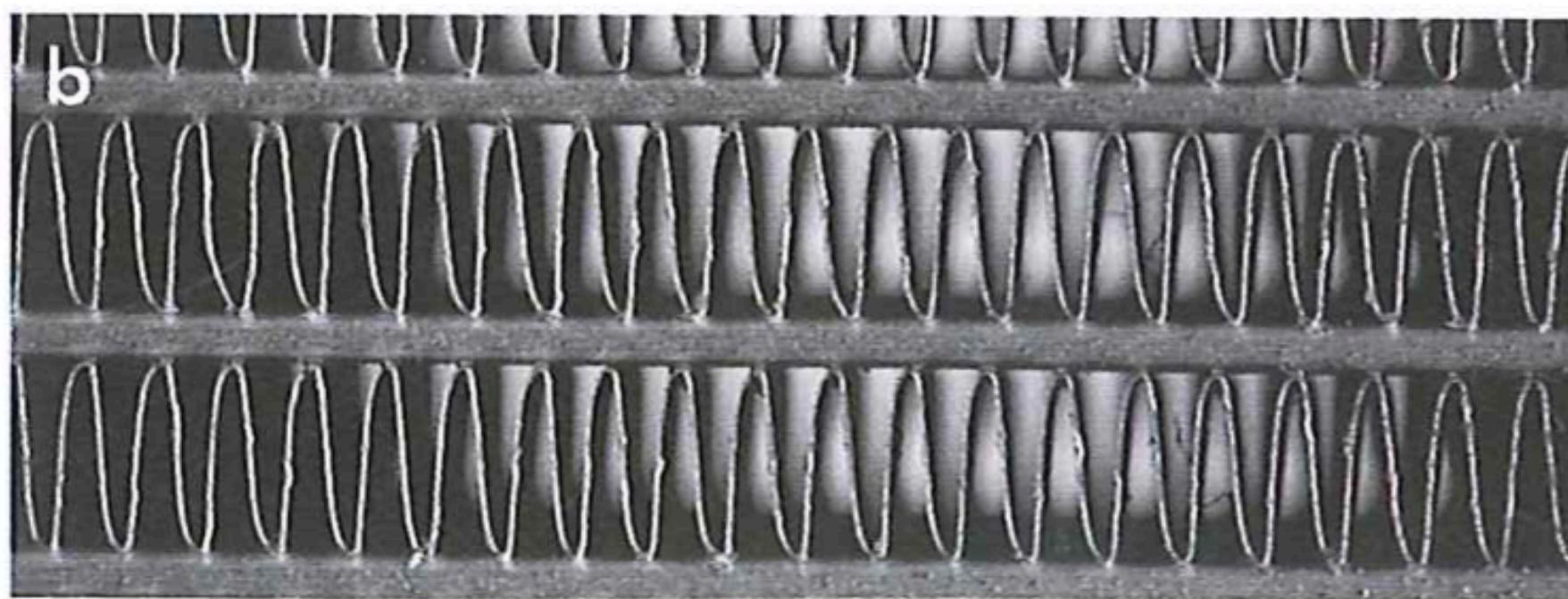
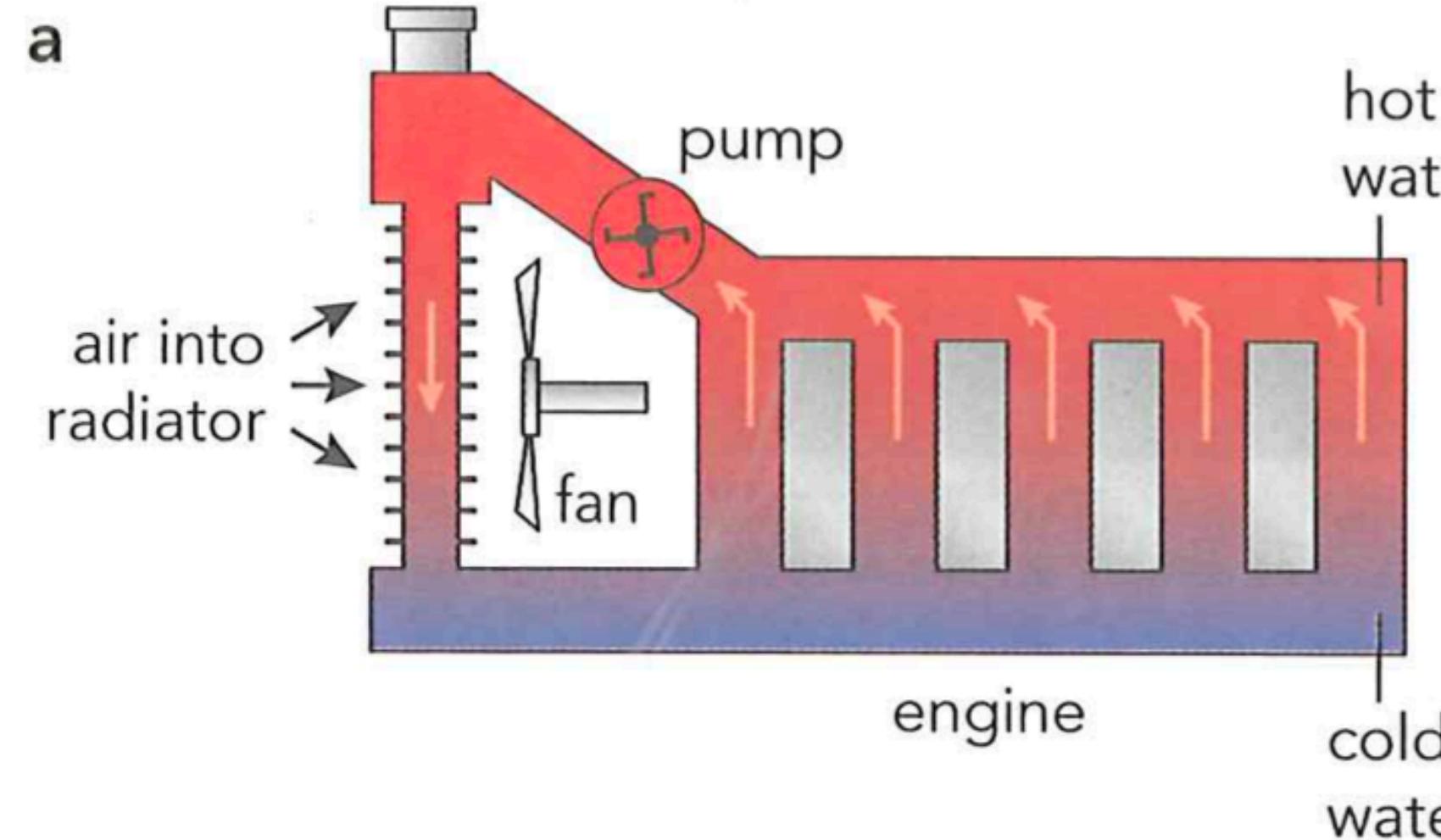
Which types of heat transfer are reduced by the vacuum?

- A** conduction and convection
- B** conduction and radiation
- C** convection and radiation
- D** conduction, convection and radiation

Radiator in a car



Radiator in a car

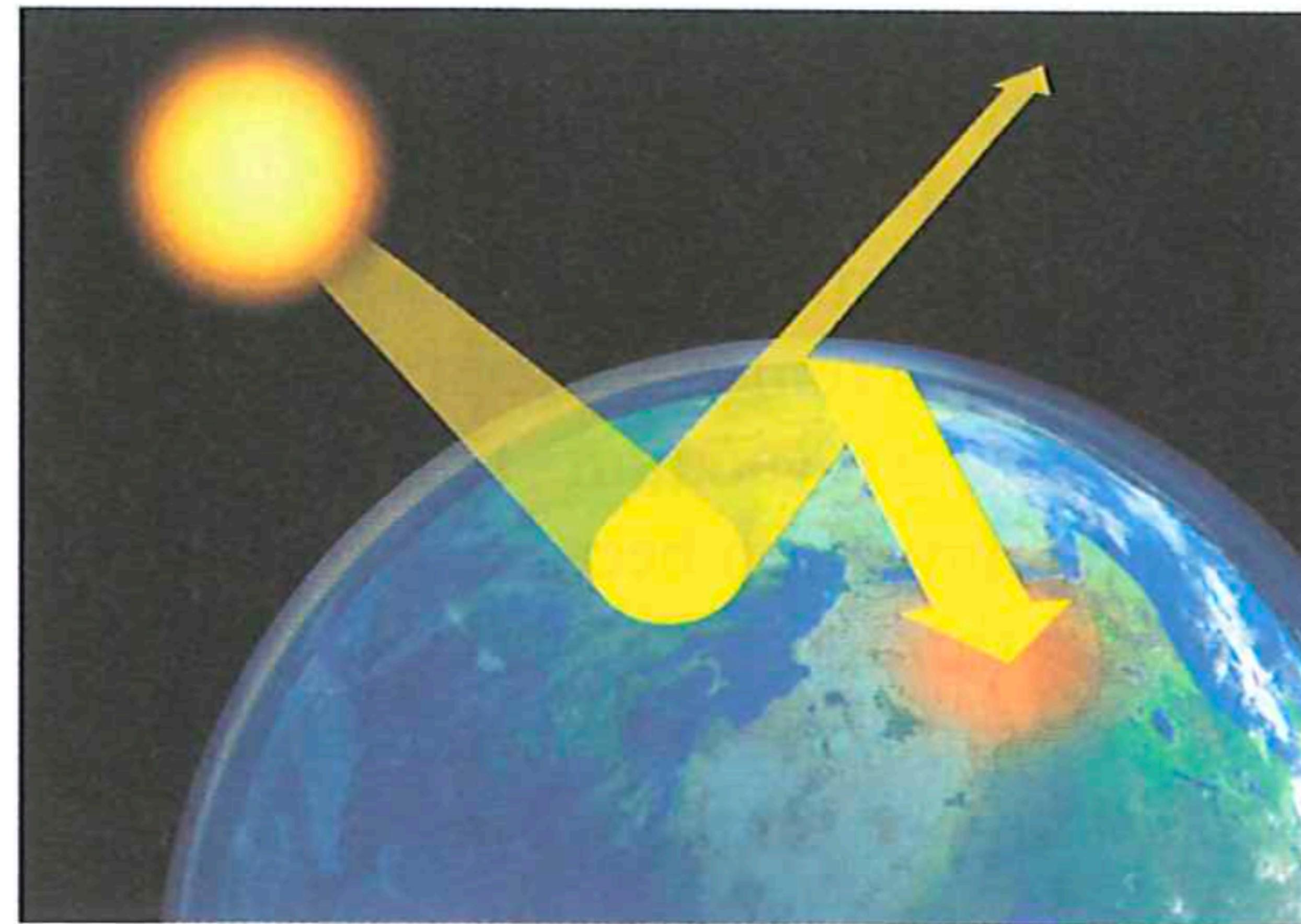


Specific heat capacity
Conduction
Convection
Radiation

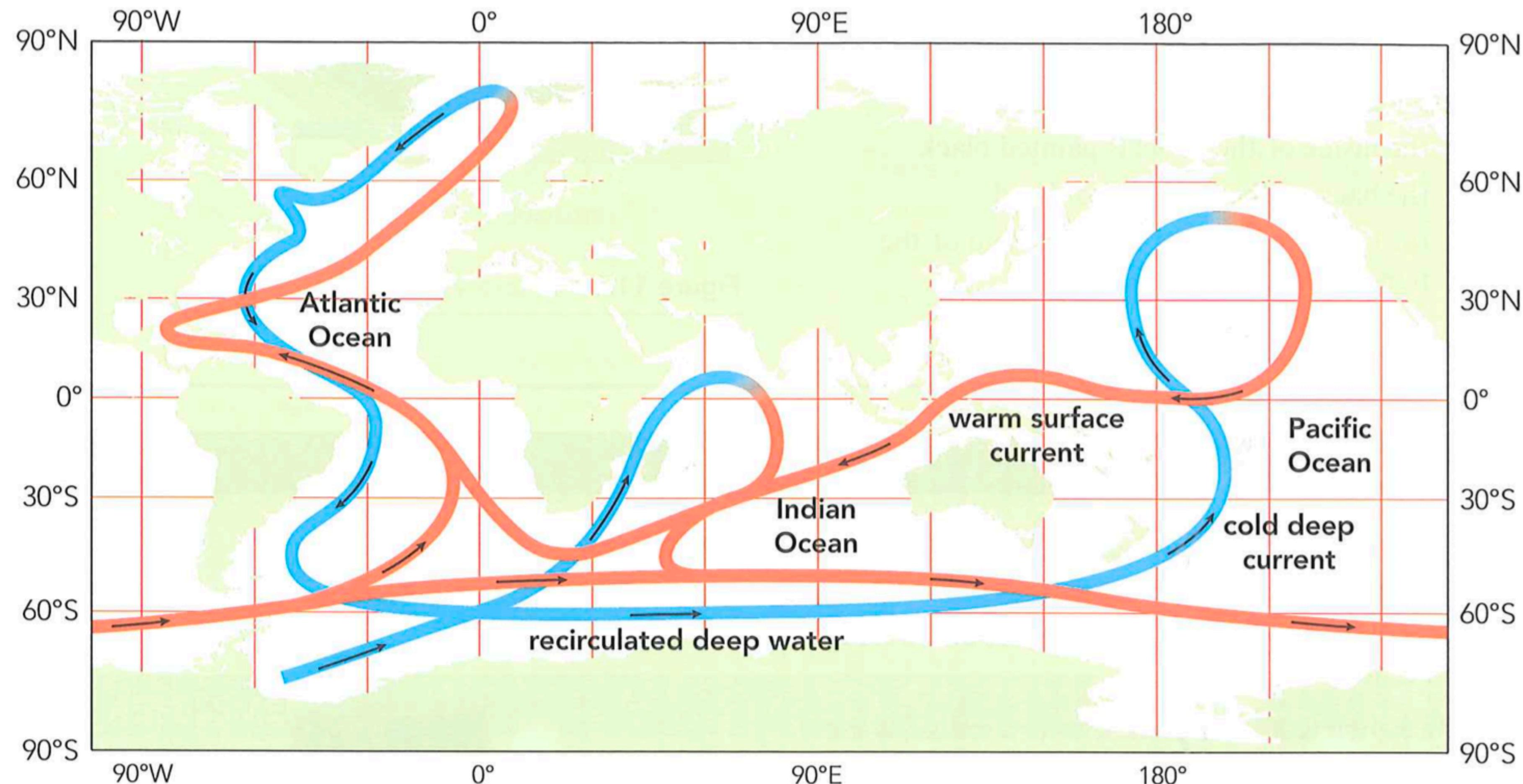
Greenhouse effect

The screenshot shows a video player interface. At the top left is the NASA Space Place logo with the text "What Is the Greenhouse Effect?". To the right are a copy icon and a "Copy link" button. Below the title, a subtitle reads "Climate change • Climate change refers to long-term shifts in temperatures and...". The main video frame features a blue-toned landscape with white clouds, green trees, and brown reeds at the bottom. The text "What is the Greenhouse Effect?" is displayed in large, light gray letters across the center of the frame. At the bottom left is a "Pause (k)" button. The bottom navigation bar includes standard video controls: a play/pause button, volume, progress bar, and timestamp "0:01 / 2:29". On the far right of the bar are icons for closed captions (CC), HD, YouTube, and other sharing options.

Greenhouse effect



Global convection: winds & oceans



Exercise

In a rolling mill, iron is heated to make it malleable and it is then passed through rollers to produce thin sheets of the metal. Explain how the following become hot in this process.

1. The roller which press the metal
2. The face of a worker
3. The air in the building

Exercise

Describe the feature of the coat which prevent thermal energy loss by:

- A. Conduction
- B. Convection
- C. Radiation



Exercise

Pictures on the left shows a solar water heater. Cold water flows through the pipes and is heated by the sun. Suggest reasons why:

1. The inside of the panel is painted black
2. The back of the panel is insulated
3. The cold water enters at the bottom of the panel, and leaves at the top

