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HEAT TRANSFER

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Specification

Energy resources and energy transfer

Energy transfer

describe how energy transfer may take place by conduction, convection and radiation

explain the role of convection in everyday phenomena

explain how insulation is used to reduce energy transfers from buildings and the human body.

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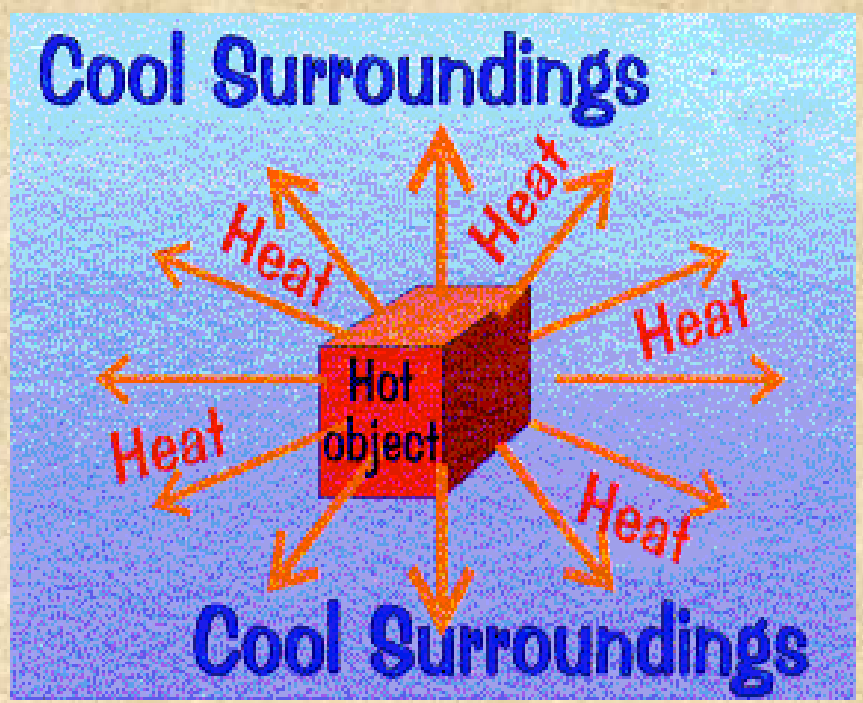
Thermal energy

Thermal or heat energy is the energy that flows from a hot region to a cold region by one or more of the processes of:

CONDUCTION
CONVECTION
and RADIATION



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Thermal Conduction

Thermal conduction is how thermal energy flows through a substance without the substance itself moving.

Solids and metals are the best conductors, gases are the worst.

A vacuum does not allow conduction.

A poor conductor is called an insulator.

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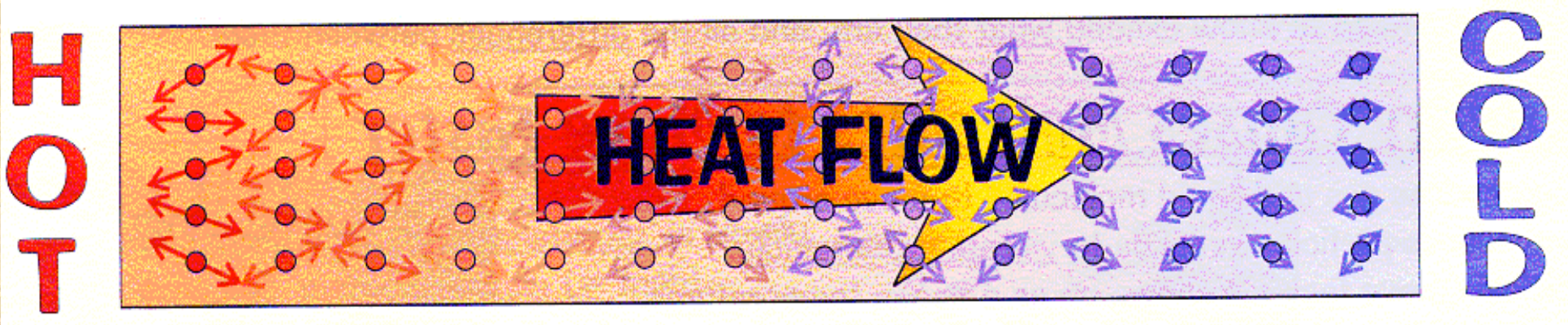
Thermal Conduction by molecules



Molecules vibrate more when they are heated.

Intermolecular forces allow the molecules to pass their vibrations from one to another.

The stronger the forces the faster the vibrations are passed.

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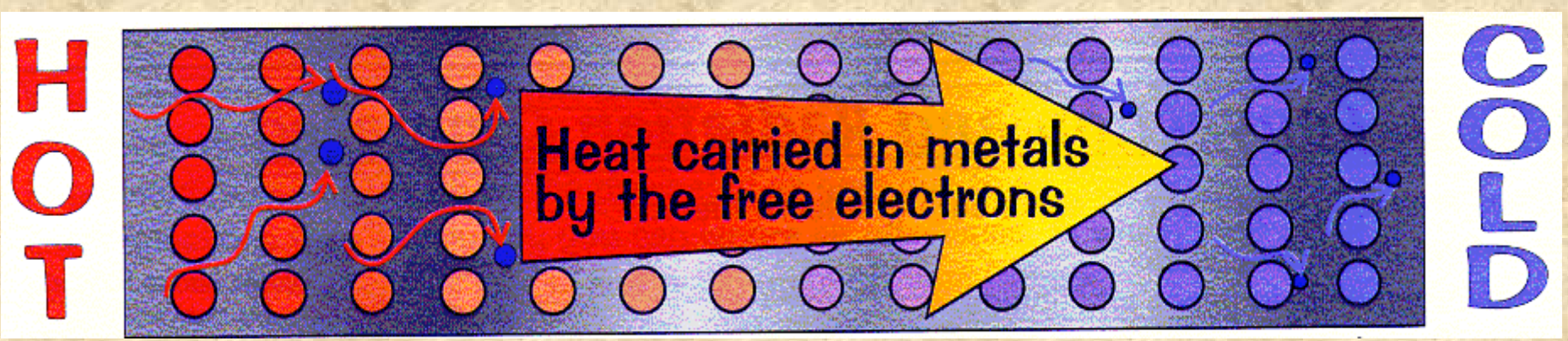
Conduction through metals

Metals have an additional method of conduction. They have electrons that can move from one atom to another. These electrons can pass energy through the metal very quickly.



Most of the best conductors are metals. However, diamond, a non-metal, is an excellent conductor because it has very strong intermolecular bonds.

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Keeping warm with clothing

Air is a good insulator.

Clothes keep us warm by trapping air around our bodies.

The more air layers are trapped the greater is the insulating effect of the clothing.

Animals keep warm in a similar way by using fur or feathers to trap insulating layers of air around their bodies.

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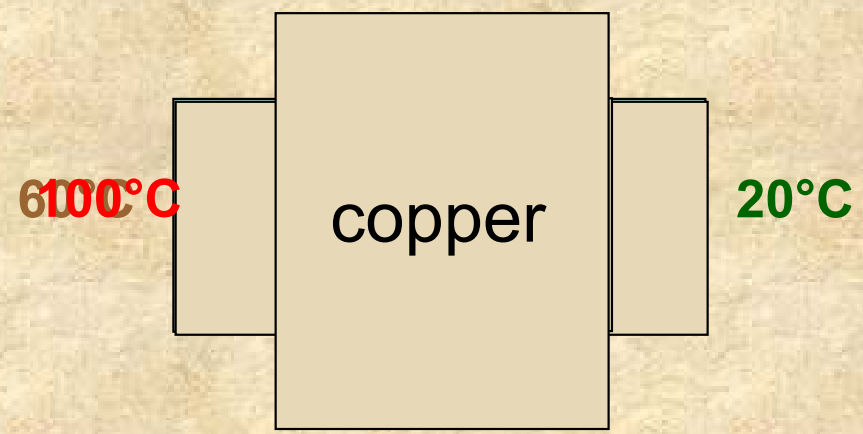
Rate of thermal transfer

Heat transfer by conduction can **increased** by:

1. using a better conducting substance
2. **decreasing** the thickness of the substance
3. **increasing** the area of the substance
4. **increasing** the temperature difference across the substance



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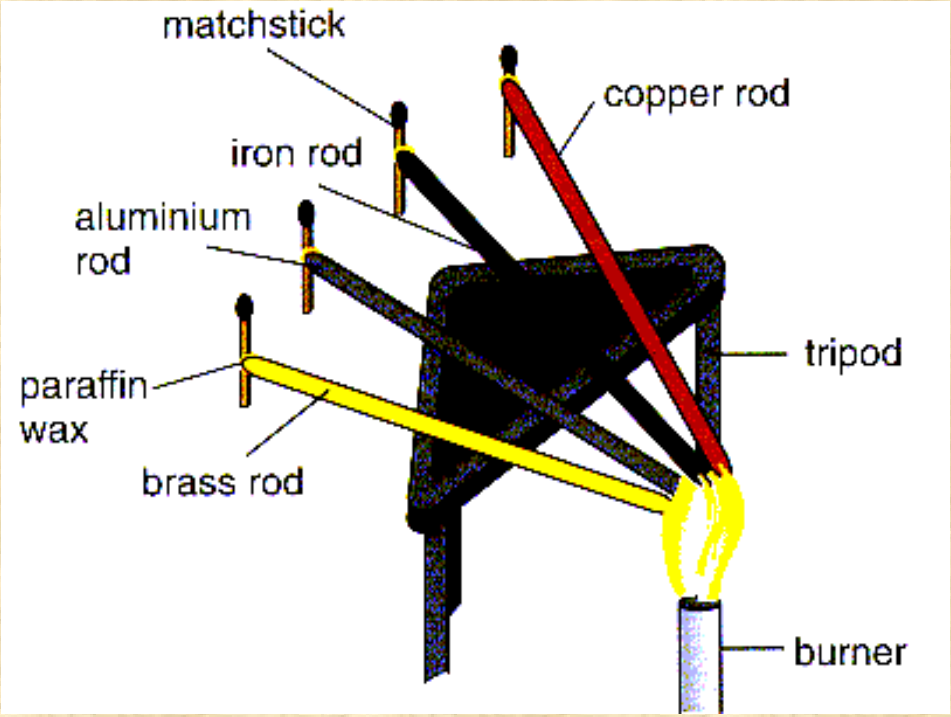
Finding the best conductor



- All the rods have the same length and cross-sectional area.
- They are all heated equally at one end with the bunsen burner.
- When the other end of a rod reaches a certain temperature the paraffin wax melts and the match stick falls off.
- A match stick will fall off the best conductor first.
- This should be the rod made of copper.

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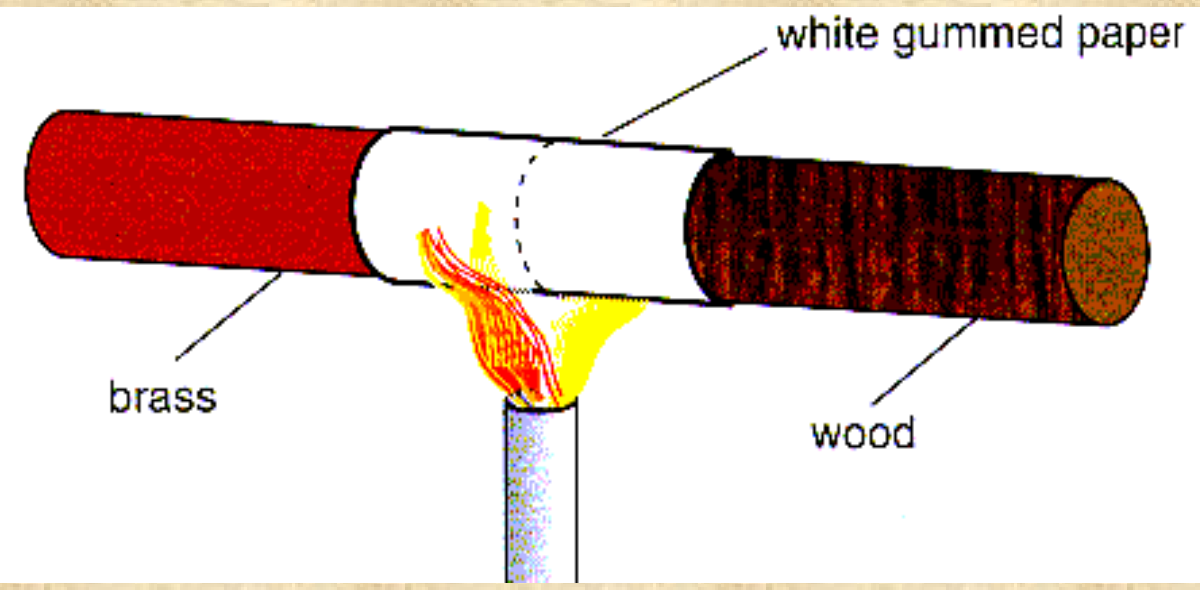
Comparing brass & wood



- The gummed paper singes and burns first on the wooden side of the rod.
- This is because the brass removes the heat away from the paper more quickly than the wood.
- Brass is therefore the better conductor.

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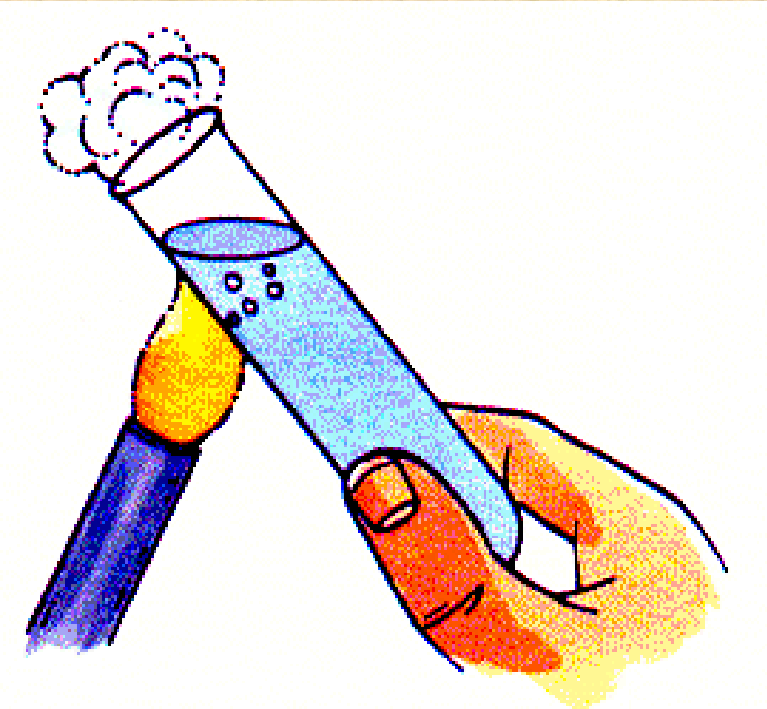
Water - a poor conductor



- A boiling tube of water is heated near the top of the water.
- Water boils at the top.
- The bottom of the tube remains cool enough to hold.
- This shows that water (and glass) only conduct heat relatively slowly.

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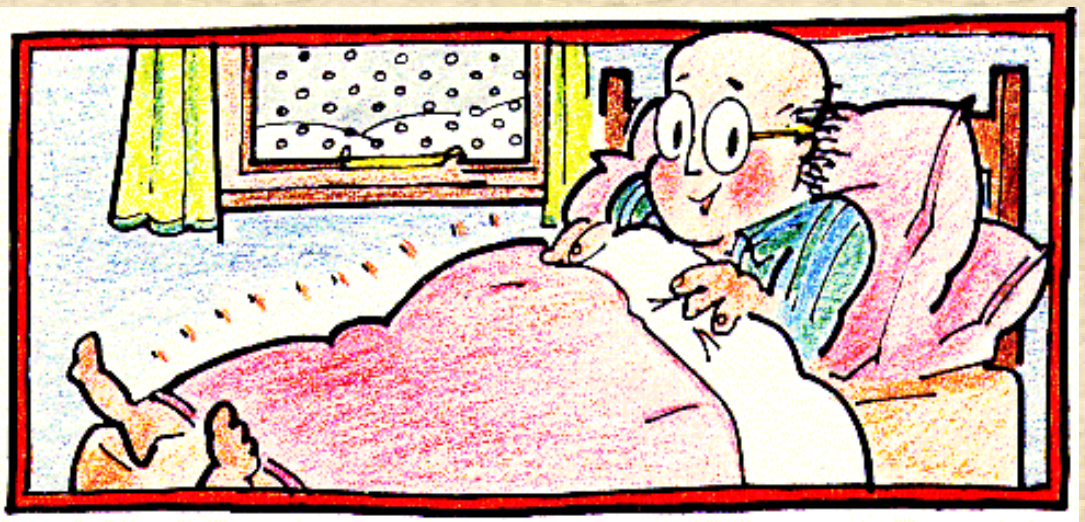
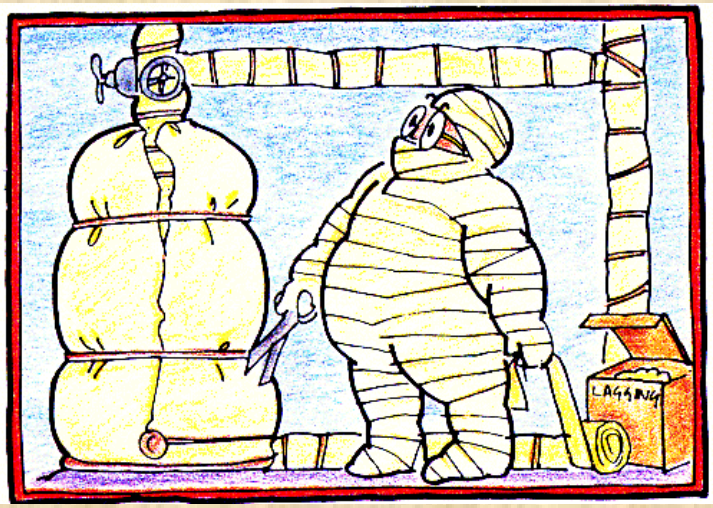
Air - a good insulator





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Question 1

Choose appropriate words to fill the gaps below:

Conduction is the main form of _____ transfer in solids. This is because the molecules are relatively _____ together.

Extra heat energy makes the molecules _____ more. They pass on their extra vibrational energy to neighbouring _____.

Metals are _____ conductors of heat energy because they contain many free _____ which can move through the solid and _____ energy.

The electrons give up their energy when they _____ with other molecules.

WORD SELECTION:

close heat good collide molecules transfer move electrons

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Question 1

Choose appropriate words to fill the gaps below:

Conduction is the main form of __heat__ transfer in solids. This is because the molecules are relatively __close__ together.

Extra heat energy makes the molecules __move__ more. They pass on their extra vibrational energy to neighbouring __molecules__.

Metals are __good__ conductors of heat energy because they contain many free __electrons__ which can move through the solid and __transfer__ energy.

The electrons give up their energy when they __collide__ with other molecules.

WORD SELECTION:

close heat good collide molecules transfer move electrons

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Question 2

Complete the table below:

substance	conductor or insulator	use
copper	conductor	cooking pan bases
feathers	insulator	keeping birds warm
water	conductor	cooling hot substances
fibre glass	insulator	roof insulation
steel	conductor	radiators
air	insulator	clothing

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Question 3

Explain why

a) newspaper wrapping keeps hot things hot, e.g. fish and chips, and cold things cold, e.g. ice cream,

b) fur coats would keep their owners warmer if they were worn inside out,

c) a string vest keeps a person warm even though it is a collection of holes bounded by string,

d) a concrete floor feels colder than a carpeted one even though they are at the same temperature.

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Convection

Convection is the transfer of heat through fluids (liquids and gases) by the upward movement of warmer, less dense regions of fluid.

Convection does not occur in solids.

A vacuum does not allow convection.

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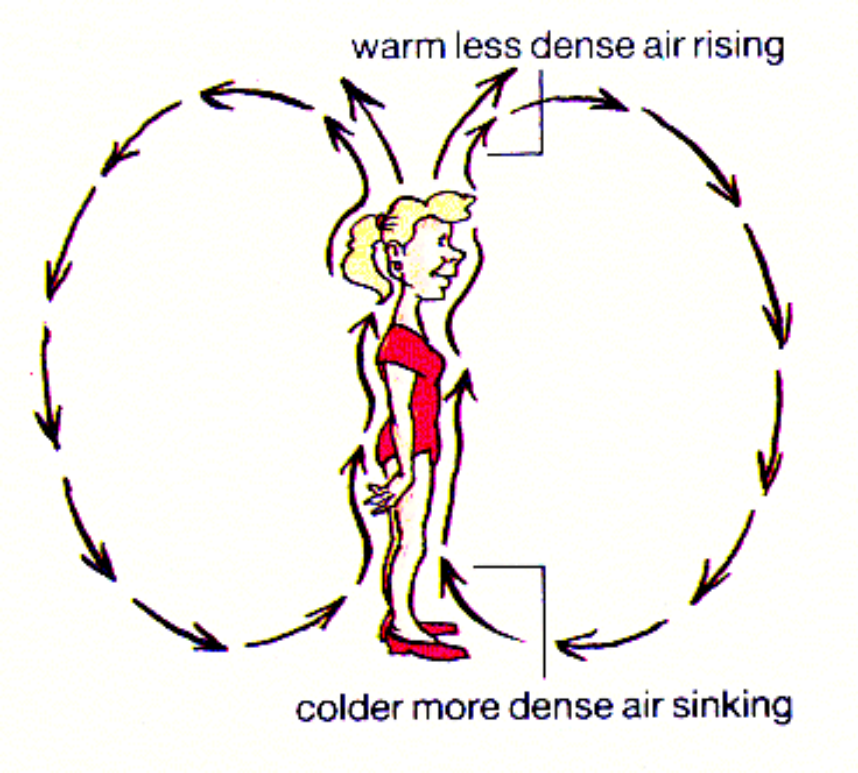
Convection currents

- When molecules are heated they move more quickly and occupy more space.
- Hotter fluids are therefore less dense than colder fluids.
- Hotter fluids rise up to float on top of colder fluids.
- A **convection current** is the path taken by rising hot fluids and sinking cold fluids.



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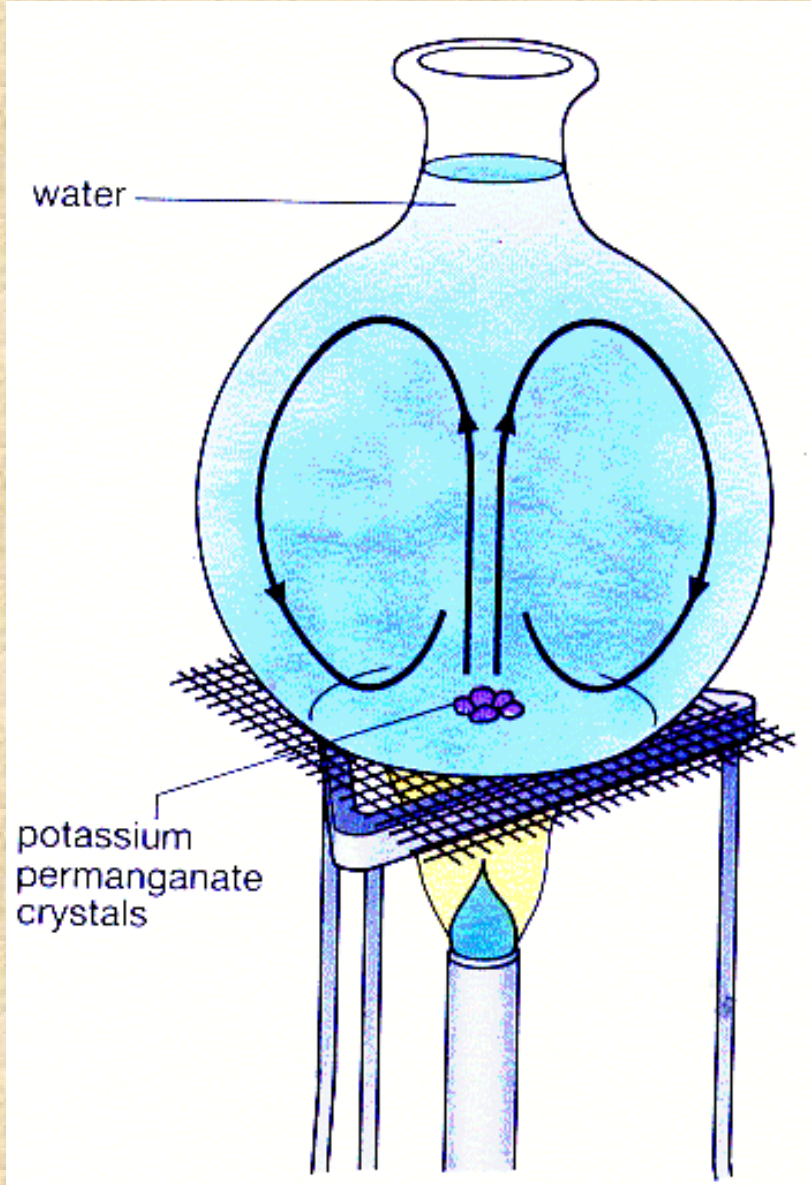
Convection in water



- Potassium permanganate crystals are used to dye water purple.
- When the bottom of the flask of water is heated warm less dense water rises.
- The potassium permanganate dye rises with the warmed water.
- When the water cools it becomes denser and sinks down to the bottom of the flask.

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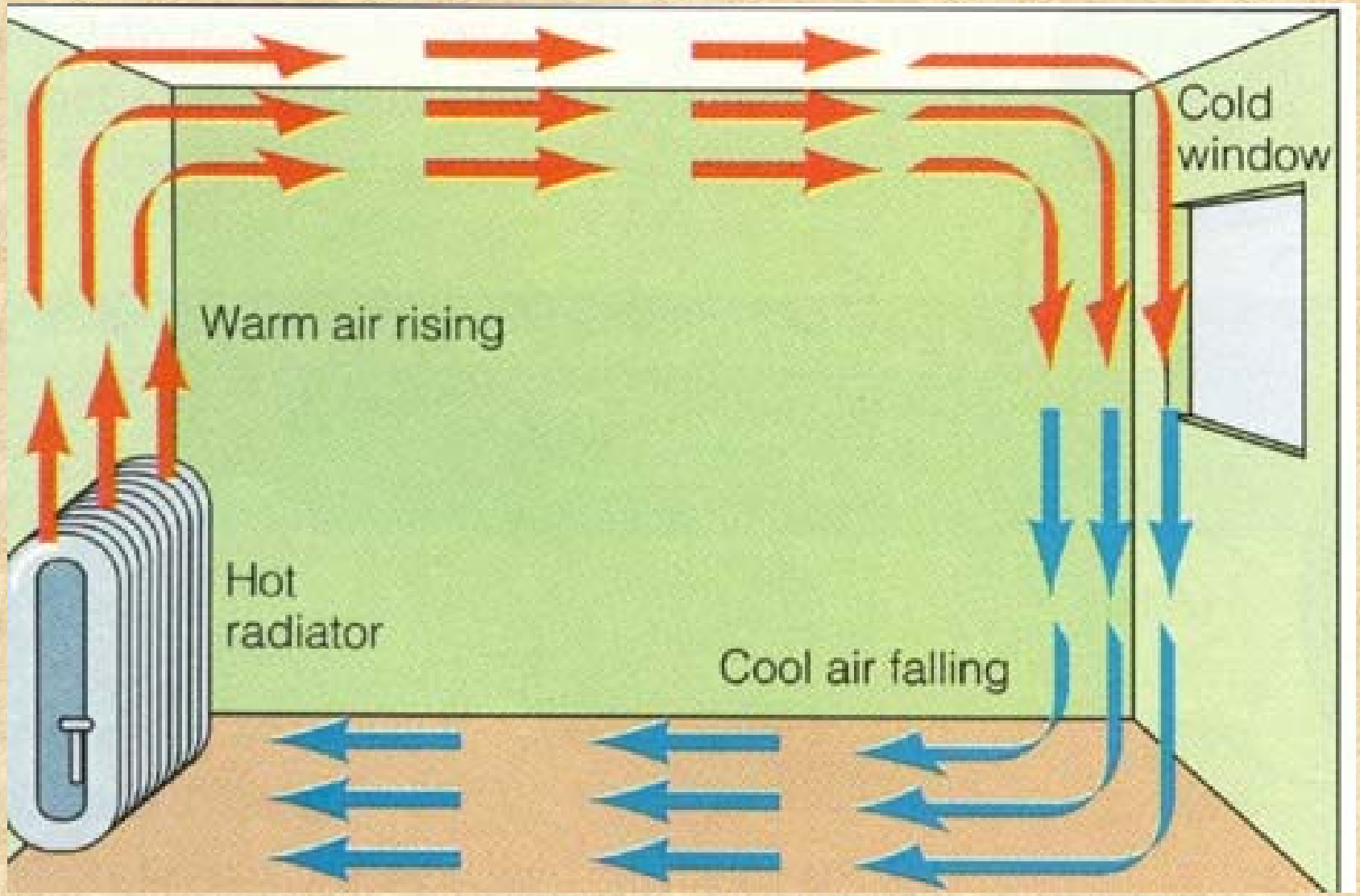
Heating a room by convection



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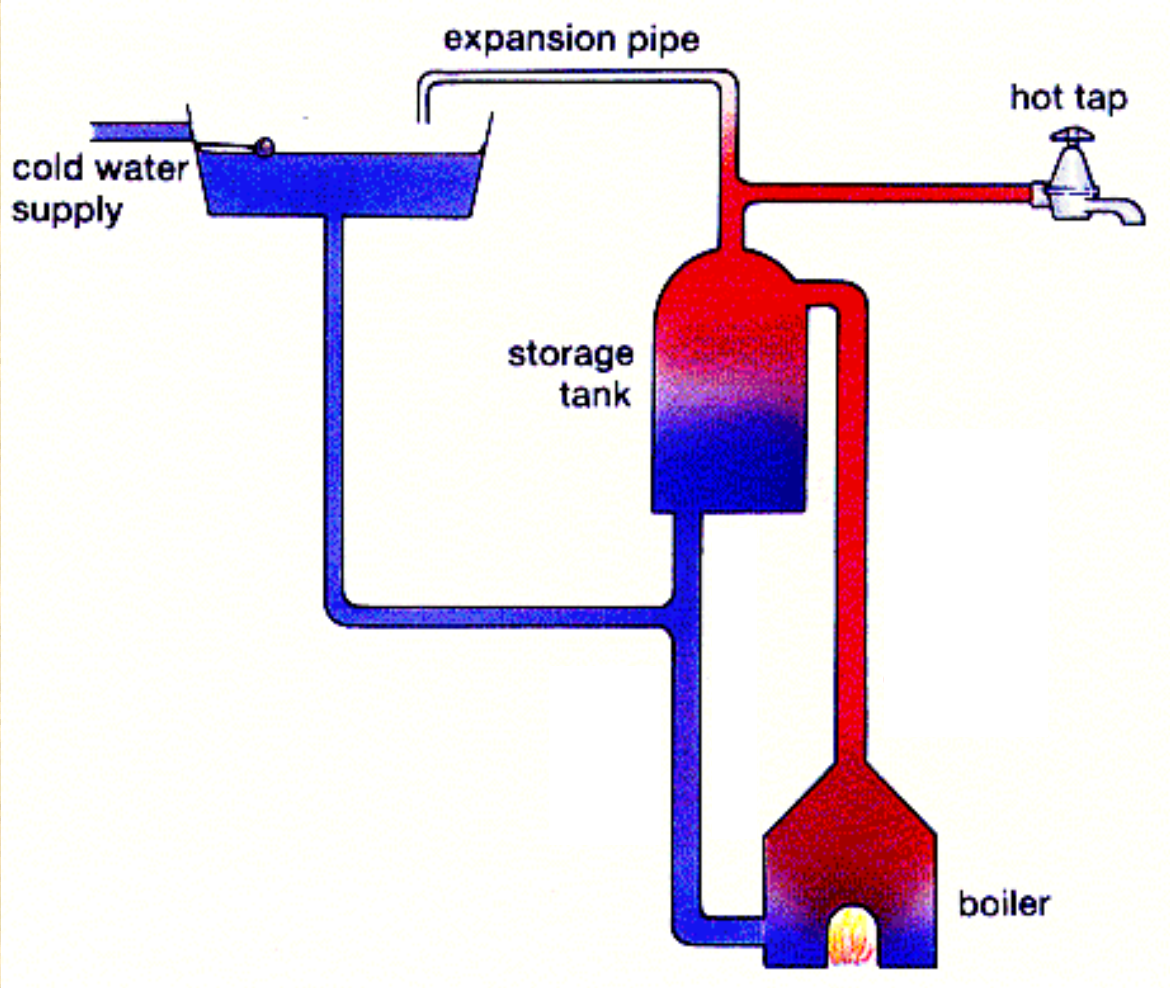
Simple house water heating system



- The boiler heats the water.
- Hot water rises to the top of the boiler and up to the top of the storage tank.
- Colder water in the tank falls to the bottom of the boiler to be heater.
- A hot water tap draws water from the top of the storage tank.
- The cold water supply replenishes the hot water drawn off.

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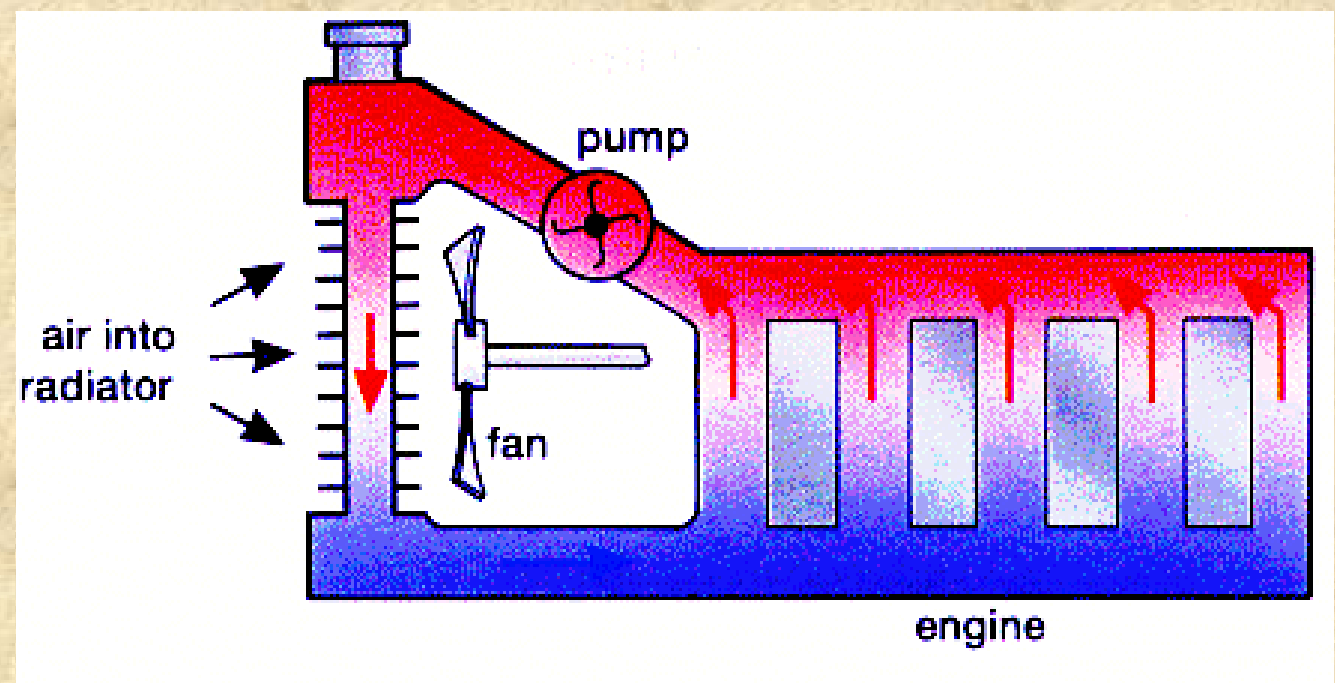
Engine water cooling system



- Water heated by the engine rises to the top of the engine.
- This water is pumped into the top of the radiator.
- The fan cools the water in the radiator.
- Cooled water falls from the radiator into the engine.

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Thermals

- Heated air provides lift for a hot air balloon.
- Heated land causes rising air currents called ***thermals*.**
- Thermals can be used by gliders to provide lift.
- Many birds also use thermals for lift.

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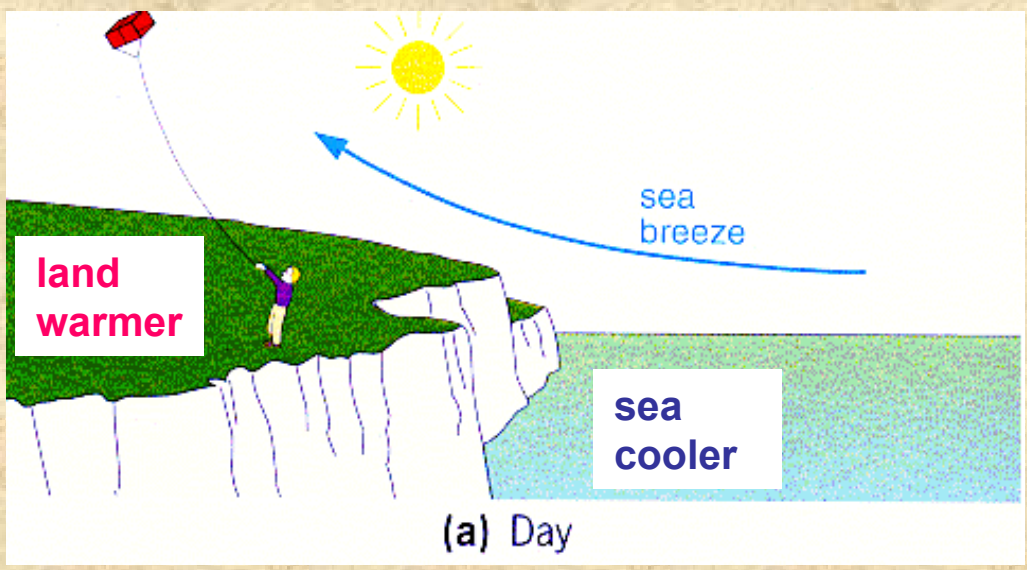
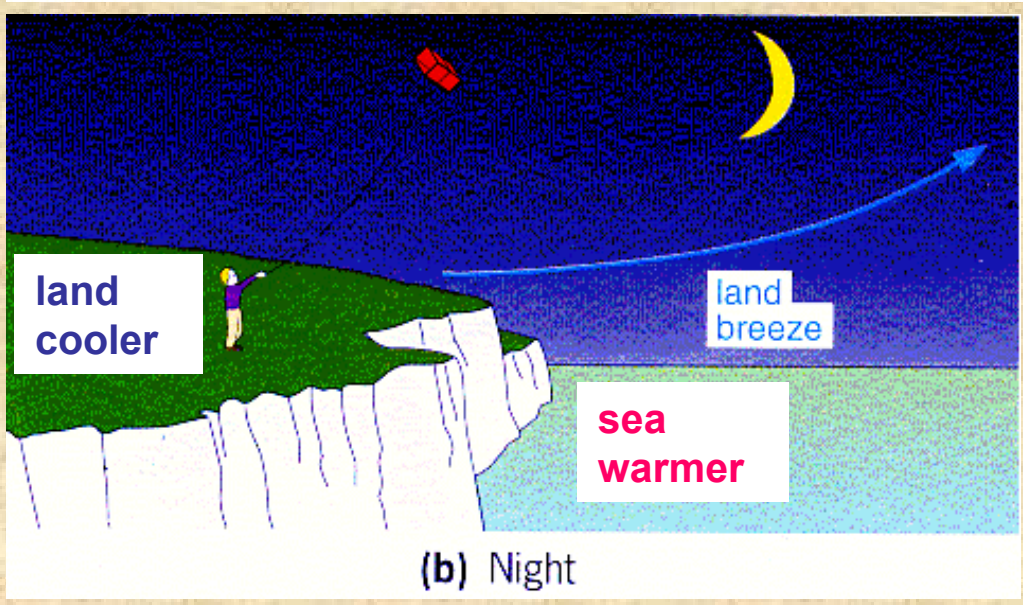
Sea and land breezes



(a) Day



(b) Night

- During a hot day heated air rises up from land that is warmer than the sea.
- A ***sea breeze*** consists of cooler air that moves in from the sea to replace the heated air.

- At night the sea is often warmer than the land.
- Air now flows to the sea. This is called a ***land breeze***.

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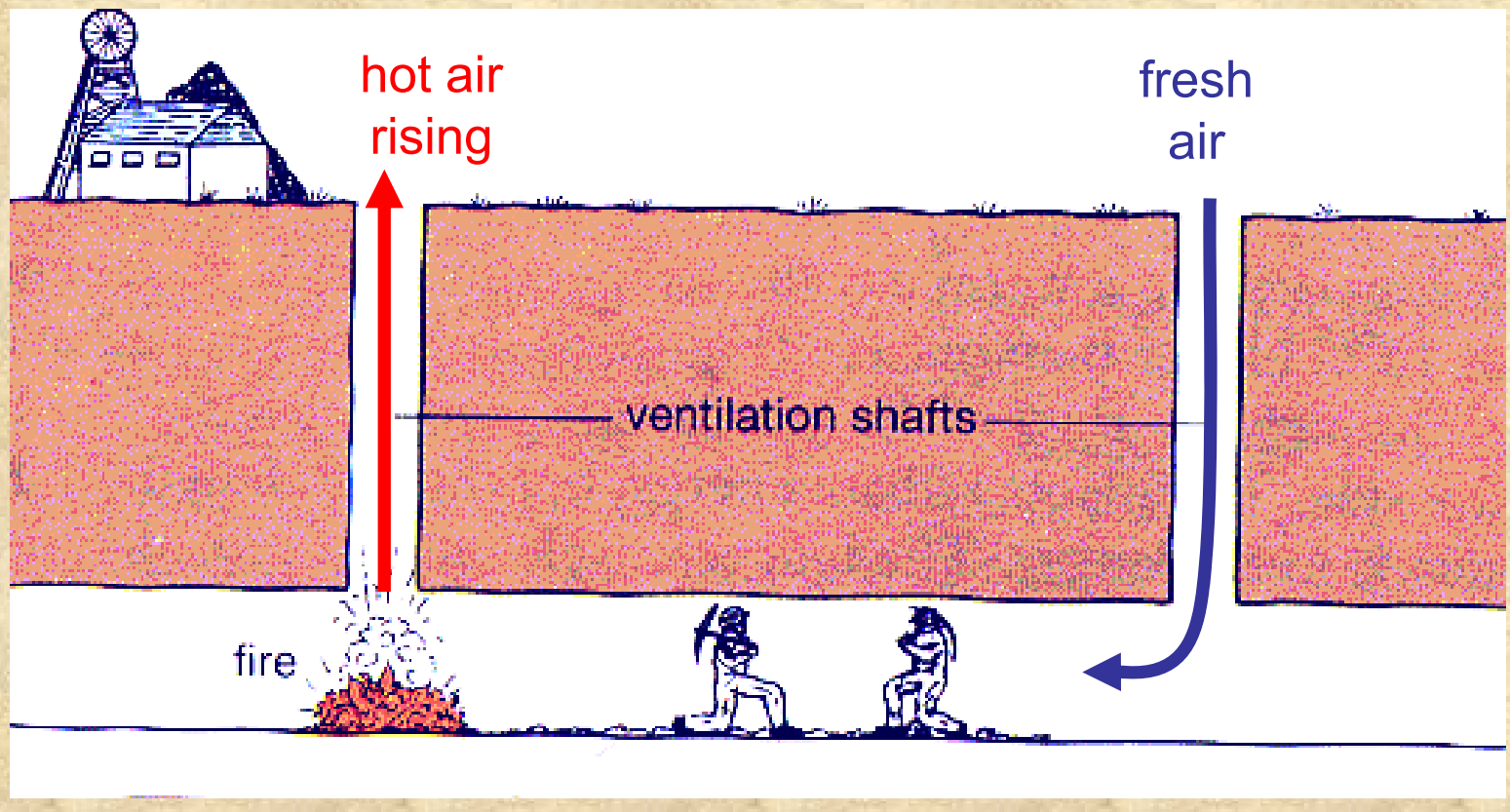
Simple mine ventilation



The fire causes hot air to rise up the shaft above it.
Cooler, fresher air is drawn down the other shaft.

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Question 1

Choose appropriate words to fill in the gaps below:

Convection is a method of heat transfer that only occurs in _____ (liquids and _____).

When part of a fluid is heated the _____ in that region move more _____ and take up more space. The heated fluid expands and becomes less _____ than the surrounding cooler fluid. The heated fluid _____ on top of the cooler fluid.

The upward path of the heated fluid is called a _____current.

WORD SELECTION:

gases convection dense molecules rises fluids quickly

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Question 1

Choose appropriate words to fill in the gaps below:

Convection is a method of heat transfer that only occurs in __fluids__ (liquids and __gases__).

When part of a fluid is heated the __molecules__ in that region move more __quickly__ and take up more space. The heated fluid expands and becomes less __dense__ than the surrounding cooler fluid. The heated fluid __rises__ on top of the cooler fluid.

The upward path of the heated fluid is called a __convection__ current.

WORD SELECTION:

gases convection dense molecules rises fluids quickly

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Question 2

Explain why

a) a hot drink will cool more slowly if a lid is put on the top of the drink,

b) clouds are often formed at the top of thermals,

c) top loading freezers are more efficient than those with side doors,

d) hot water radiators are best placed\under a window.

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Thermal Radiation

Thermal radiation is the transfer of energy by infra-red (IR) waves.

Radiation is the only type of heat transfer that can travel through a vacuum through which it travels at the speed of light (300 000 km/s or 186 000 miles per second).

Gases tend to allow radiation through better than liquids, liquids better than solids.

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Detecting thermal radiation

- We can feel thermal radiation with our skin.
- Special cameras can be used to take infra-red pictures.

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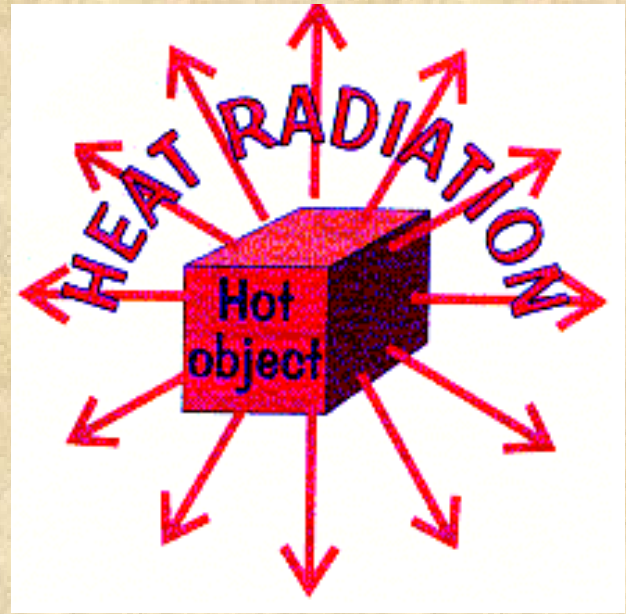
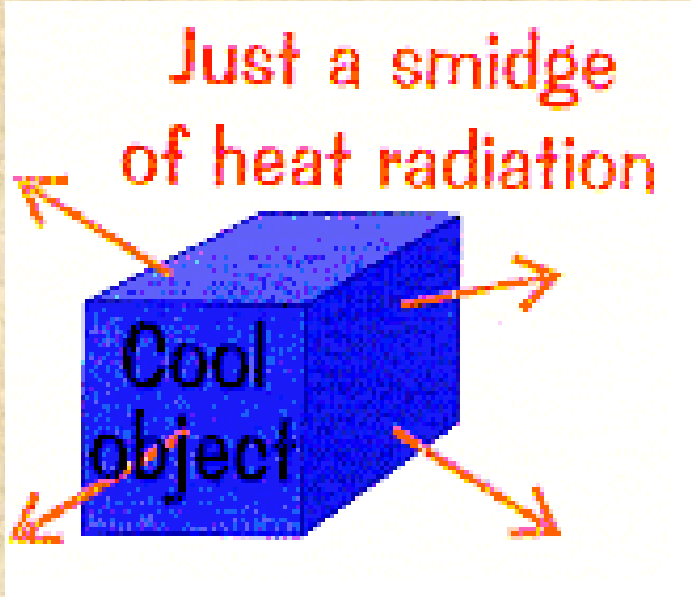
Thermal radiation & temperature

All objects above **absolute zero** (-273 ˚C) give off thermal radiation.

The hotter an object the more radiation it gives off.





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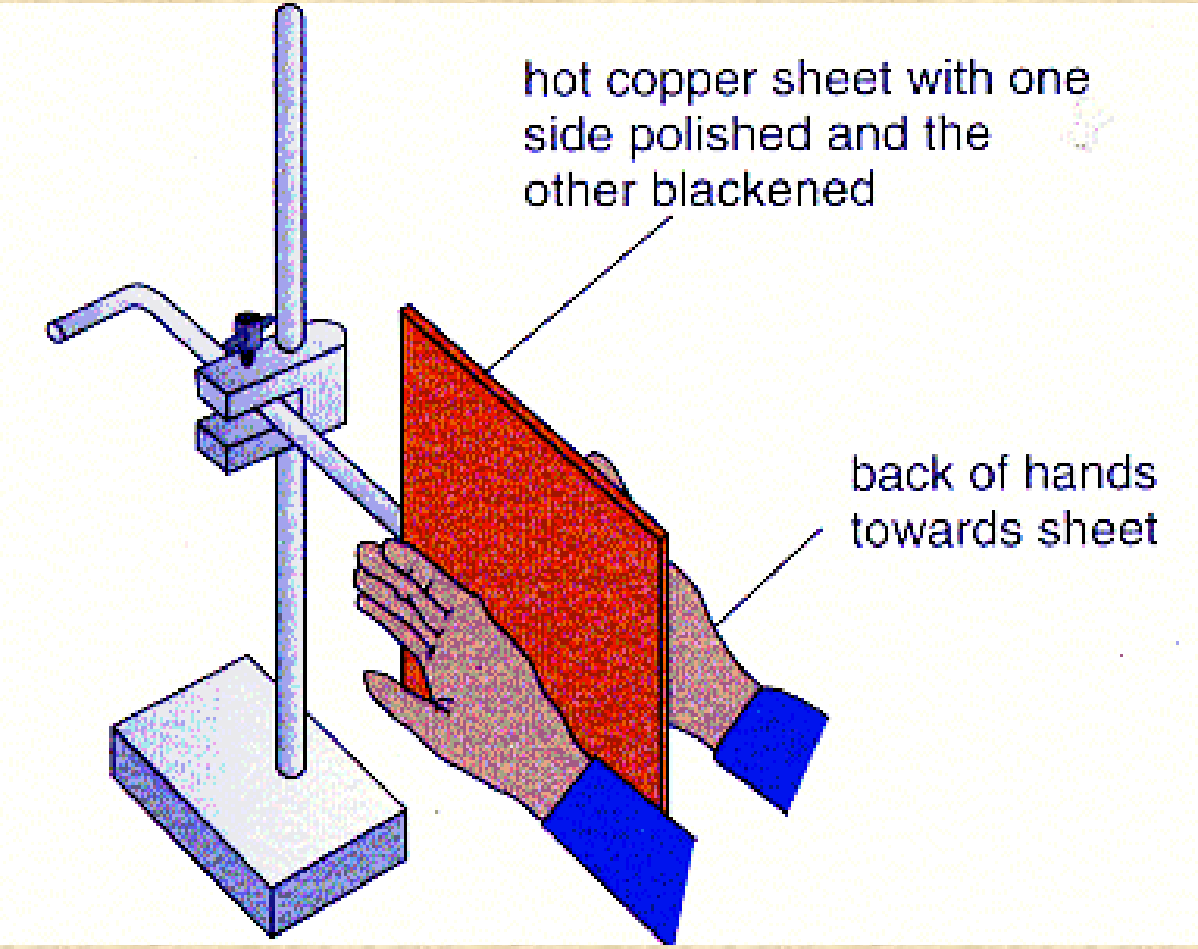
Surface and emission



Dark surfaces emit radiation better than bright surfaces.

Rough surfaces emit radiation better than polished surfaces.

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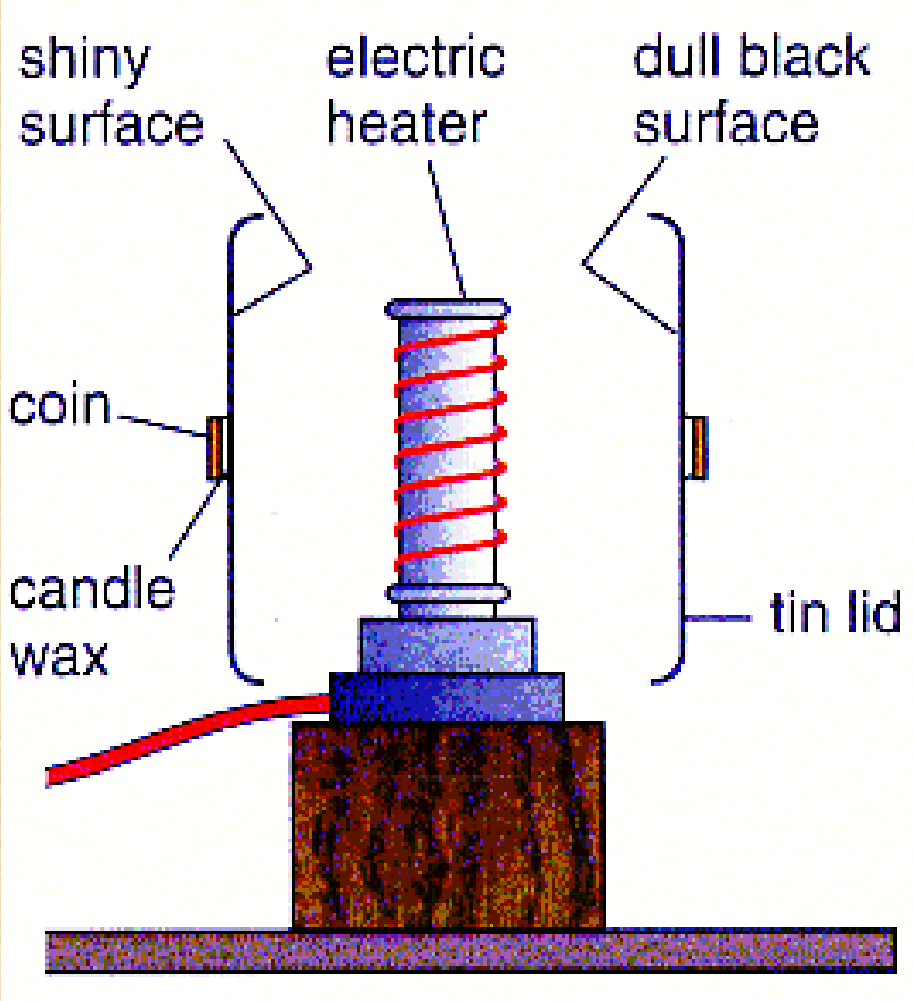
Absorption & Reflection



Dark surfaces absorb radiation best.

Bright surfaces reflect radiation best.

Rough surfaces absorb radiation best.

Polished surfaces reflect radiation best.

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Silvered surfaces

A metal kettle, a firefighter and a marathon runner make use of silvered surfaces.

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Question 1

Choose appropriate words to fill in the gaps below:

Thermal radiation, also known as _____ radiation, is how heat travels by _____ waves.

Radiation travels equally in all _____and most quickly through a _____ where its speed is _____ km/s.

All objects above absolute zero (_____ ^{o}C) give off thermal radiation.

Hot, _____ and rough surfaces emit radiation best.

Bright and _____surfaces reflect radiation best.

WORD SELECTION:

electromagnetic vacuum - 273 heat directions 300 000 dark smooth

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Question 1

Choose appropriate words to fill in the gaps below:

Thermal radiation, also known as __heat__ radiation, is how heat travels by __electromagnetic__ waves.

Radiation travels equally in all __directions__ and most quickly through a __vacuum__ where its speed is __300 000__ km/s.

All objects above absolute zero (__- 273__ ^{o}C) give off thermal radiation.

Hot, __dark__ and rough surfaces emit radiation best.

Bright and __smooth__ surfaces reflect radiation best.

WORD SELECTION:

electromagnetic vacuum - 273 heat directions 300 000 dark smooth

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Question 2

Explain why

a) heat from the Sun can only reach us by thermal radiation,

b) in hot countries houses are often painted white,

c) car radiators are black,

d) solar cells are black.

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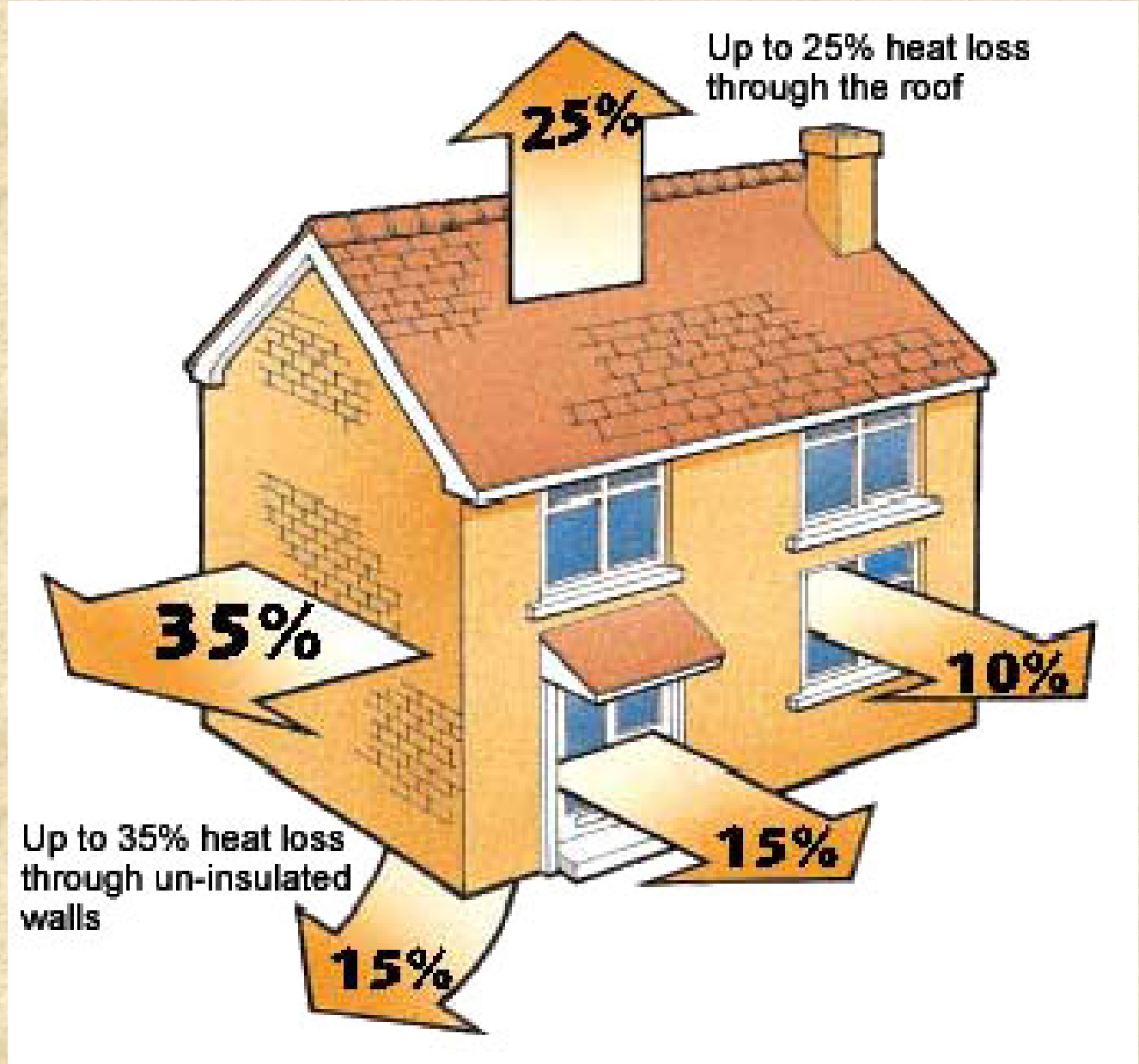
Heat losses from a house



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How heat losses are reduced

location	heat saving device(s)
doors	
windows	
roof	
floors	
walls	

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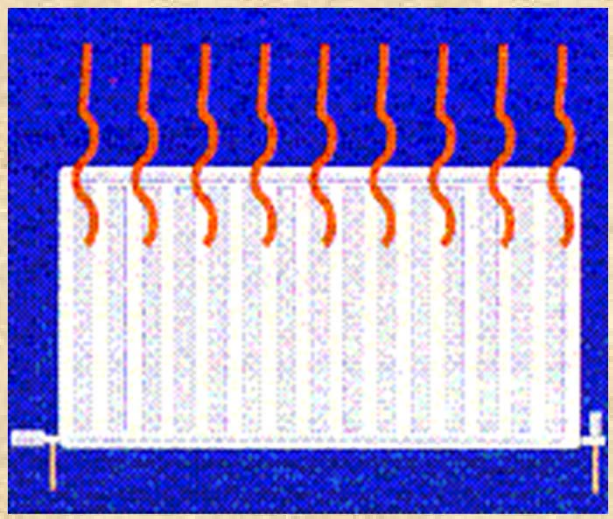
Heating a room using a water radiator



Hot water heats the metal radiator by **conduction**.

The outer metal surface heats air in contact by **conduction** and **radiation**.

Hot air circulates a room by **convection**.

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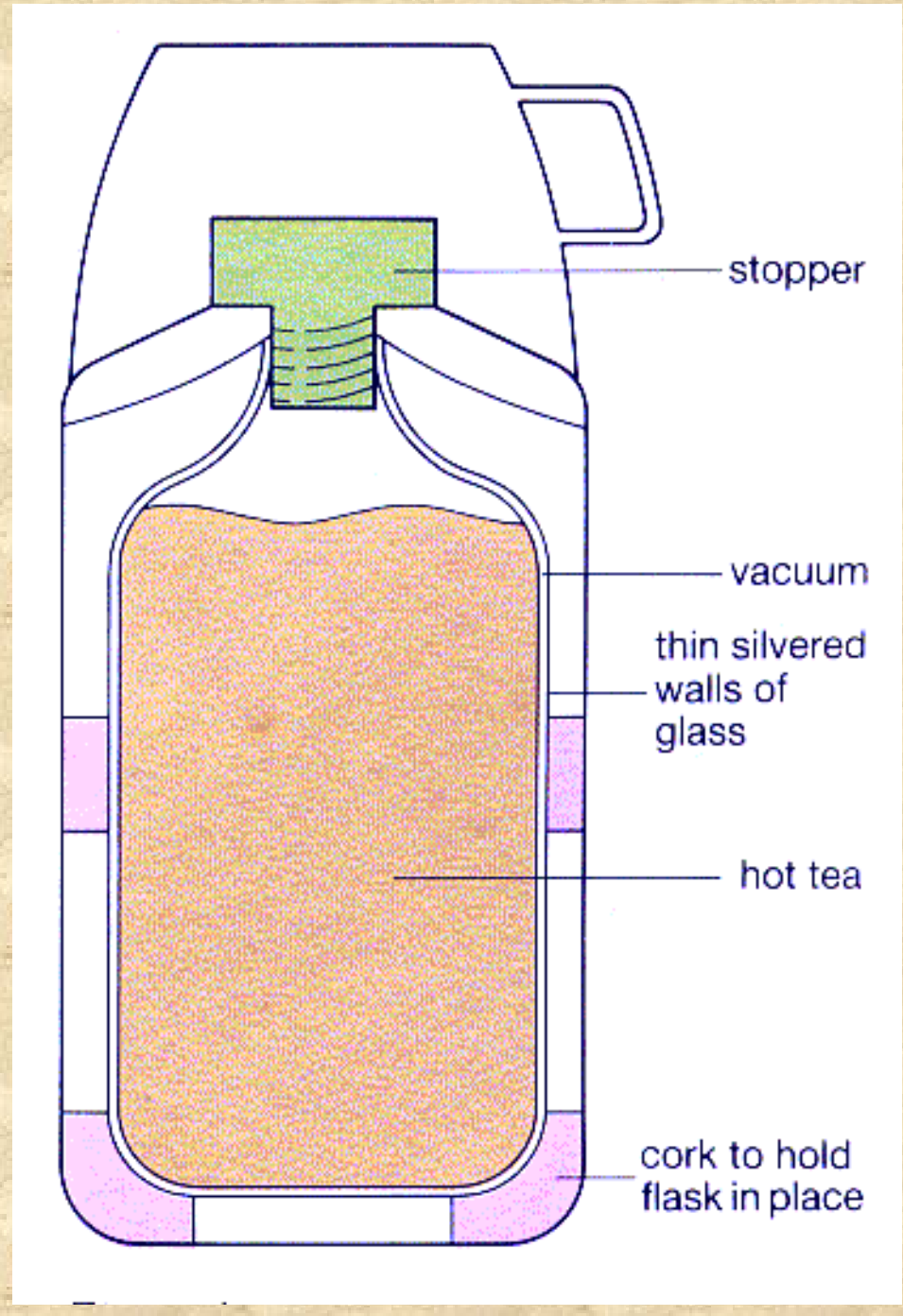

Reducing heat transfer using a vacuum flask

CONDUCTION

– reduced by the vacuum, stopper, glass, cork and air spaces.

CONVECTION

– reduced by the vacuum, stopper and the trapped air spaces.

RADIATION

– reduced by the silvered glass walls.

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Question 1

Choose appropriate words to fill in the gaps in below:

_____ is the form of energy that _____ from a hot place to a cold one because of the _____ difference between these two places.

Heat moves by conduction, _____ and radiation.

_____ energy is an alternative name for heat energy.

WORD SELECTION:

thermal temperature travels heat convection

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Question 1

Choose appropriate words to fill in the gaps in below:

___heat___ is the form of energy that ___travels___ from a hot place to a cold one because of the ___temperature___ difference between these two places.

Heat moves by conduction, ___convection___ and radiation.

___thermal___ energy is an alternative name for heat energy.

WORD SELECTION:

thermal temperature travels heat convection

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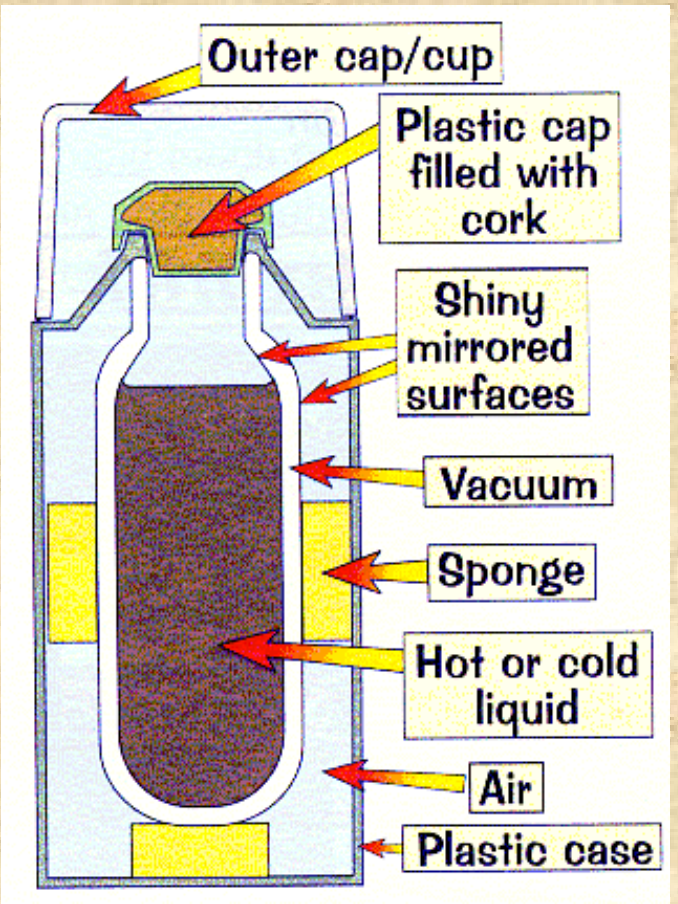
Question 2

Write down the ways in which a vacuum flask reduces heat transfer



part of flask	processes reduced (eg 'conduction')
outer cap / cup	
plastic cap	
shiny mirror surfaces	
vacuum	
sponge	
air	
plastic case	

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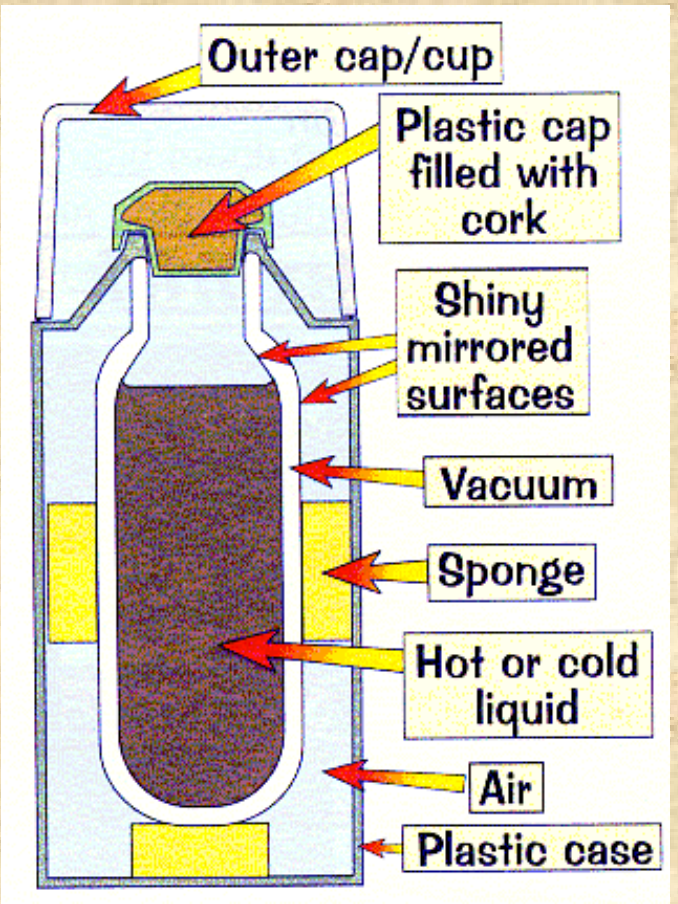
Question 2

Write down the ways in which a vacuum flask reduces heat transfer



part of flask	processes reduced (eg 'conduction')
outer cap / cup	conduction & convection
plastic cap	convection & conduction
shiny mirror surfaces	radiation
vacuum	conduction & convection
sponge	conduction
air	conduction
plastic case	conduction