2018 Year 11 Physics Week 8

Thermal Energy Transfer

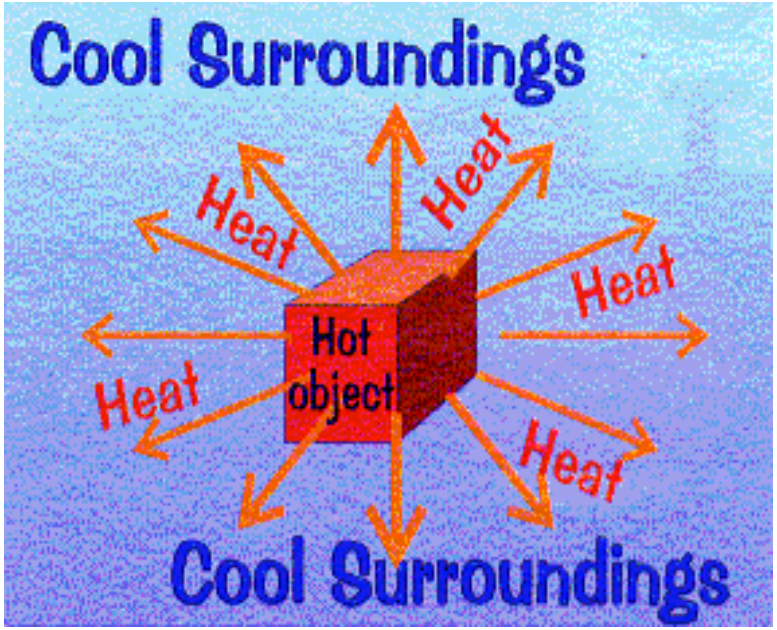
Thermal energy

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

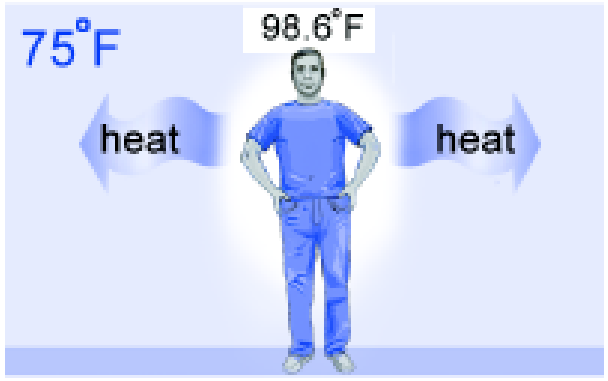
CONVECTION

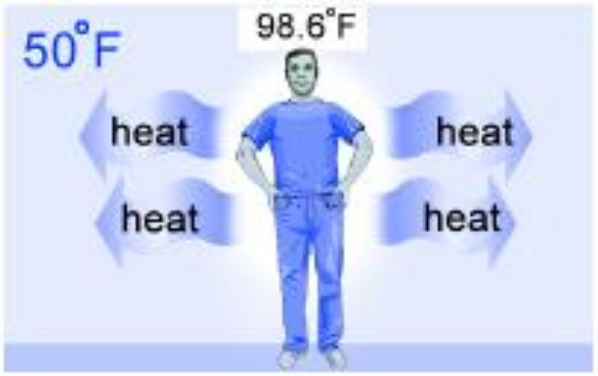
and RADIATION

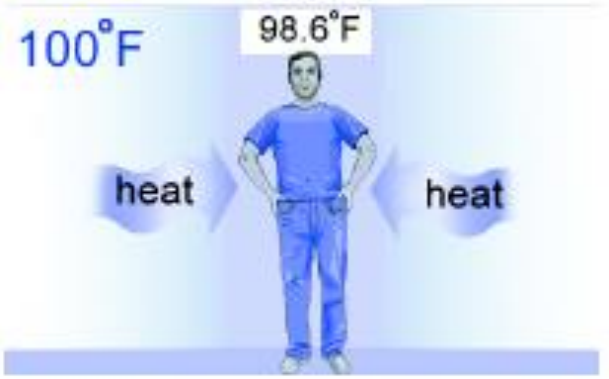


Heat Transfer

- The science of how heat flows is called heat transfer.
- There are three ways heat transfer works: conduction, convection, and radiation.
- Heat flow depends on the temperature difference.

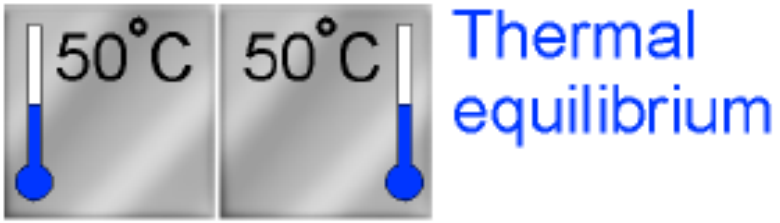


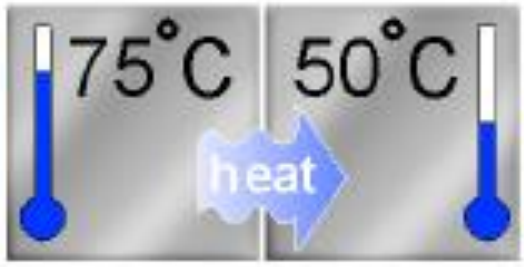




Thermal Equilibrium

- Two bodies are in thermal equilibrium with each other when they have the same temperature.
- In nature, heat always flows from hot to cold until thermal equilibrium is reached.





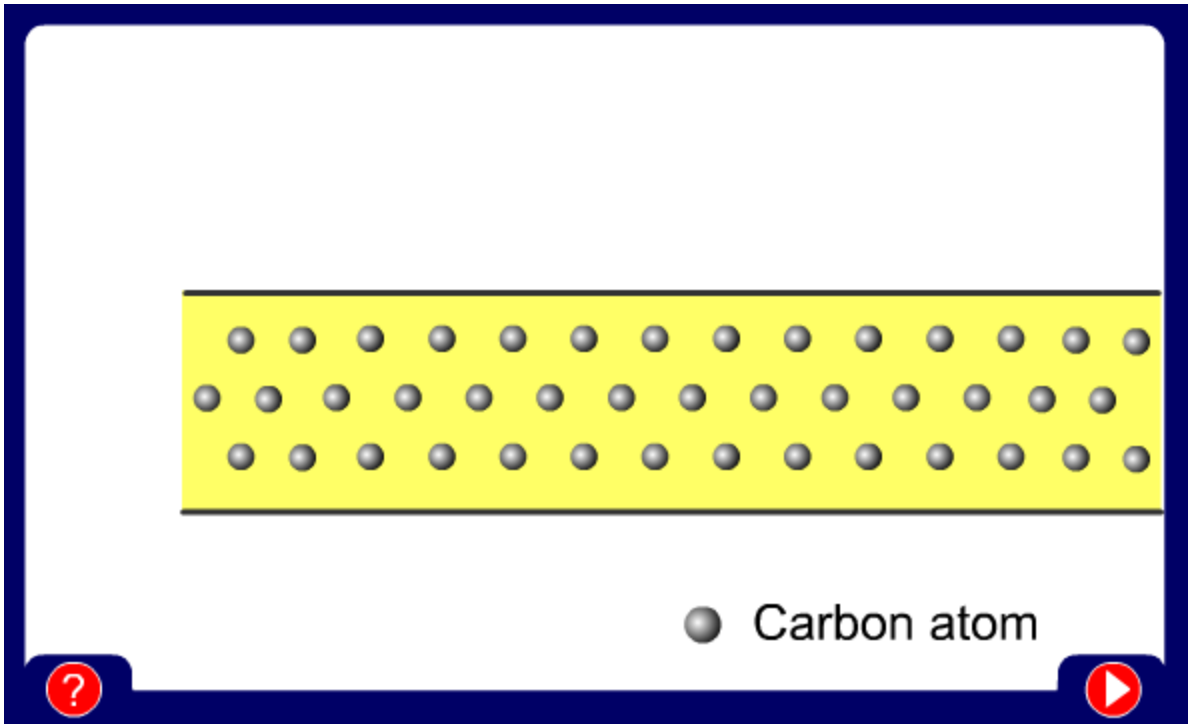
Thermal Conduction

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

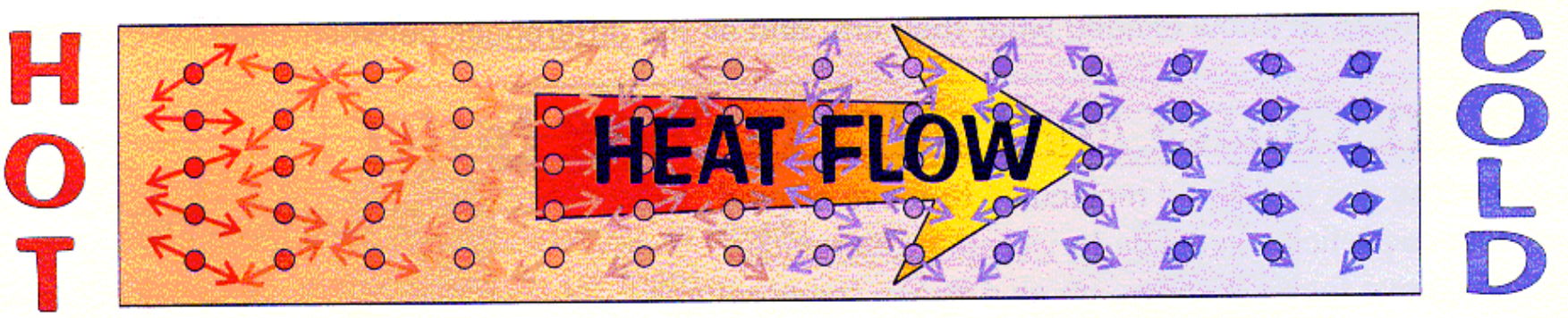
Solids and metals are the best conductors, gases are the worst.

A vacuum does not allow conduction.

A poor conductor is called an insulator.


Carbon atom

Thermal Conduction by molecules



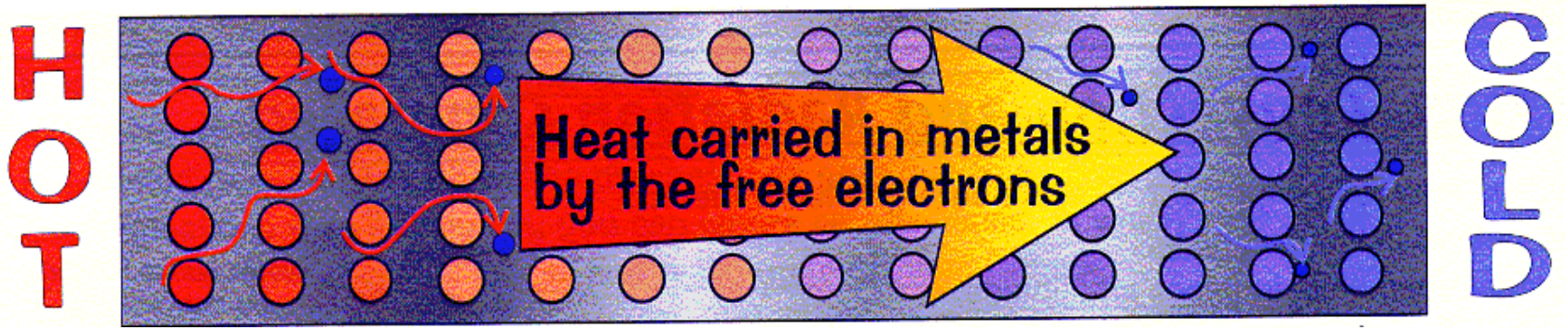
Molecules vibrate more when they are heated.

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

The stronger the forces the faster the vibrations are passed.

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.

Keeping warm with clothing

Air is a good insulator.

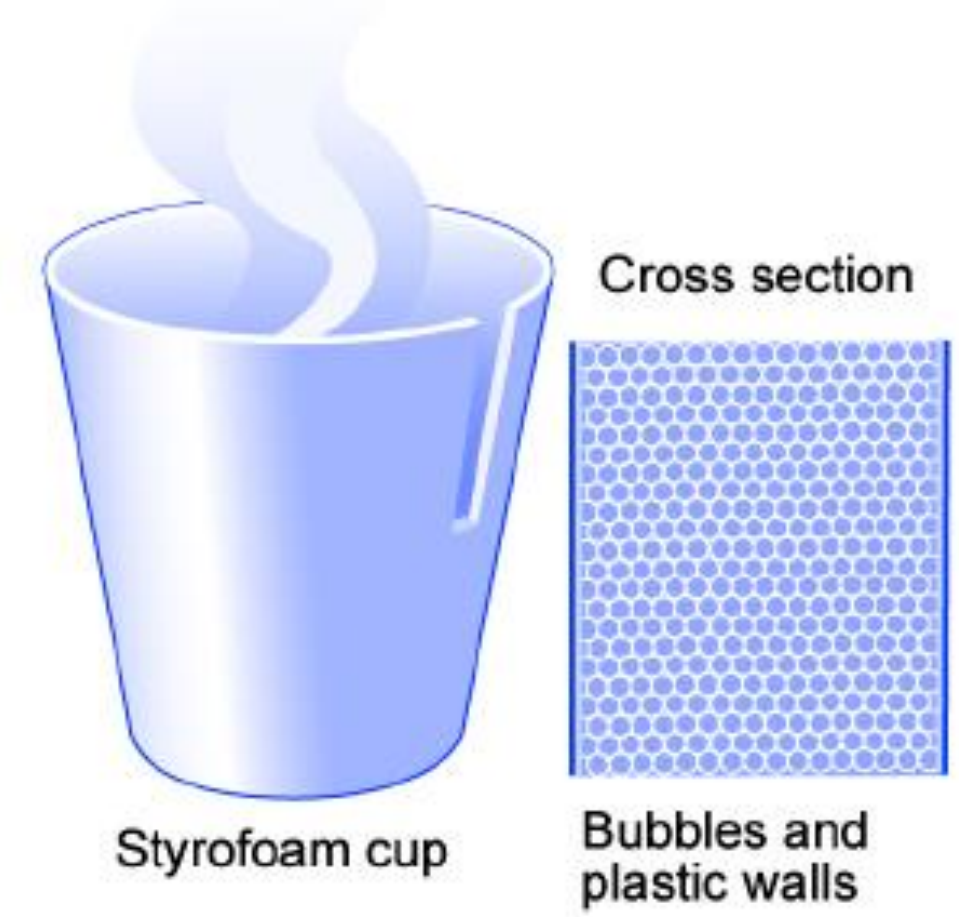
Clothes keep us warm by trapping air around our bodies.

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.

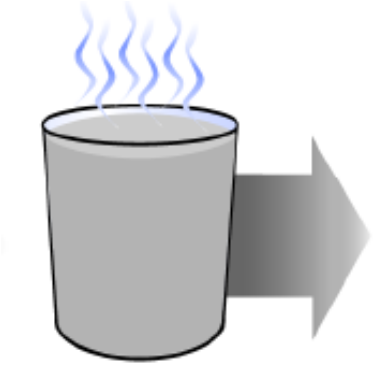
Heat Conduction

- Styrofoam gets its insulating ability by trapping spaces of air in bubbles.
- Solids usually are better heat conductors than liquids, and liquids are better conductors than gases.



Heat Conduction

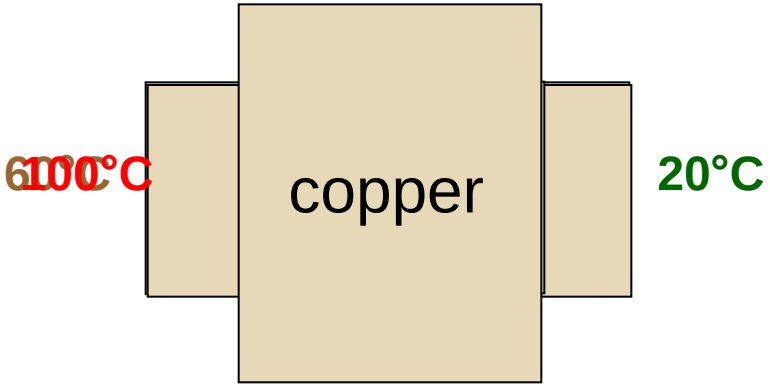
- The ability to conduct heat often depends more on the structure of a material than on the material itself.
  - Solid glass is a thermal conductor when it is formed into a beaker or cup.
  - When glass is spun into fine fibers, the trapped air makes a thermal insulator.



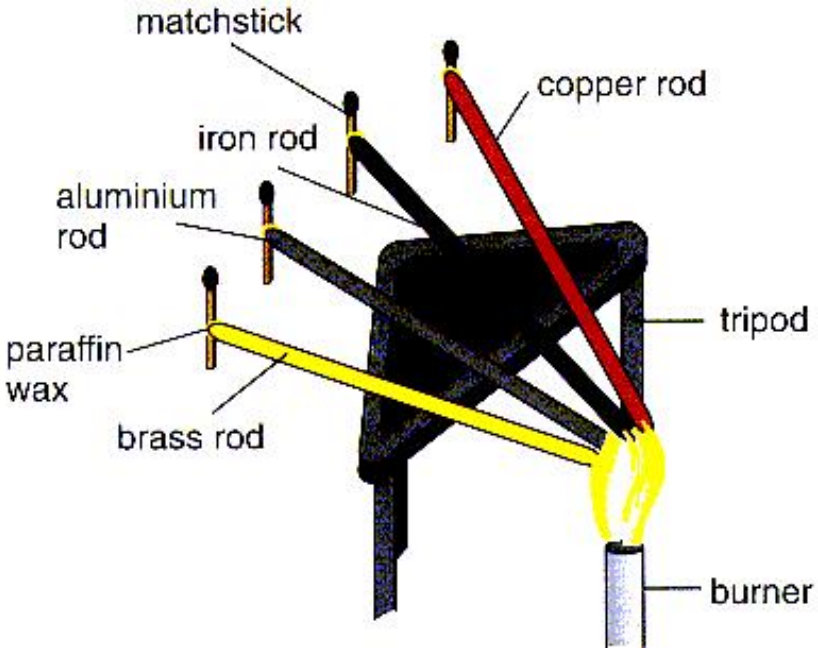
Rate of thermal transfer

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

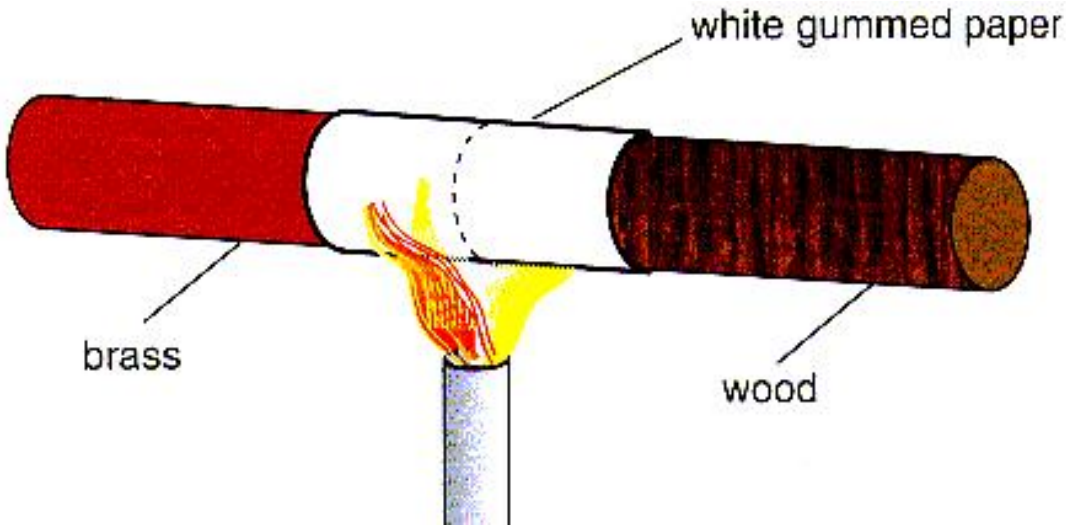


Finding the best conductor



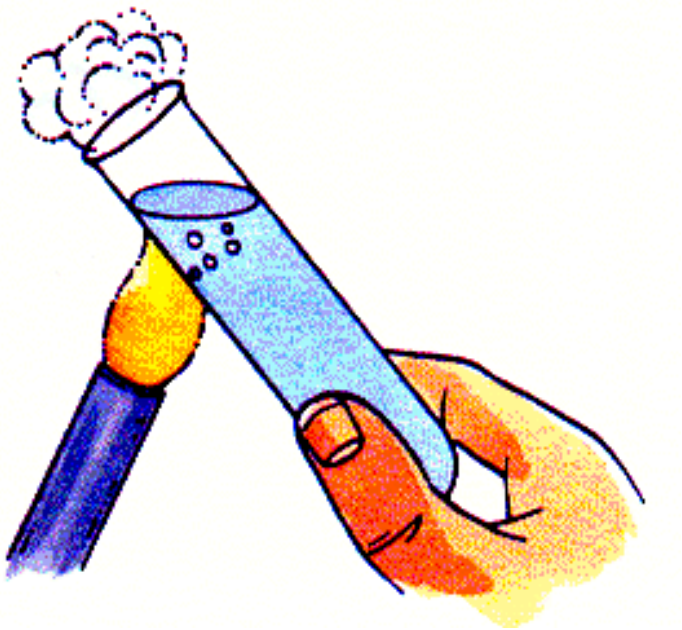
- All the rods have the same length and cross-sectional area.
- They are all heated equally at one end with the bunsen burner.
- When the other end of a rod reaches a certain temperature the paraffin wax melts and the match stick falls off.
- A match stick will fall off the best conductor first.
- This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

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.**

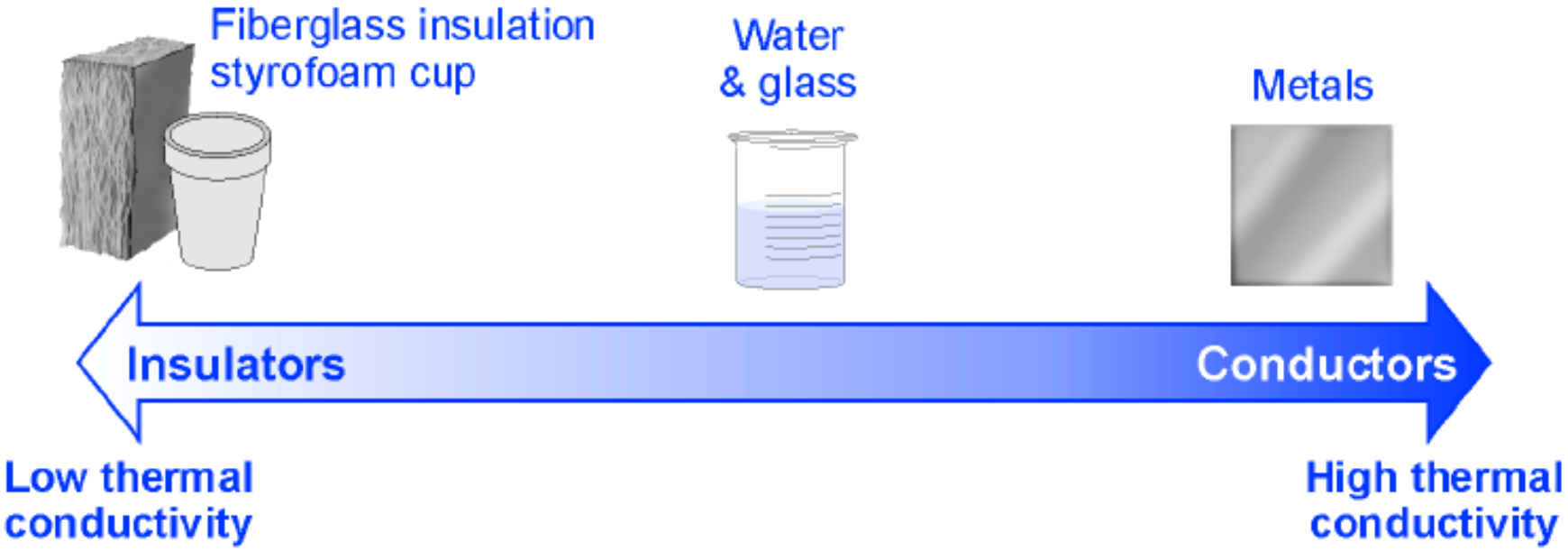
Water - a poor conductor



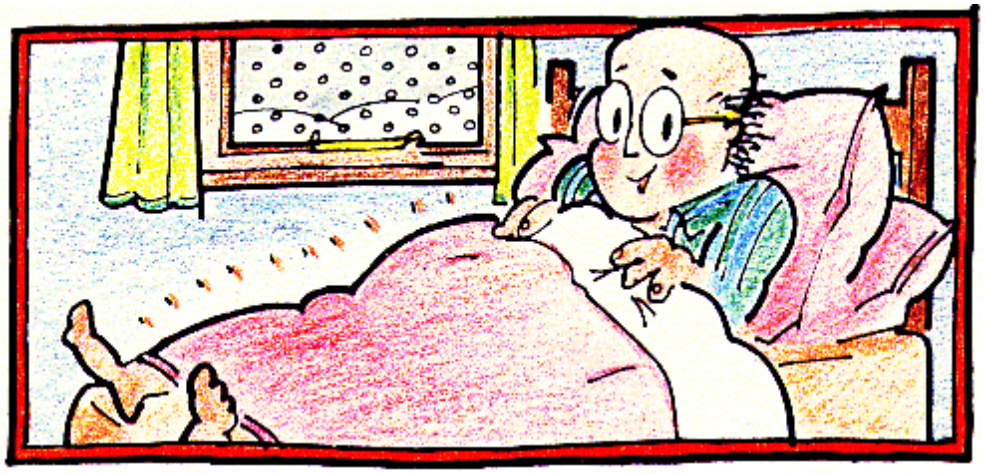
- A boiling tube of water is heated near the top of the water.
- Water boils at the top.
- The bottom of the tube remains cool enough to hold.
- This shows that water (and glass) only conduct heat relatively slowly.

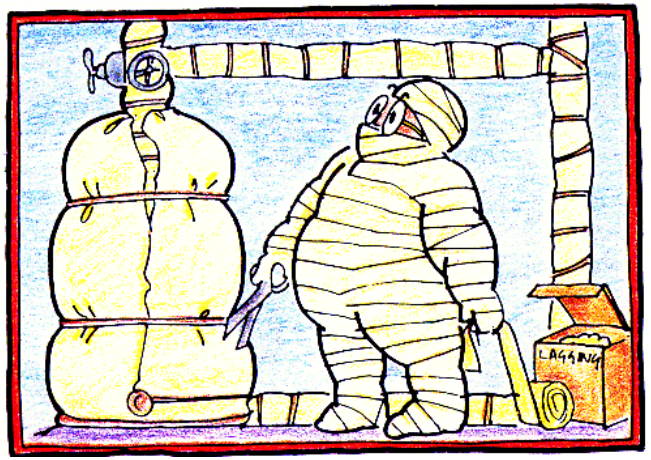
Thermal Conductivity

- The thermal conductivity of a material describes how well the material conducts heat.



Air - a good insulator



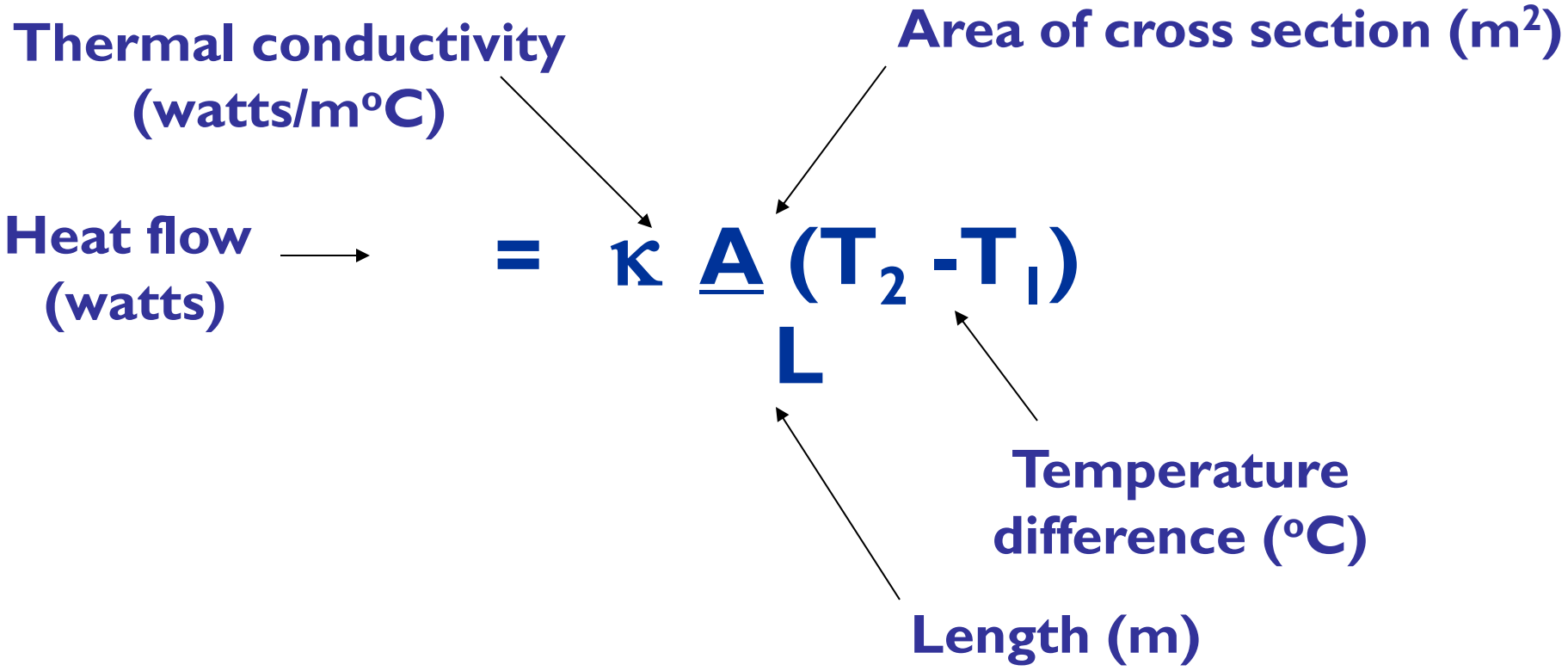


Material	Thermal cond. (W/m°C)
IIa diamond	2,650
Copper	401
Aluminum	226
Steel	43
Rock	3
Glass	2.2
Ice	2.2
Liquid water	0.58
Wood	0.11
Wool fabric	0.038
Fiberglass insulation	0.038
Styrofoam	0.025
Air	0.026

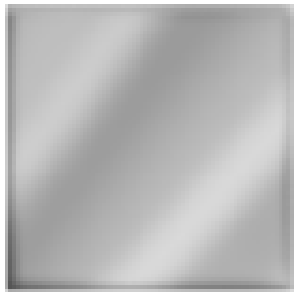
Thermal Conductivity

- Heat conduction in solids and liquids works by transferring energy through bonds between atoms or molecules.

Heat Conduction Equation

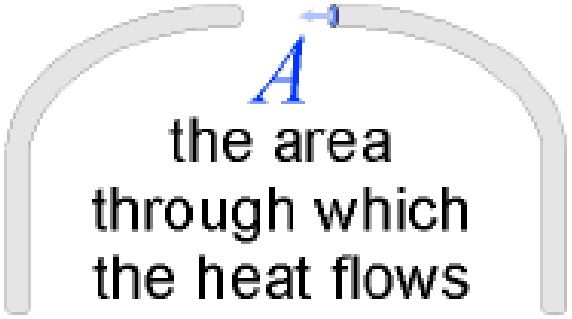


Variables for conduction



k

the thermal conductivity of the metal



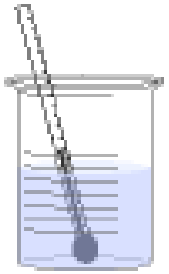
A

the area through which the heat flows

L

the length the heat has to travel

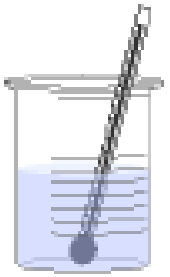
0°C



$T_2 - T_1$

the temperature difference

100°C



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

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

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.

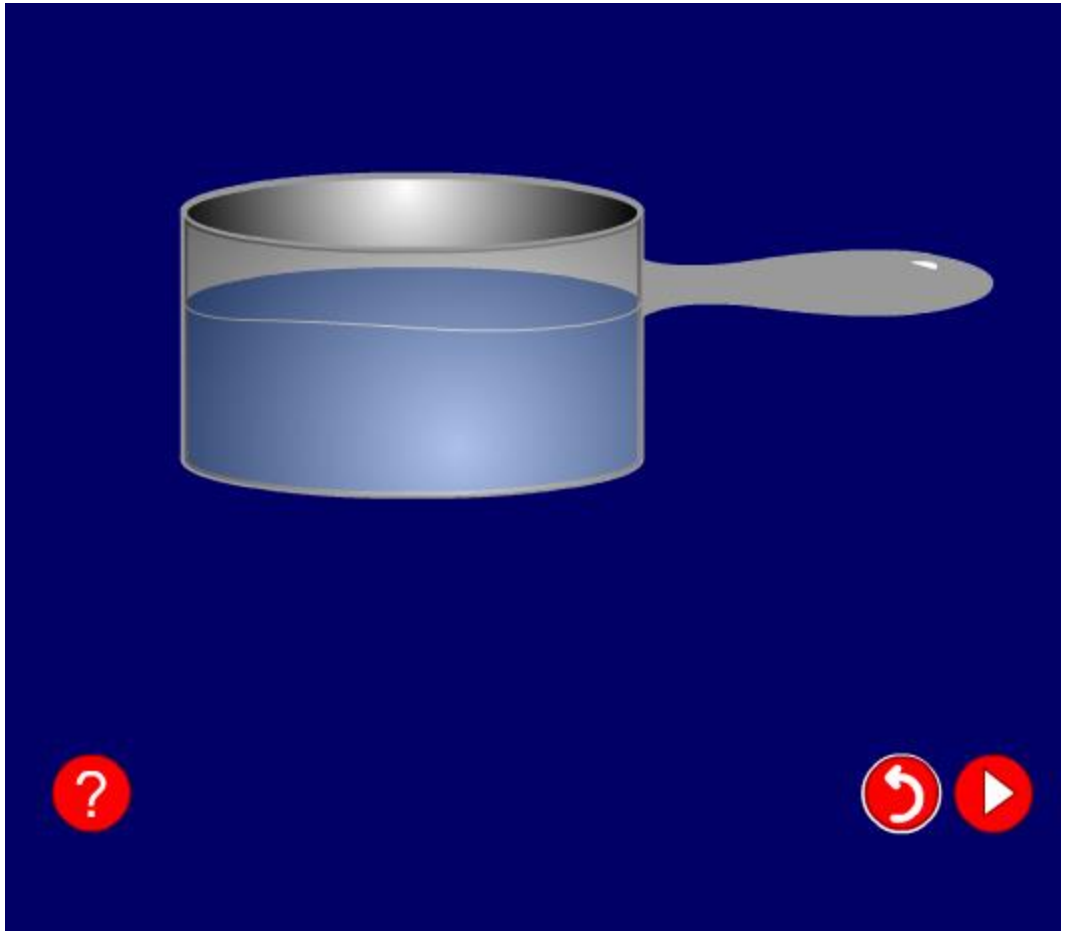
A vacuum does not allow convection.

Water movement

Cools at the surface

Convection current

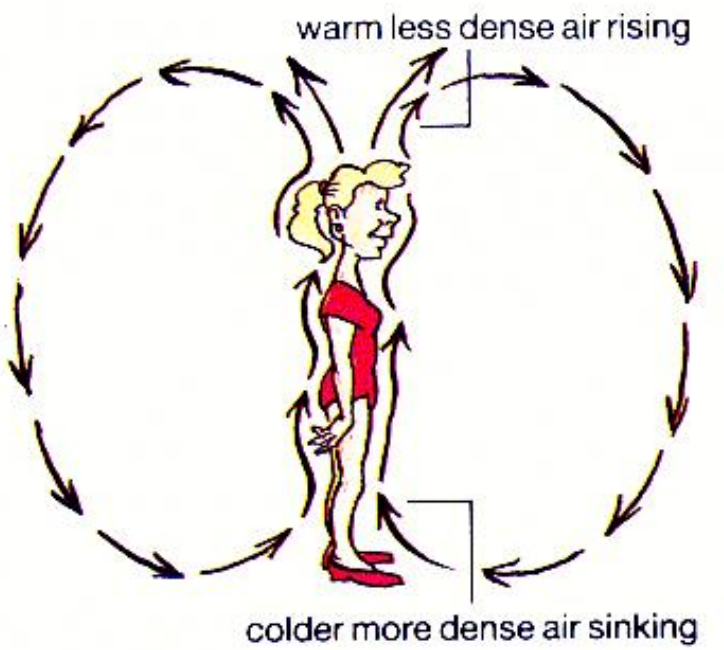
Cooler water sinks



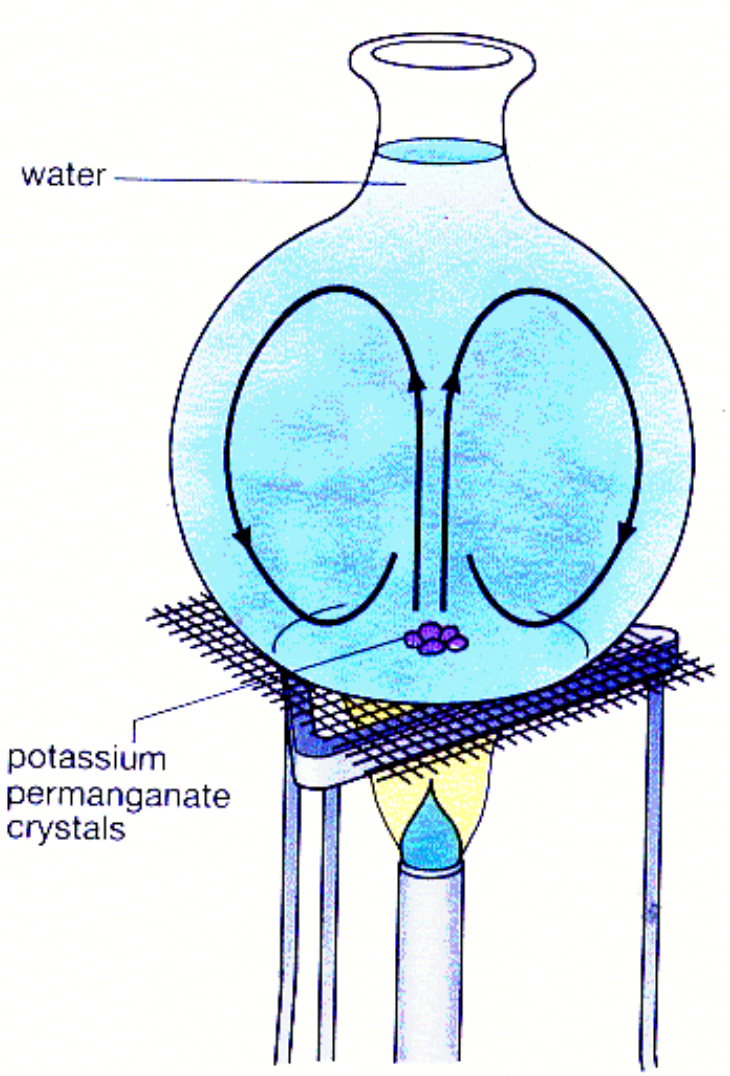
Hot water rises

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.

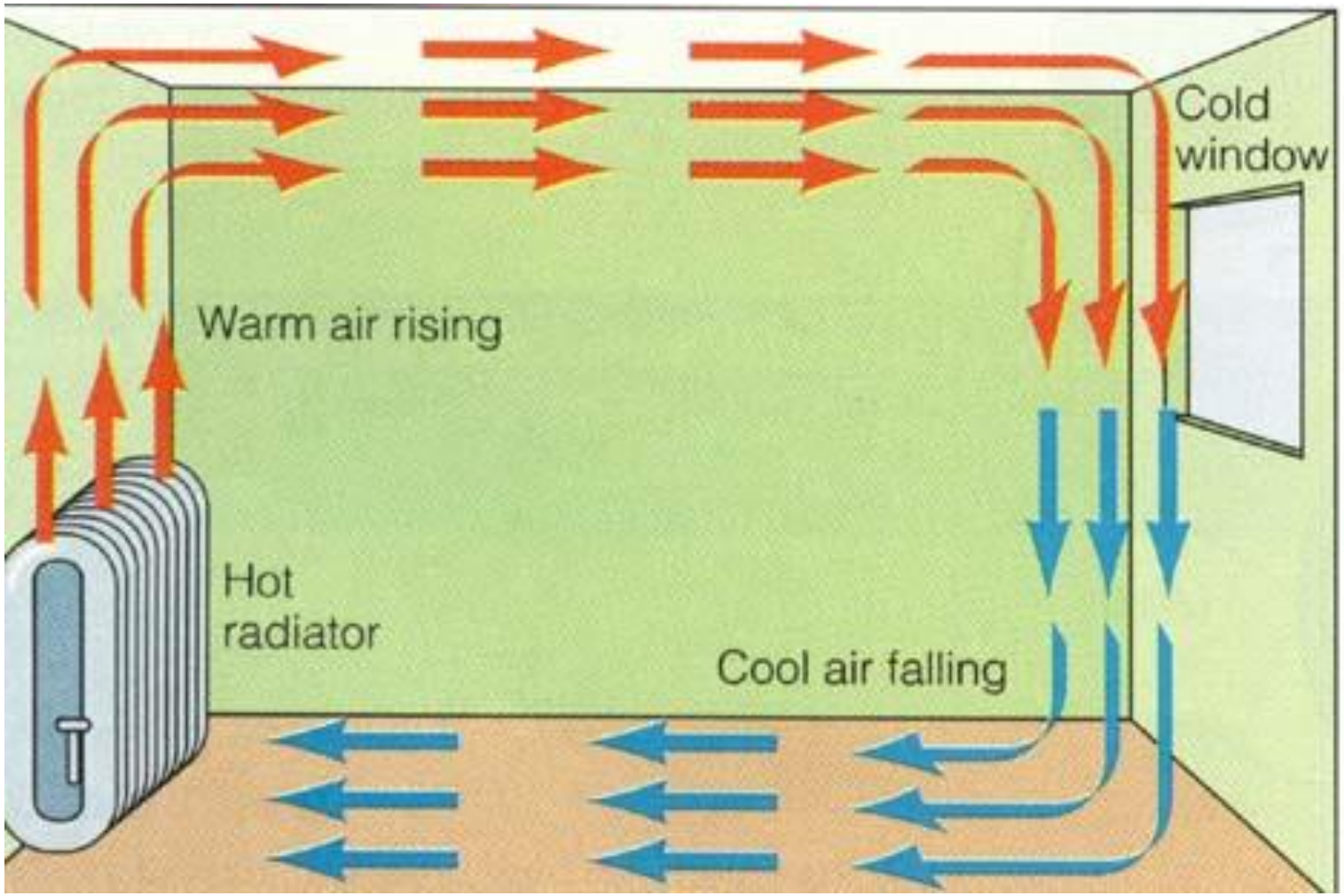


Convection in water

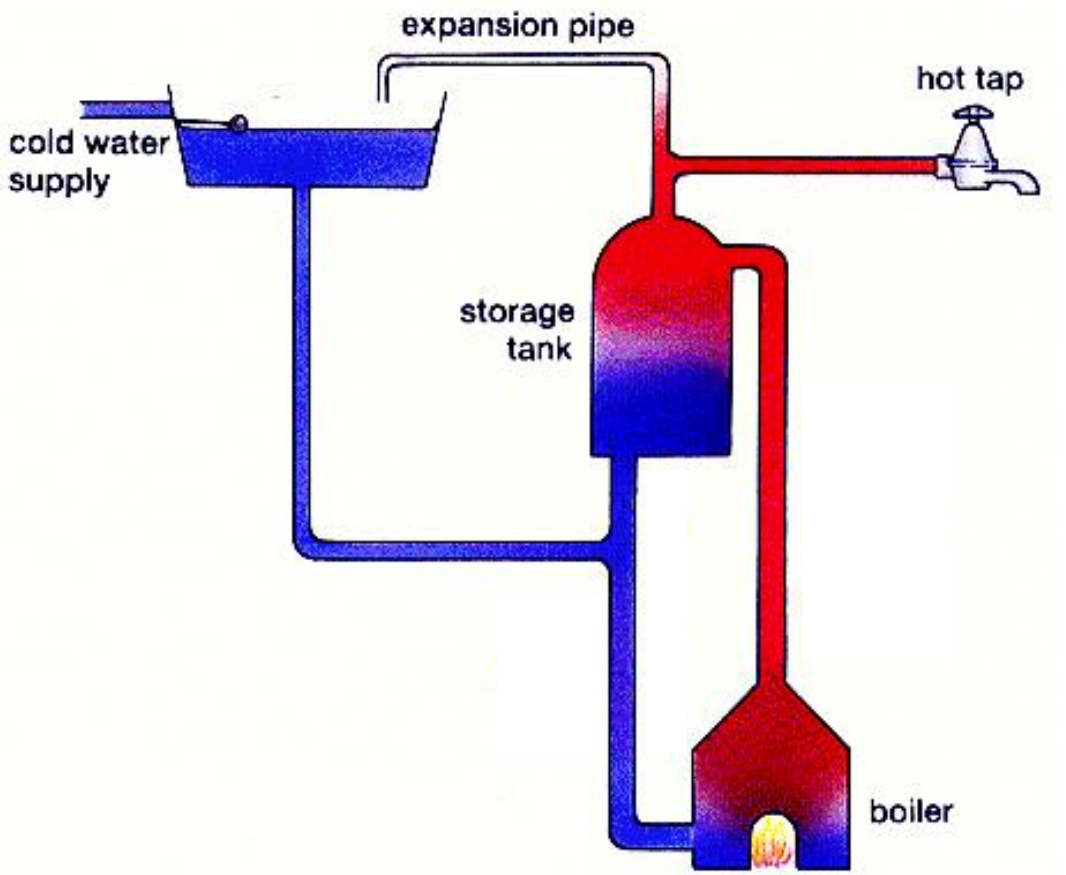


- Potassium permanganate crystals are used to dye water purple.
- When the bottom of the flask of water is heated warm less dense water rises.
- The potassium permanganate dye rises with the warmed water.
- When the water cools it becomes denser and sinks down to the bottom of the flask.

Heating a room by convection

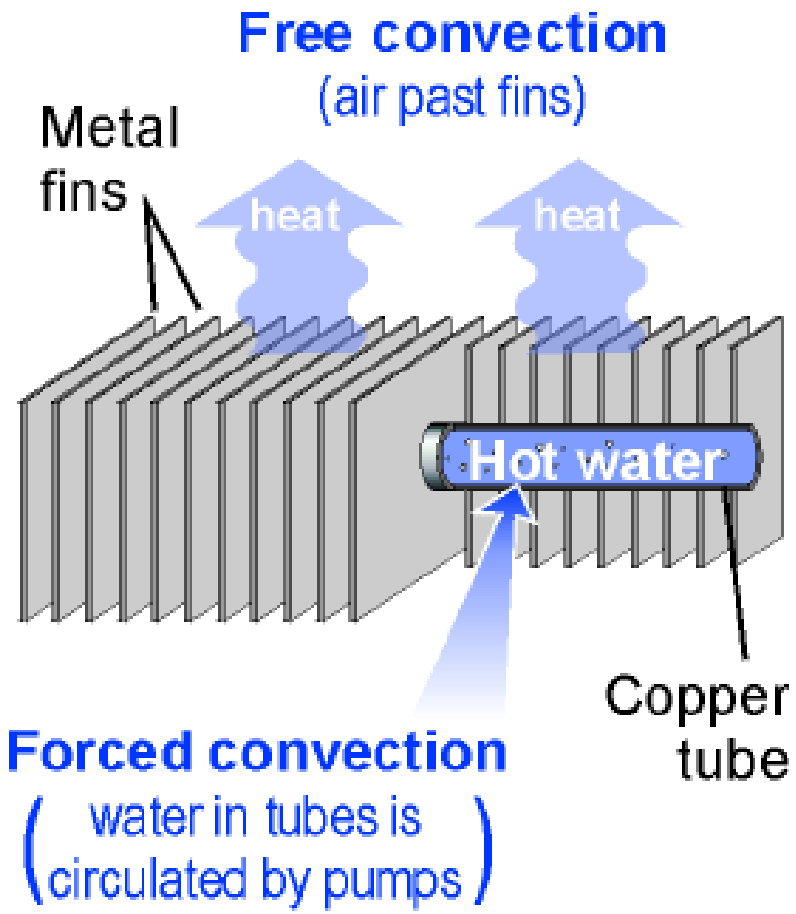


Simple house water heating system



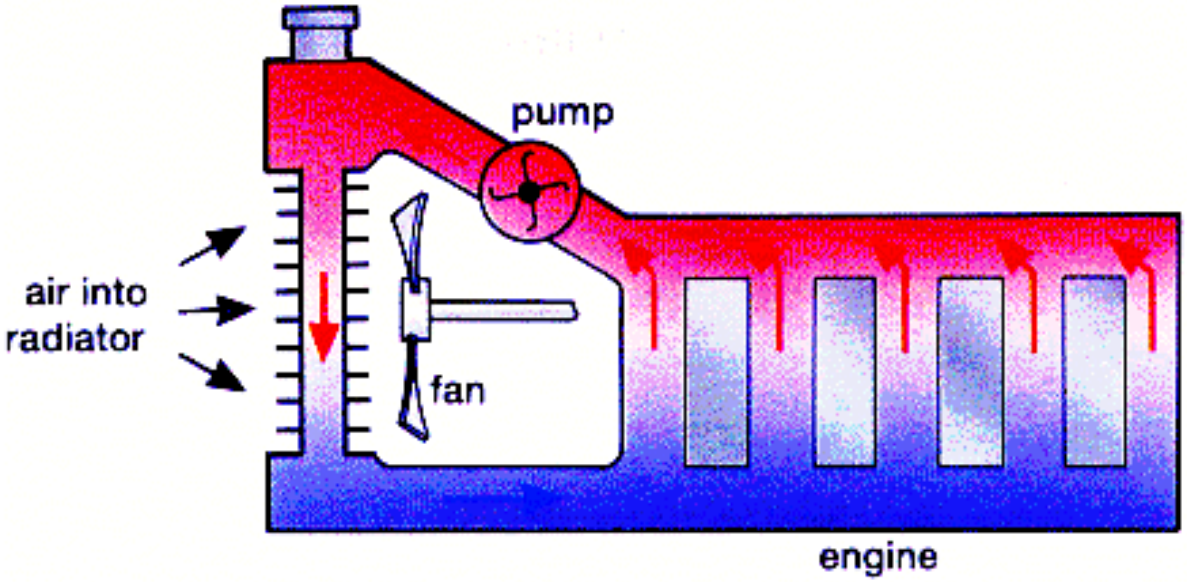
- The boiler heats the water.
- Hot water rises to the top of the boiler and up to the top of the storage tank.
- Colder water in the tank falls to the bottom of the boiler to be heater.
- A hot water tap draws water from the top of the storage tank.
- The cold water supply replenishes the hot water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

Convection



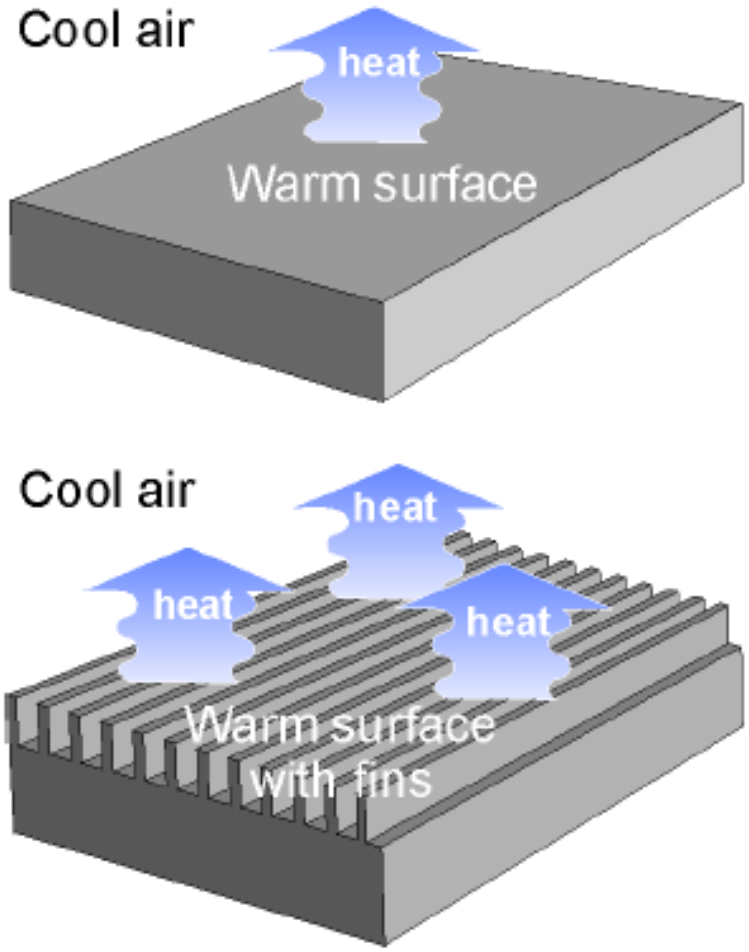
- When the flow of gas or liquid comes from differences in density and temperature, it is called free convection.
- When the flow of gas or liquid is circulated by pumps or fans it is called forced convection.

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.

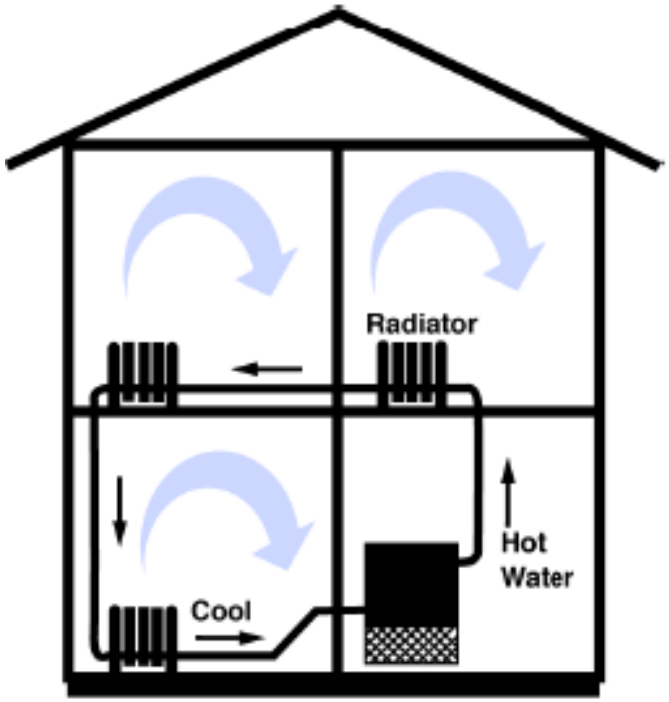
Convection

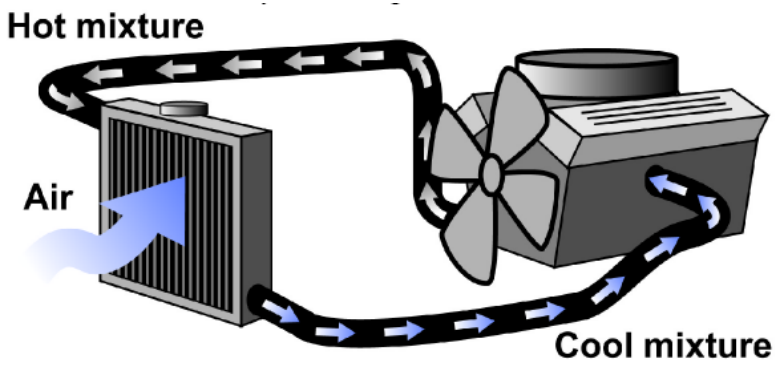


- Convection depends on surface area.
- If the surface contacting the fluid is increased, the rate of heat transfer also increases.
- Almost all devices made for convection have fins for this purpose.

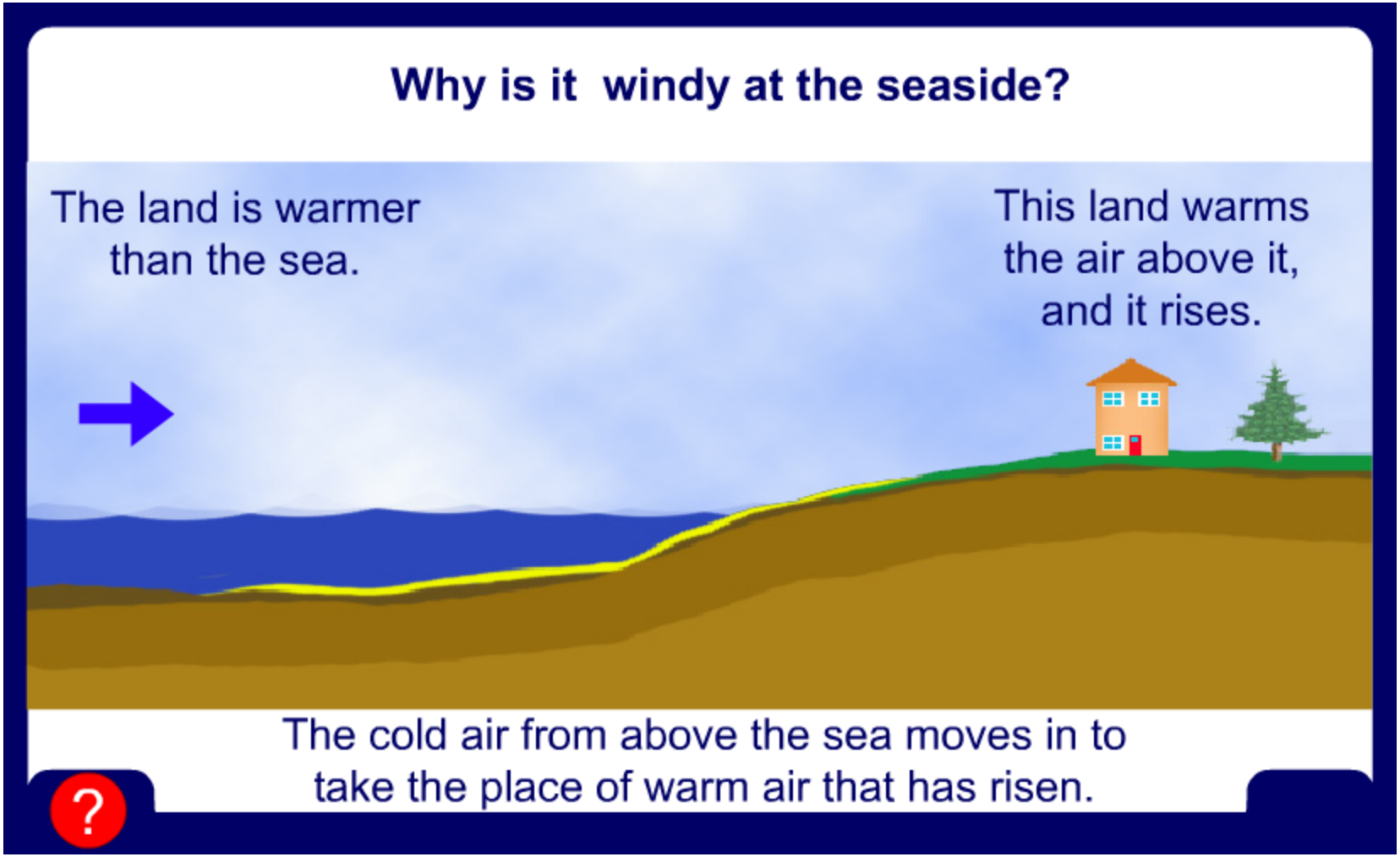
Forced Convection

- Both free and forced convection help to heat houses and cool car engines.

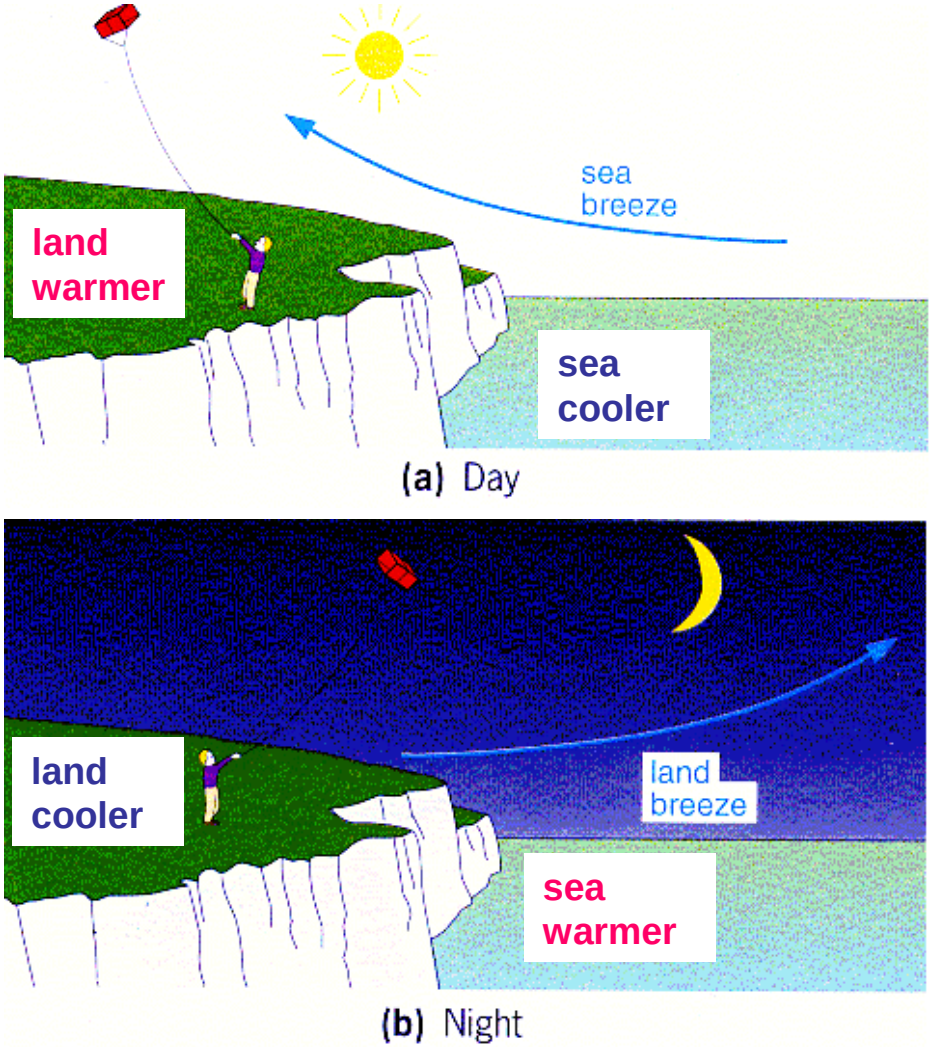




Why is it windy at the seaside?



Sea and land breezes

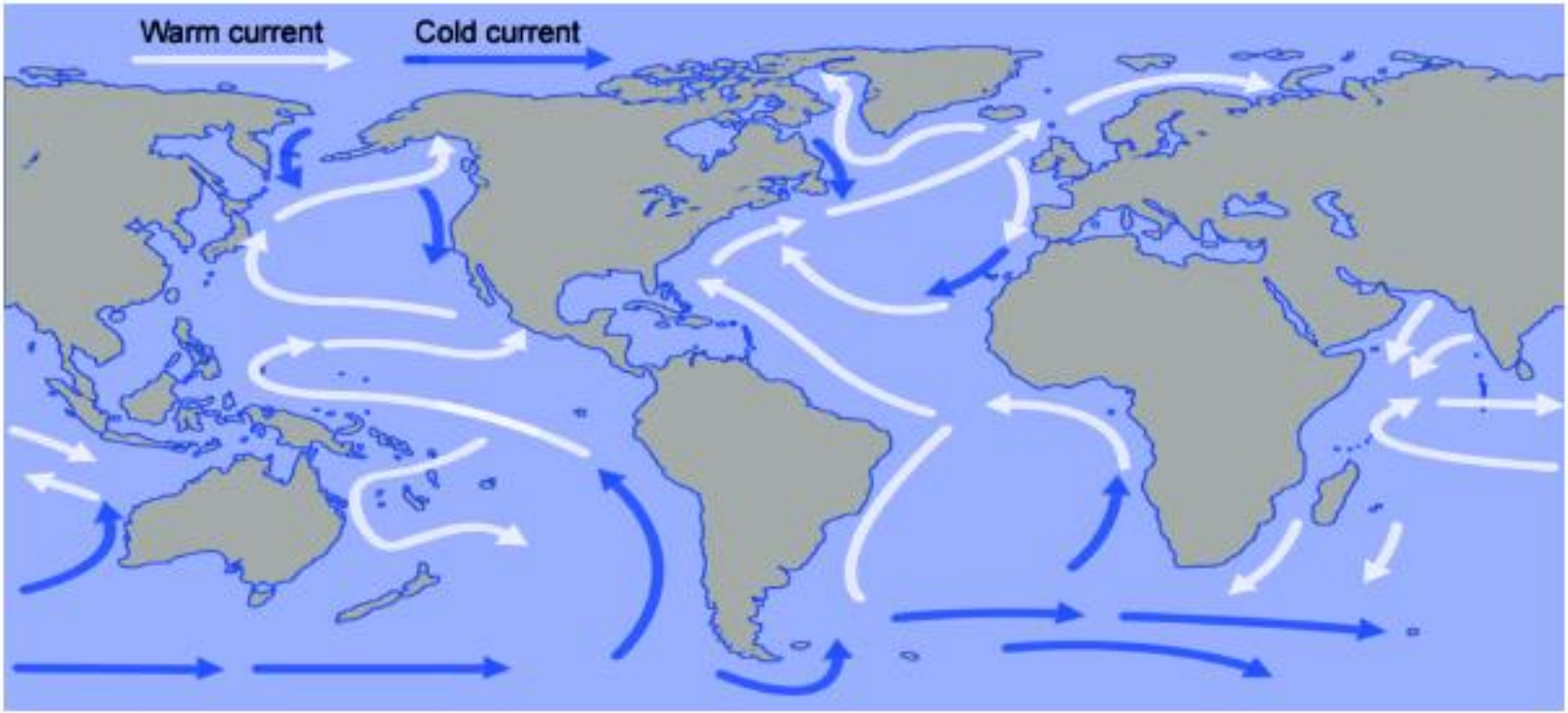


- During a hot day heated air rises up from land that is warmer than the sea.
- A ***sea breeze*** consists of cooler air that moves in from the sea to replace the heated air.

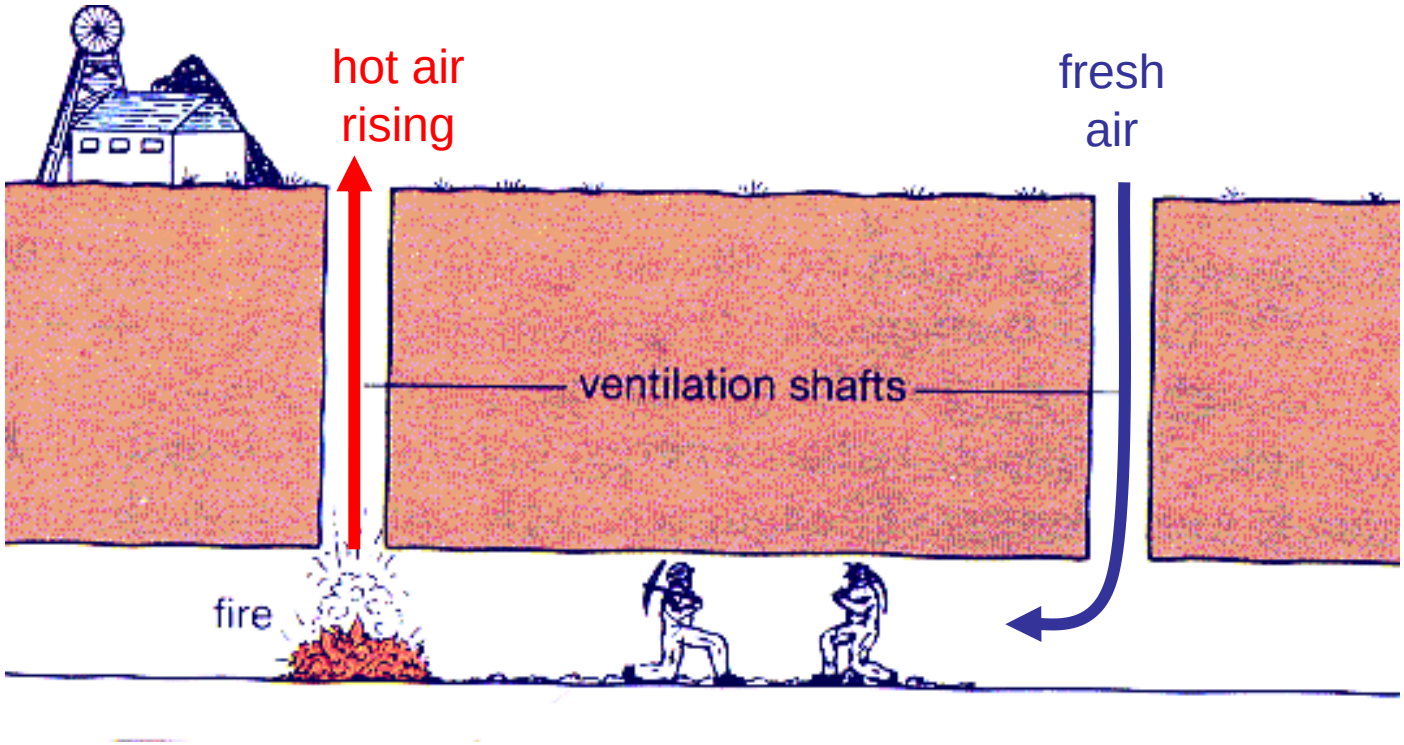
- At night the sea is often warmer than the land.
- Air now flows to the sea. This is called a ***land breeze*.**

Convection Currents

- Much of the Earth's climate is regulated by giant convection currents in the ocean.



Simple mine ventilation



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

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

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).

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

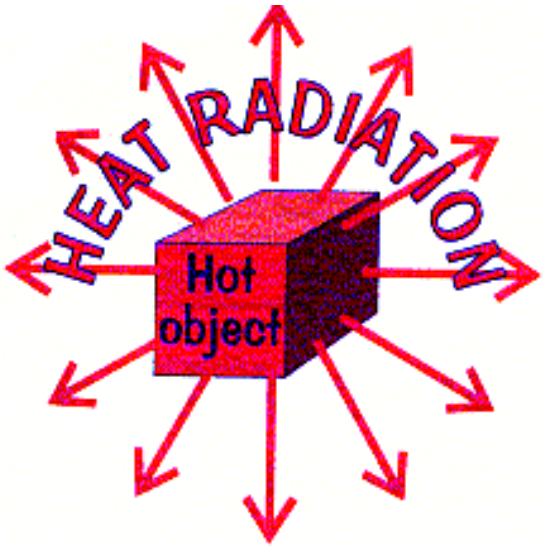
Detecting thermal radiation

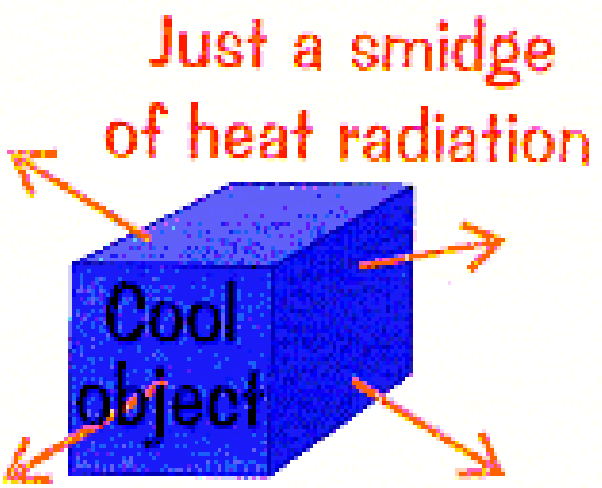
- We can feel thermal radiation with our skin.
- Special cameras can be used to take infra-red pictures.

Thermal radiation & temperature

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

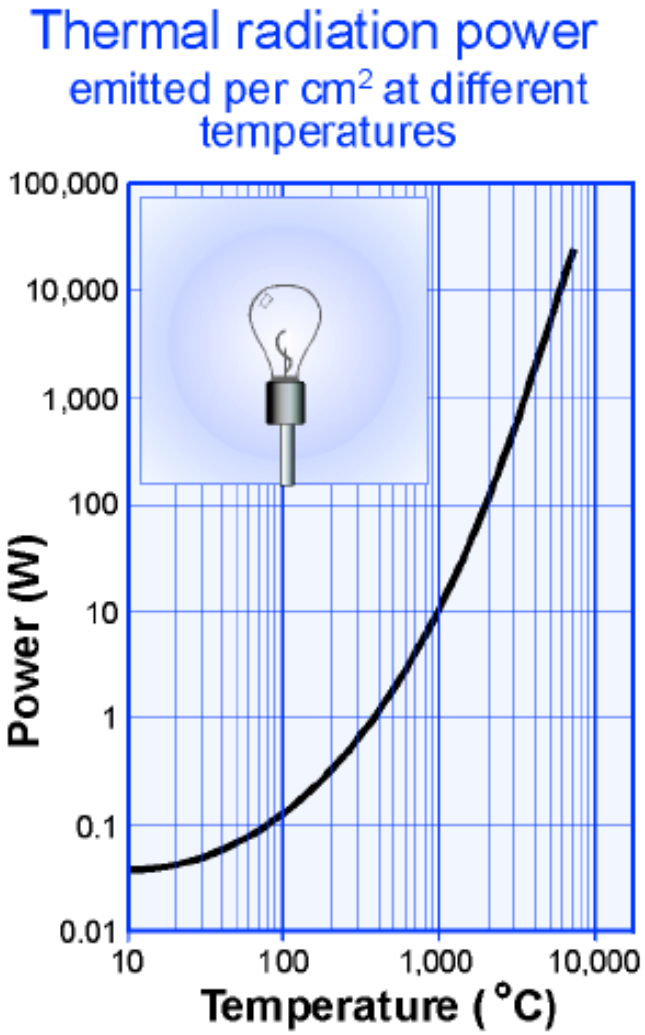
The hotter an object the more radiation it gives off.



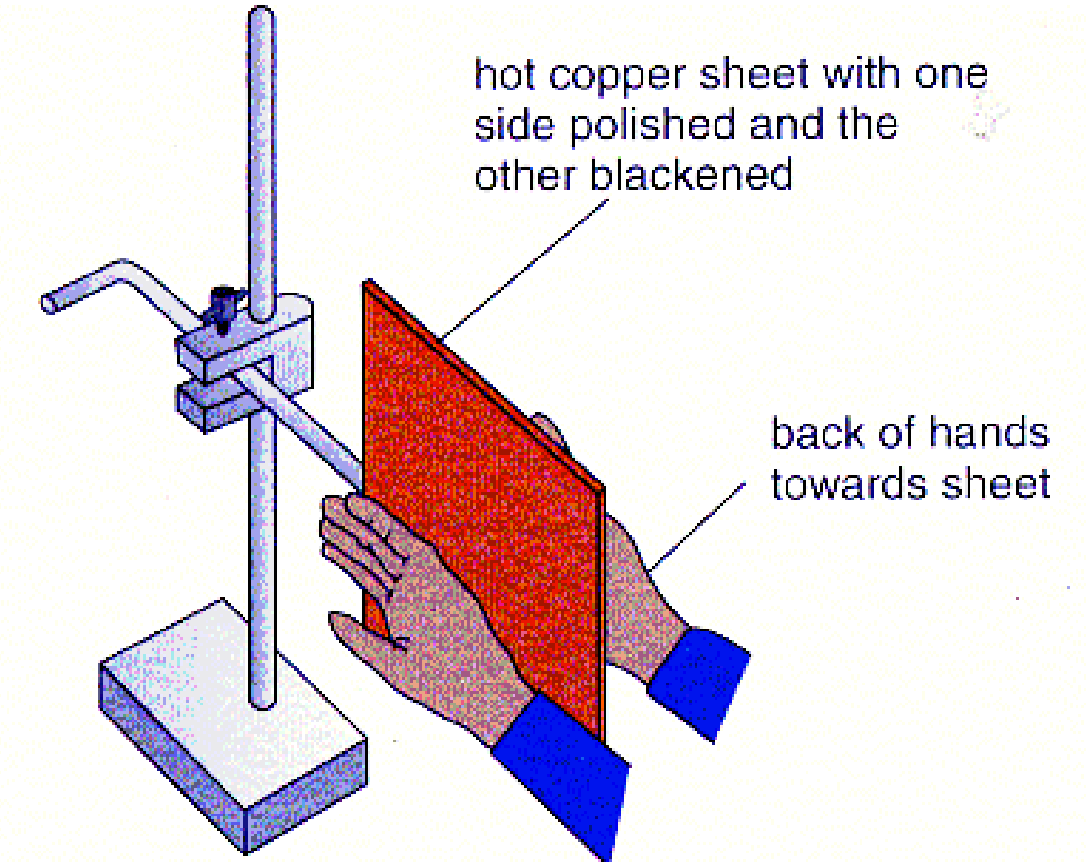


Radiation

- Radiation is heat transfer by electromagnetic waves.
- Thermal radiation is electromagnetic waves (including light) produced by objects because of their temperature.
- The higher the temperature of an object, the more thermal radiation it gives off.



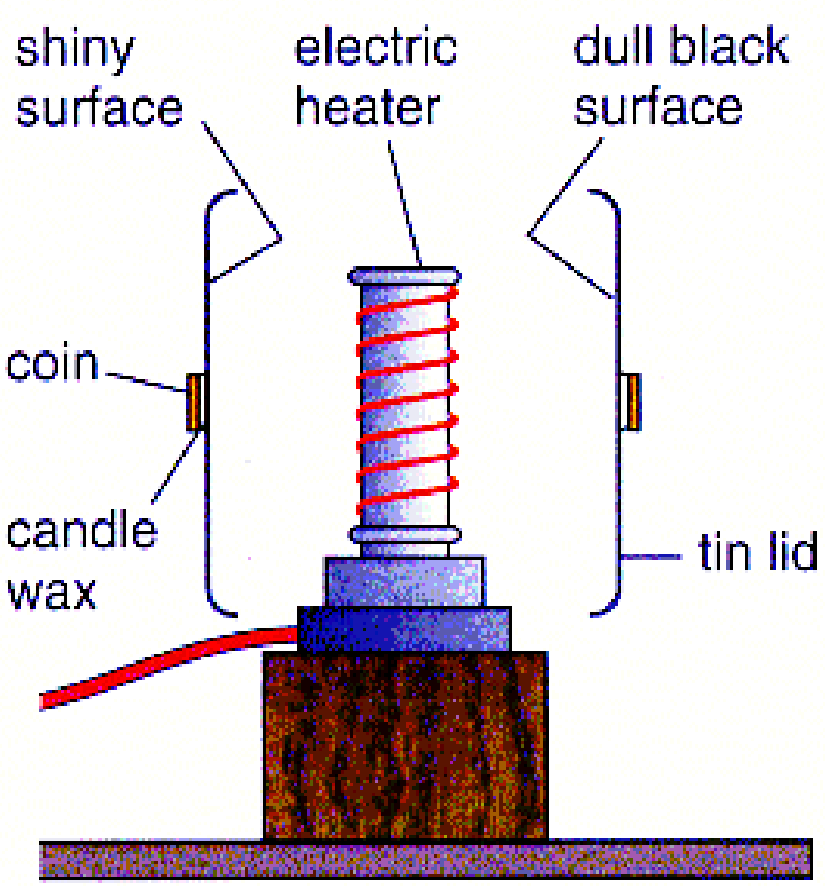
Surface and emission



Dark surfaces emit radiation better than bright surfaces.

Rough surfaces emit radiation better than polished surfaces.

Absorption & Reflection



Dark surfaces absorb radiation best.

Bright surfaces reflect radiation best.

Rough surfaces absorb radiation best.

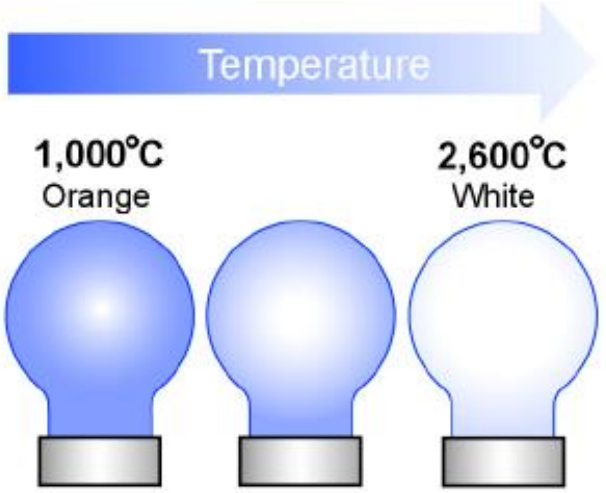
Polished surfaces reflect radiation best.

Silvered surfaces

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

Radiant Heat

- As the temperature rises, thermal radiation produces shorter-wavelength, higher energy light.
- At 1,000°C the colour is yellow-orange, turning to white at 1,500°C.
- If you carefully watch a bulb on a dimmer switch, you see its color change as the filament gets hotter.
- The bright white light from a bulb is thermal radiation from an extremely hot filament, near 2,600°C.



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.**

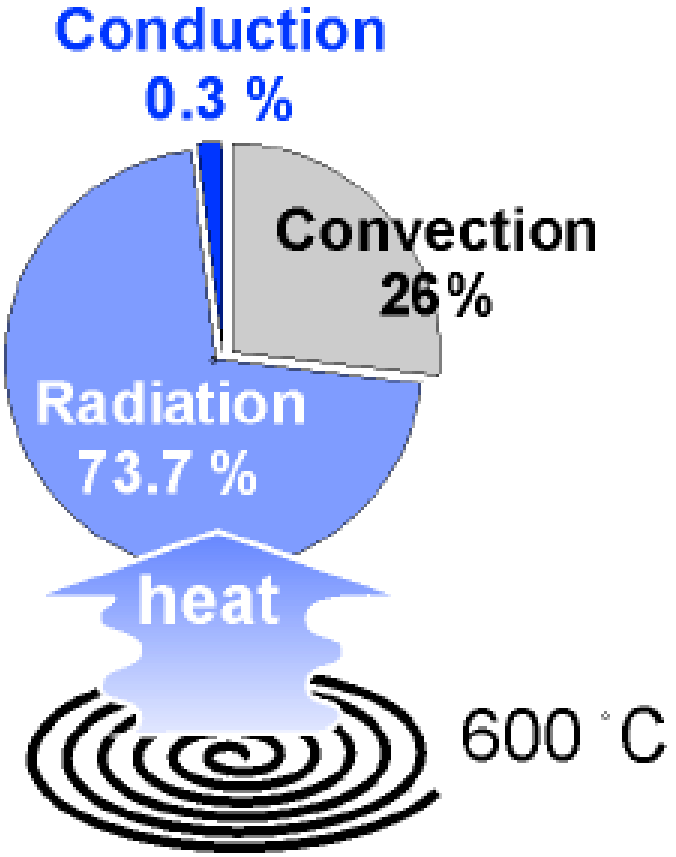
Hot, dark **and rough surfaces emit radiation best.**

Bright and smooth **surfaces reflect radiation best.**

WORD SELECTION:

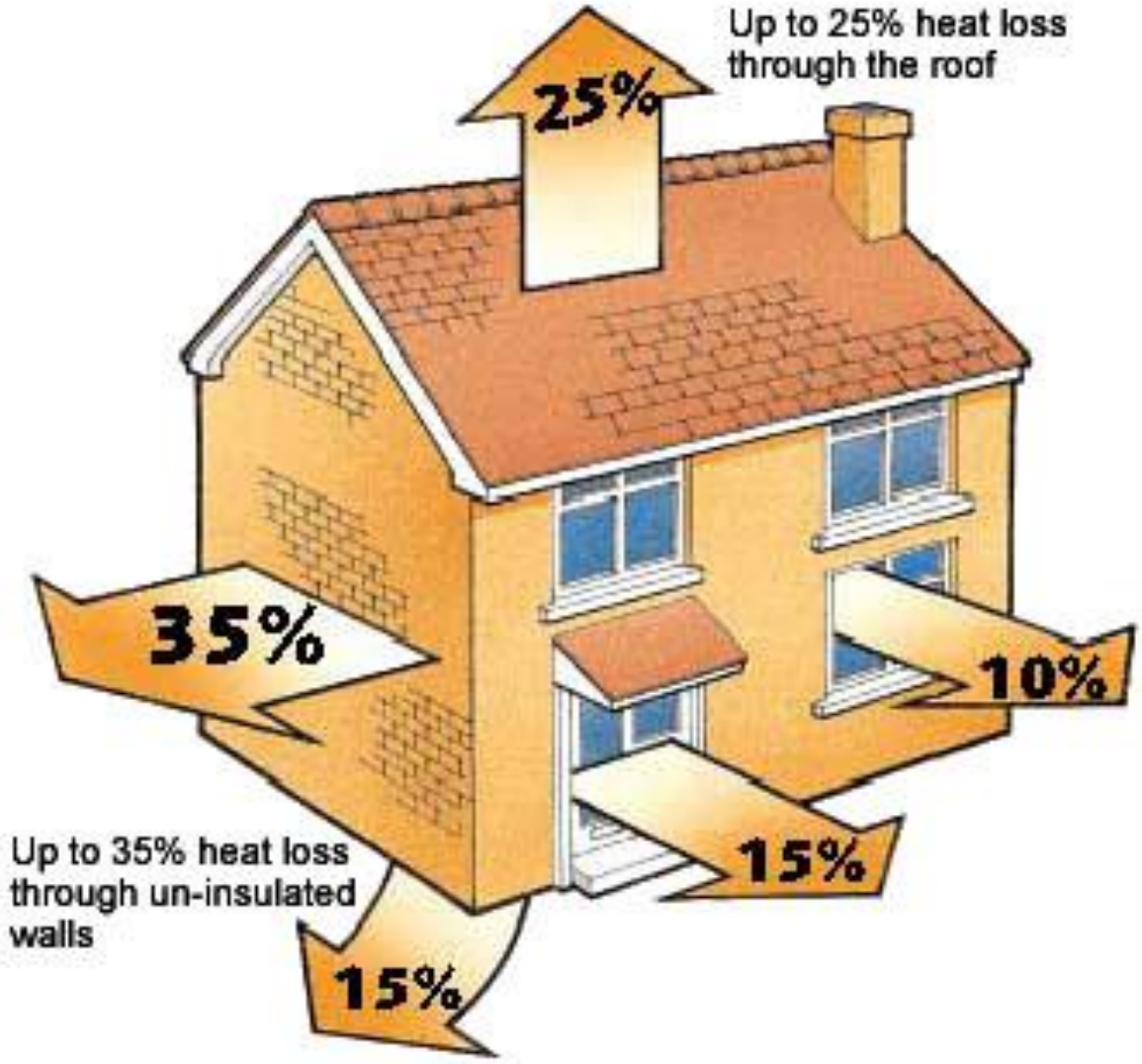
electromagnetic vacuum - 273 heat directions 300 000 dark smooth

Radiant Heat



- When comparing heat transfer for a pot 10 cm above a heating element on a stove, radiant heat accounts for 74%
- How is heat transferred when the pot sits on the element?

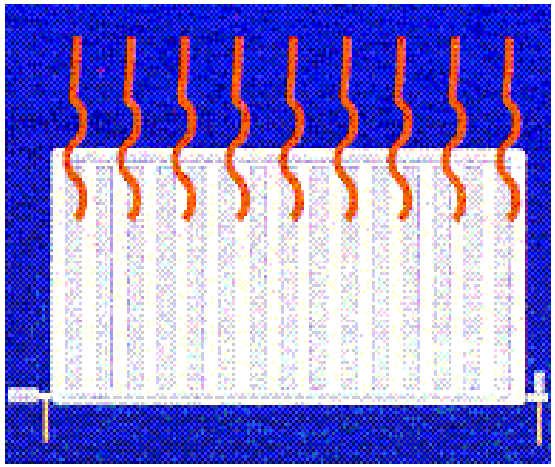
Heat losses from a house



How heat losses are reduced

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

Heating a room using a water radiator

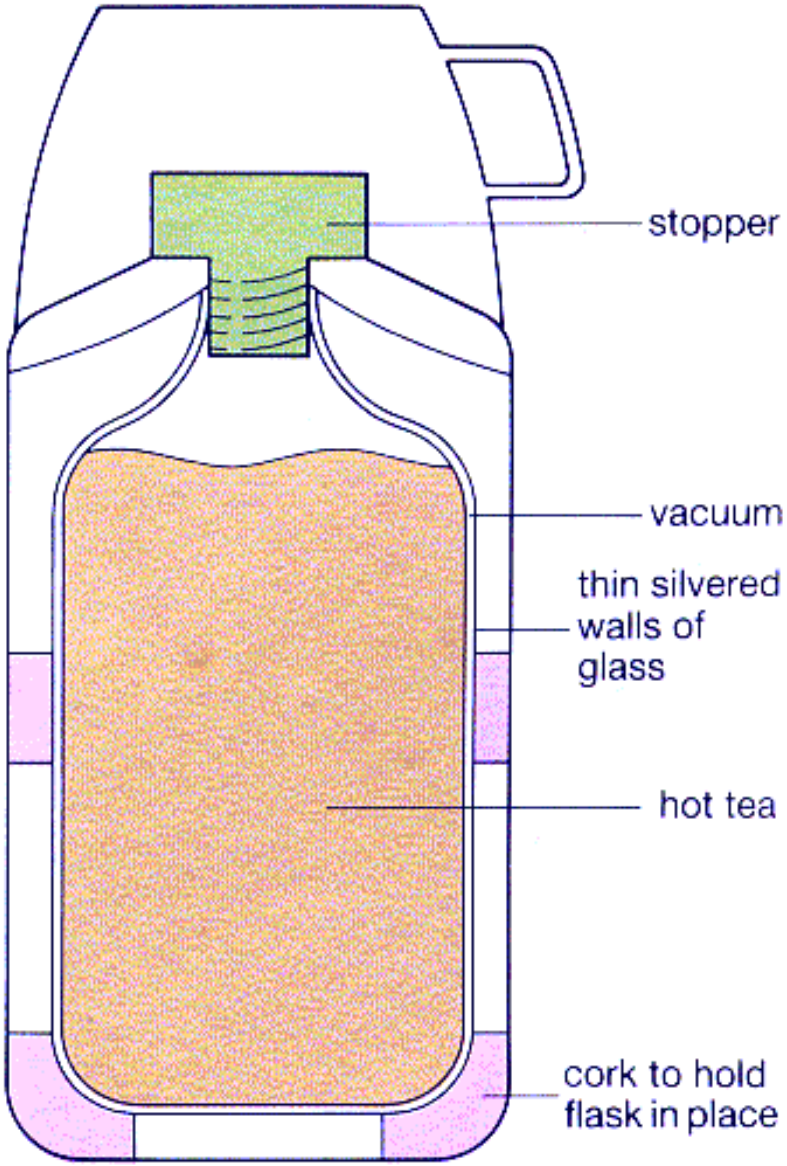


Hot water heats the metal radiator by **conduction**.

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

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

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.

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.

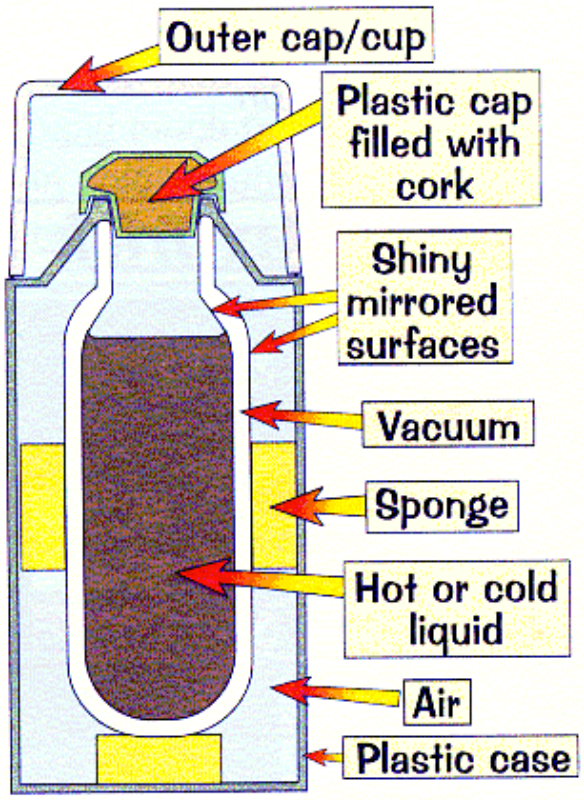
__thermal__ energy is an alternative name for heat energy.

WORD SELECTION:

thermal temperature travels heat convection

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

Question 3

Write down six different ways in which heat flow from a house can be reduced in the table below:

device or part of a house	processes reduced
draught excluders	**convection**
double glazing	**conduction & convection**
reflecting strips behind radiators	**radiation**
loft insulation	**conduction & convection**
carpets	**conduction**
cavity wall insulation	**conduction & convection**