# Unit 6: Transfer of Thermal Energy

## Learning Outcomes

### 1. Thermal Equilibrium

- show understanding that thermal energy is transferred from region of higher temperature to a region of lower temperature
- show understanding that regions of equal temperature will be in thermal equilibrium

### 2. Heat Transfer

- Conduction: Describe in molecular terms, how energy transfer occurs in solids
- Convection: Describe, in terms of density changes, convection in fluids
- Radiation: Show understanding that energy transfer by radiation does not require a material medium and its rate is affected by: (i) colour and texture of the surface, (ii) surface temperature and (iii) surface area

### 3. Applications of Thermal Energy Transfer Concept

- Describe how the concept of heat transfer can be applied to everyday practical applications and problem solving.


Physics
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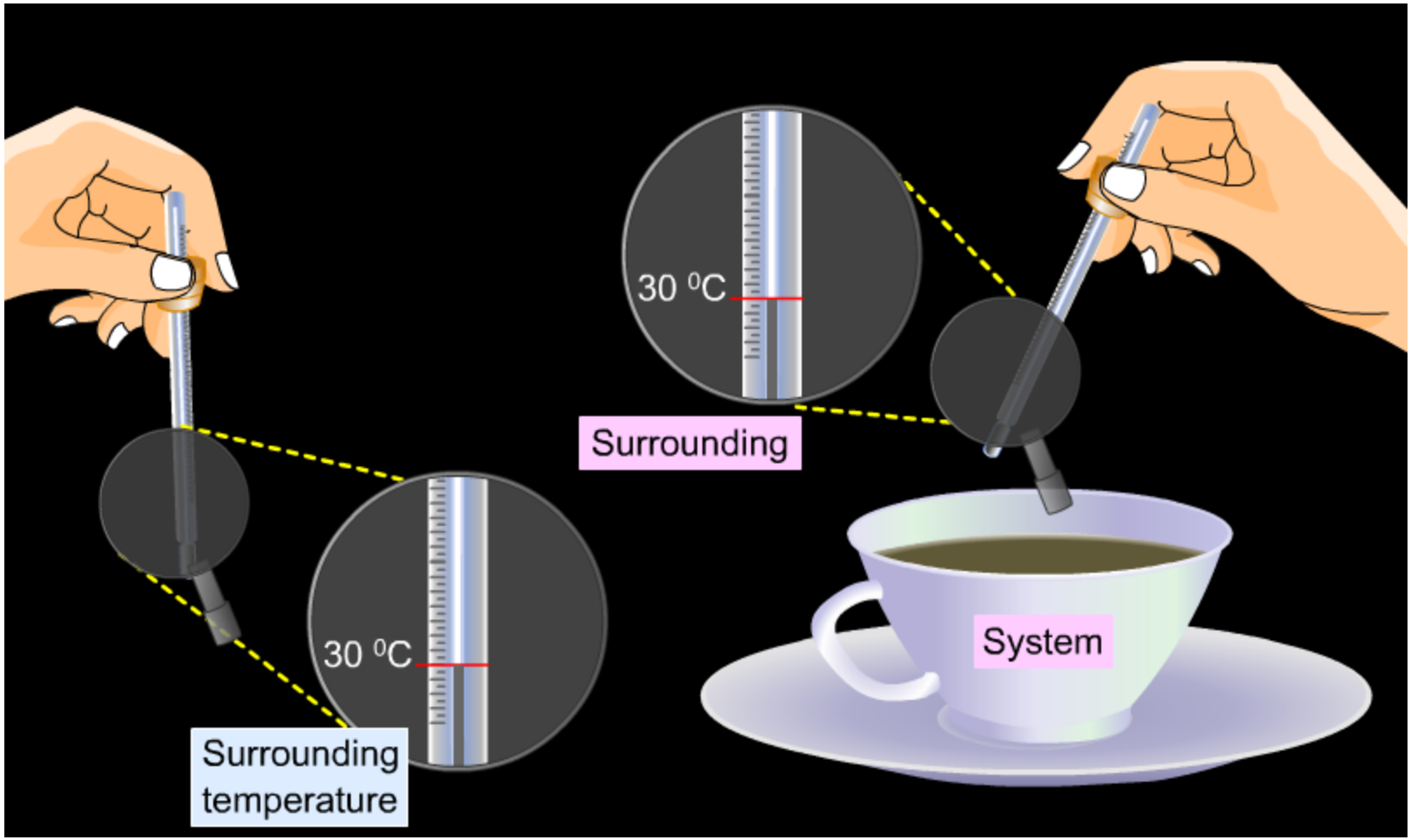

30 °C
Surrounding
30 °C
Surrounding temperature
System

# What causes transfer of thermal energy?

- Thermal energy is transferred only when there is a difference in temperature.
- Thermal energy always flows from a region of higher temperature to a region of lower temperature.
- When thermal equilibrium is reached between two bodies (i.e. both bodies are at the same temperature), there is no net flow of thermal energy between them.

What are the processes that enables heat to travel?

# Heat Transfer Process

**There are three processes by which heat may be transmitted:**

- Conduction
- Convection
- Radiation

# Suppose…

We have a cool glass which is poured with boiling hot water. Will it be easy for us to lift it up with our bare hands after a while?

How come?

Why did the glass  become hot too?

# So what has happened?

Heat has flowed from water through the glass.

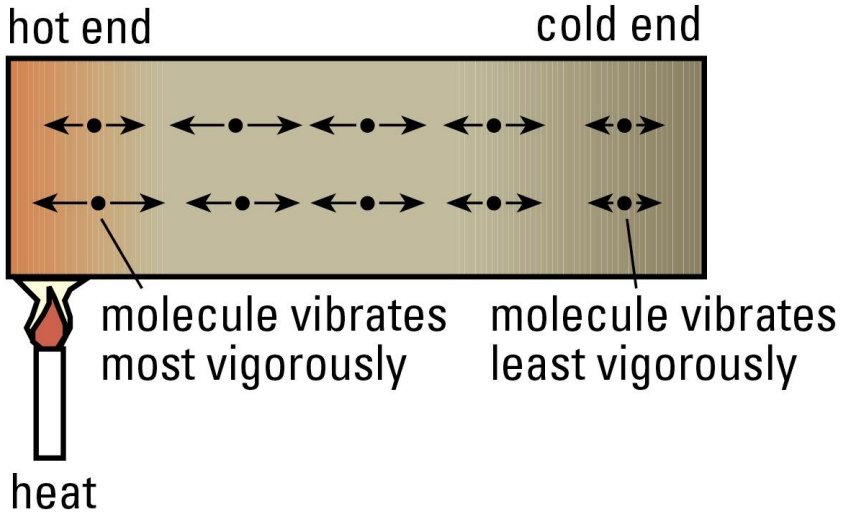
The process of transferring heat in solids is conduction

It does not involve movement or flow in the matter itself

So how is the heat transferred? What happened?

# Conduction

Conduction is the process by which heat is transferred from one particle to another through a medium from a region of higher temperature to a region of lower temperature.

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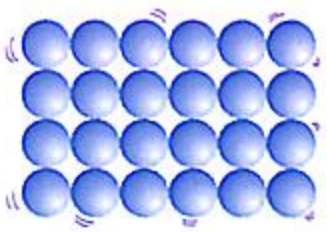
# Conduction

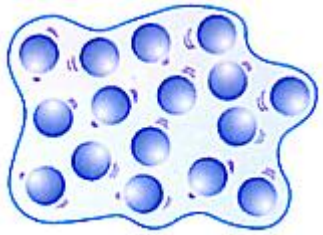
a) When the medium is heated at one end, the particles at the heated end, gain energy and vibrate faster about their fixed positions.
b) These vibrating particles collide with their less energetic neighbours
c) Some energy is transferred to these neighbouring particles which in turn gain kinetic energy
d) In this way, heat is passed along the medium by the vibrating particles
e) There is no net movement of particles during the process of conduction.

Note: This is a rather slow process of heat transfer!
Occurs in all matters.

# Conduction



**Solid**



**Liquid**

**Gas**

Which matter is a better conductor of heat?

- Solids are better conductors than liquids and gases because the particles are closer together
- Liquids and gases are poor conductors of heat because their particles are very far apart and the collisions between the particles are less frequent as compared to solids.
- Heat conduction through a fluid is inefficient.

http://www.scienceonline.co.uk/flash/all.html

# Conduction

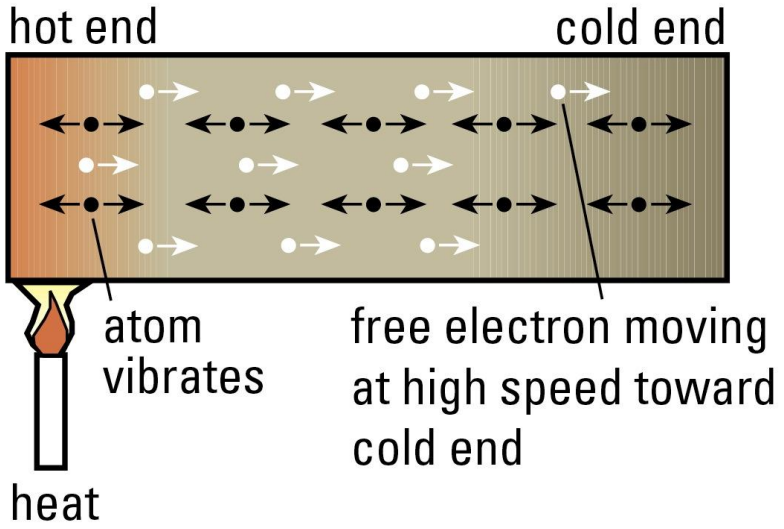
- Different solids conduct heat differently – some fast, some slow.
- Good conductors, like metals, conduct heat quickly from one end to another.
- Poor conductors (or good INSULATORS), like wool or cloth, conduct heat SLOWLY from one end to another.

http://schools.moe.edu.sg/canberra/science/genscience/scienceflashfiles/frame_hotpotato_flash3.htm

# Conduction

**Good Conductor**

- In metals, another much faster mechanism of thermal energy transfer takes place at the same time -***free electron diffusion*****.**
- The free electrons gain kinetic energy and move faster.
- The fast-moving electrons then diffuse into cooler parts of the metal.
- They also transfer their kinetic energy to the molecules by colliding with them.

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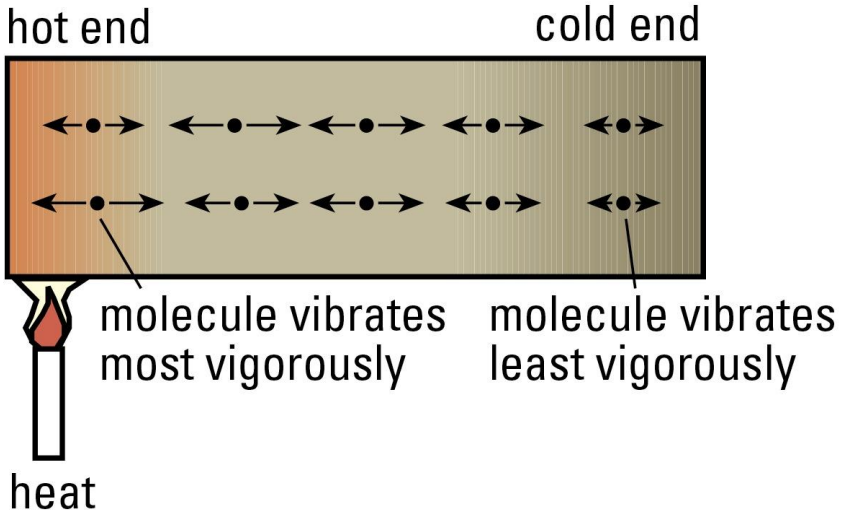
# Conduction

**Insulators**

- In insulators, the transfer of thermal energy is solely the results of vibrating atoms and molecules.
- There is no free electrons.



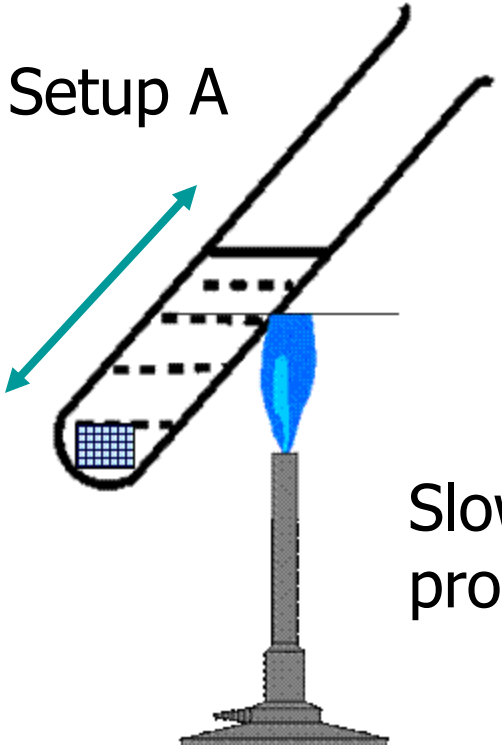
# Summary

1. Conduction is the transfer of thermal energy without any flow of the material medium.
2. The two mechanisms for conduction are atomic or molecular vibrations (for both metals and non-metals) and free electron diffusion (for metals only).
3. Liquids and gases are poor conductors of heat compared to solids.

# Demonstration on Conduction in fluid:

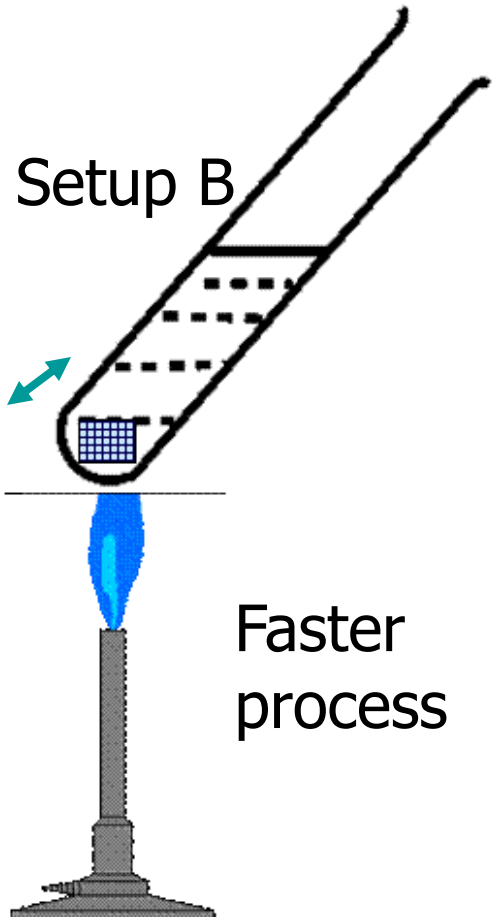
Which setup's ice cube melts faster?

Setup A



Slower process

Setup B

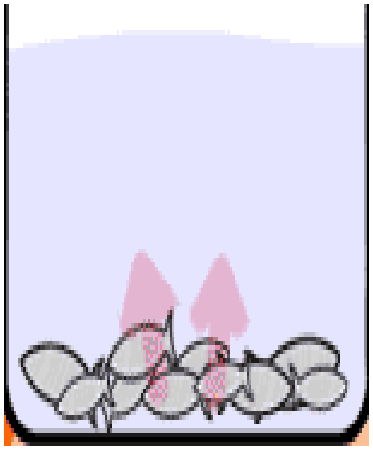


Faster process

Setup A shows water is a poor conductor of heat

# Convection

Convection – Heat transfer process that involves the bulk movement of fluid molecules that carry heat with them.

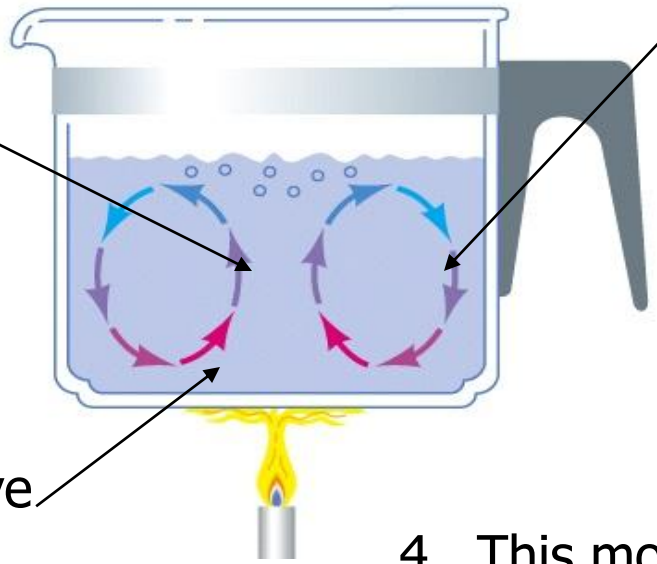


http://www.youtube.com/watch?v=p_wr_kSDPPw&feature=related

# How Convection Works

2. As water becomes less dense, will start to rise to the surface of the water.

This water that rise up will take the place of the cooler water above.



3. The denser, cooler water will move down to take the place of the void created when warm water rises. A circular motion created

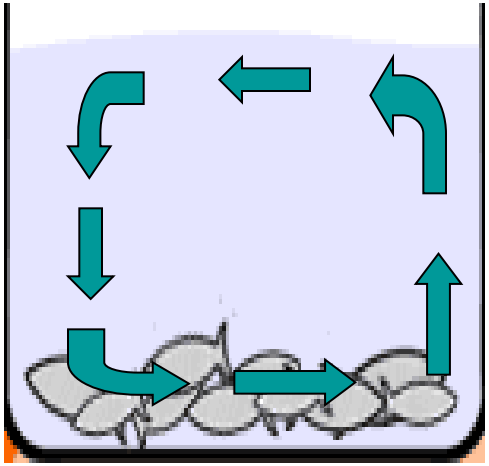
1. Water directly above heat source heats up, with molecular structure expanding. Hence becoming less dense than surrounding fluid

4. This movement of liquid due to difference in density sets up the convection current

# Thinking Question

Will there be any change if the Bunsen burner is shifted to the right side if the beaker?

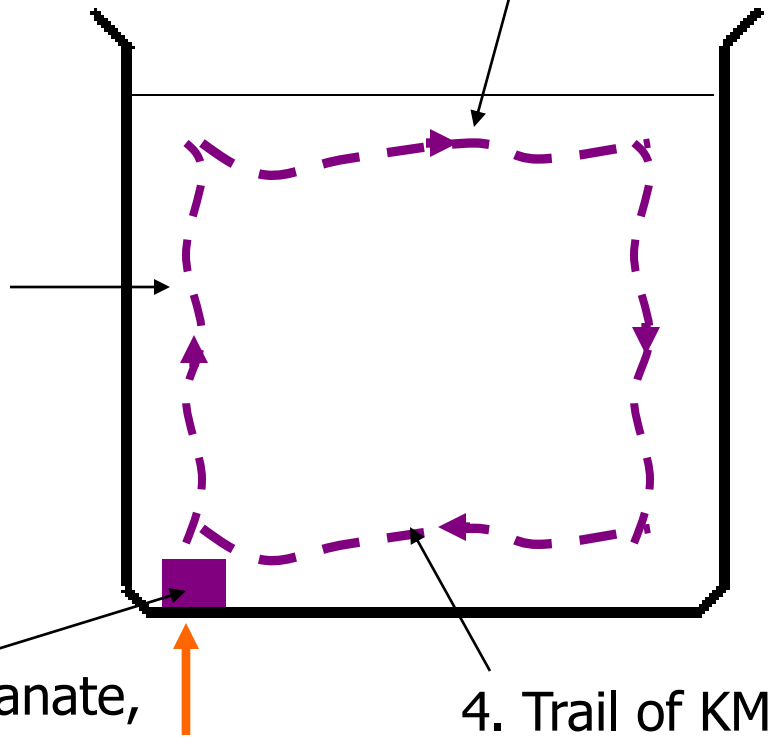
What will the convection current look like?



# Observations of Convection

$KMn0_4$ serves as a marker showing the movement of water molecules

3. Trail of $KMn0_4$ moves across.



2. Trail of $KMn0_4$ rises – indicating movement of fluid.

1. Potassium permanganate, $KMn0_4$ melts.

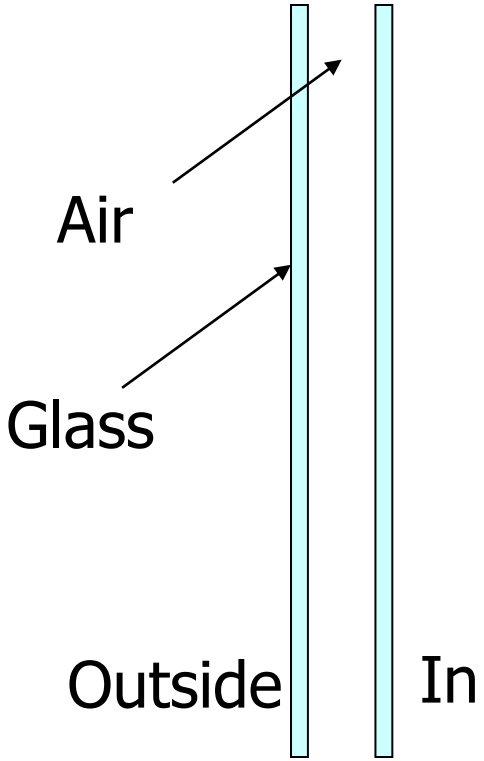
Heat

4. Trail of $KMn0_4$ completes circular motion. Indicates that fluid moving in circular manner

# Application of Conduction

Uses of insulators:

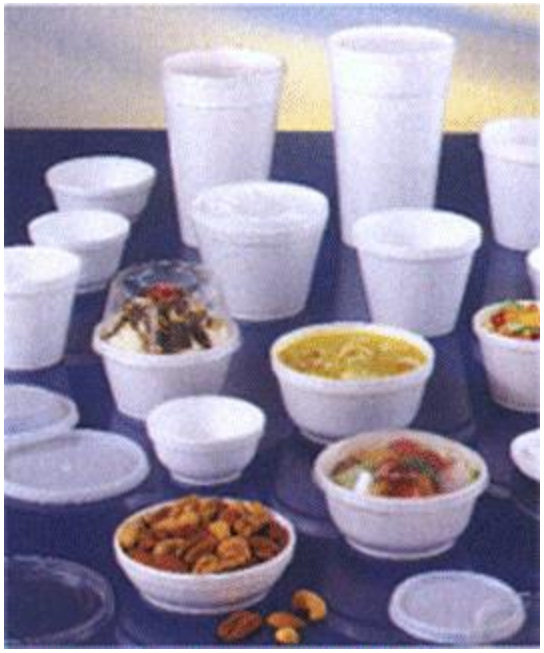
- Air is poor conductor of heat.
- Animals like bears, sheep have fur that trap air to protect them from cold. It minimises heat loss in the body
- Man uses woolen clothes that trap air
- Double-glazing used to insulate homes



# Application of Conduction

## Uses of insulators:

- Fibreglass, felt, expanded polystyrene trap air as well.
- Fibreglass: insulate roofs in temperate countries
- Expanded polystyrene: insulate food
- Handles of pots and pans made of plastic or wood which are poor conductors of heat

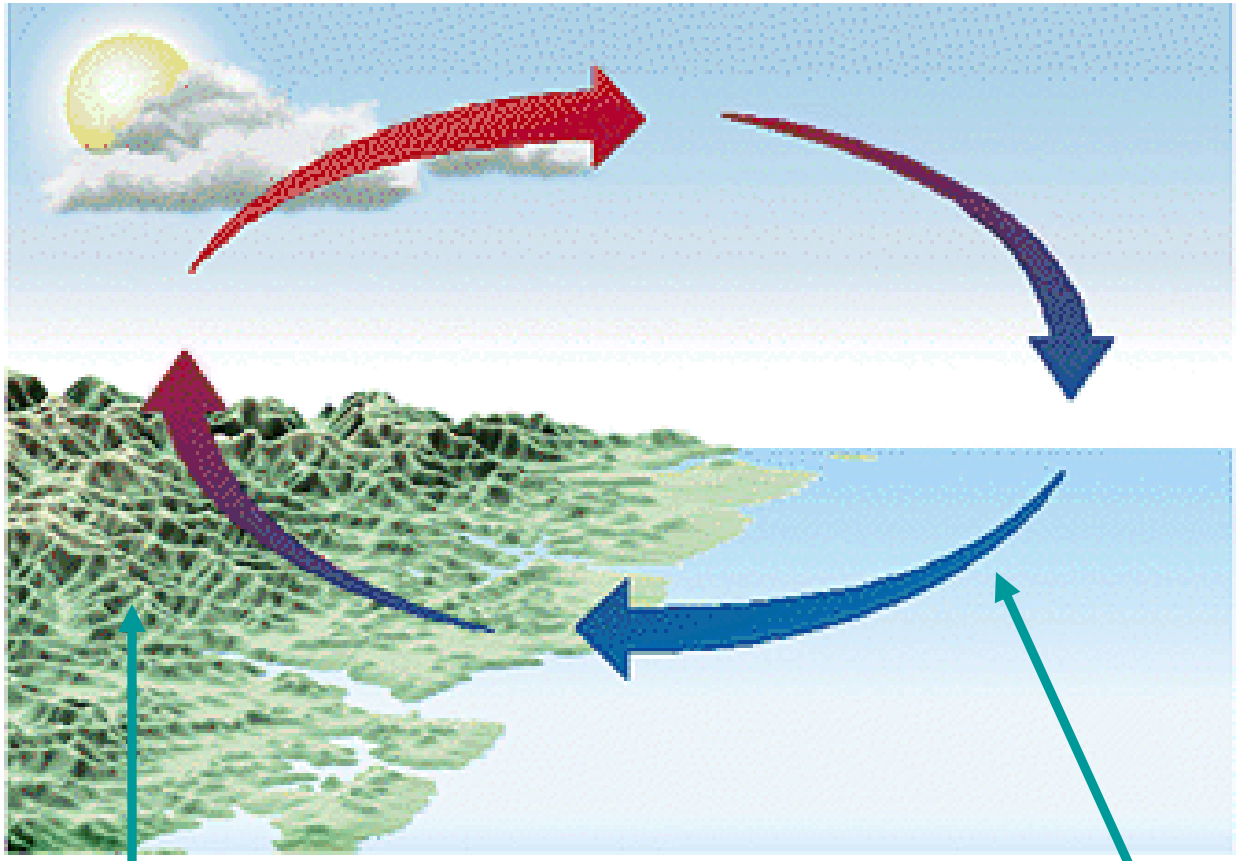


# Application of Conduction

Uses of conductors:

- Used in situations where heat has to be transmitted quickly.
- Cooking utensils
- Heating elements in ovens, kettles

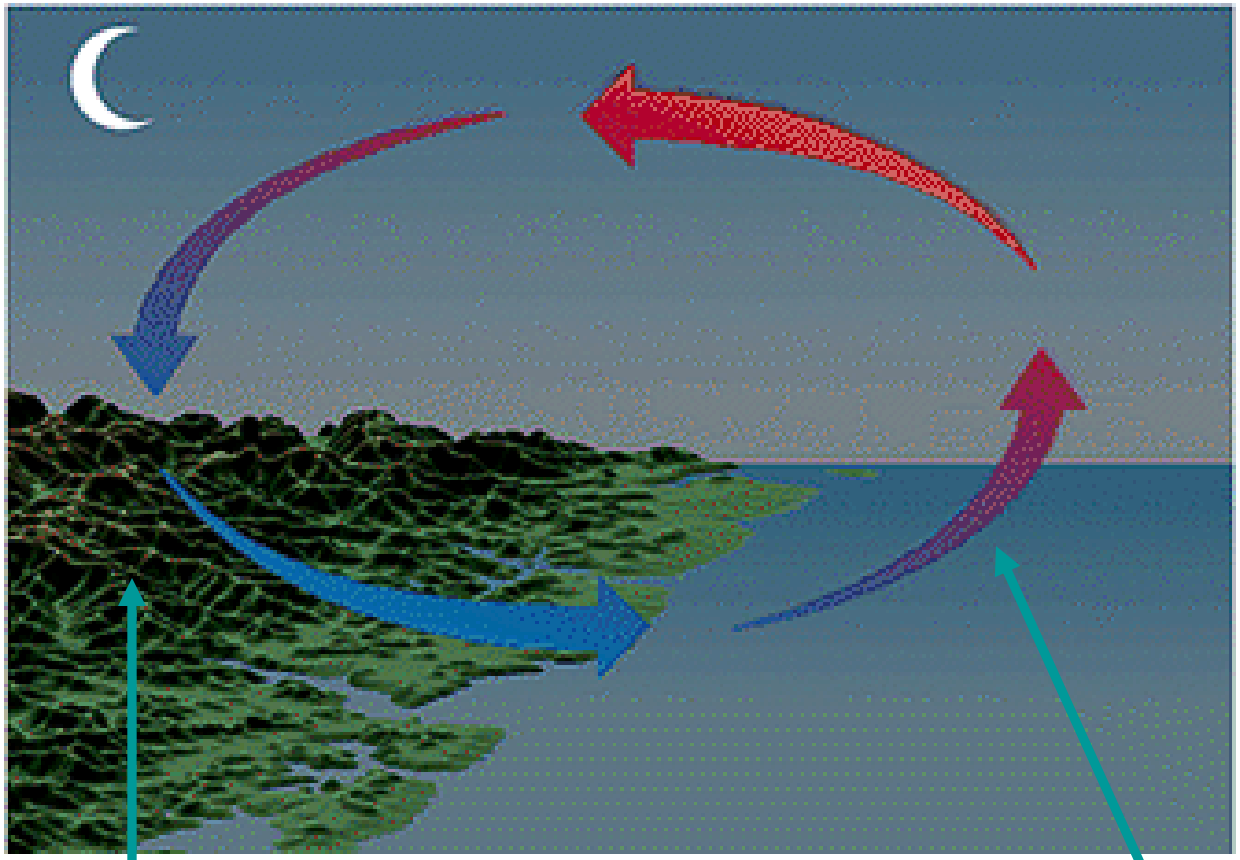
- Convection in Nature: Sea breezes



Land mass heats up faster than water. Air above land heats up, rising up as it is less dense

Water body takes longer time to heat up. Air above water is cool. Will flow towards land as air above land rises.

- Convection in Nature: Land breezes



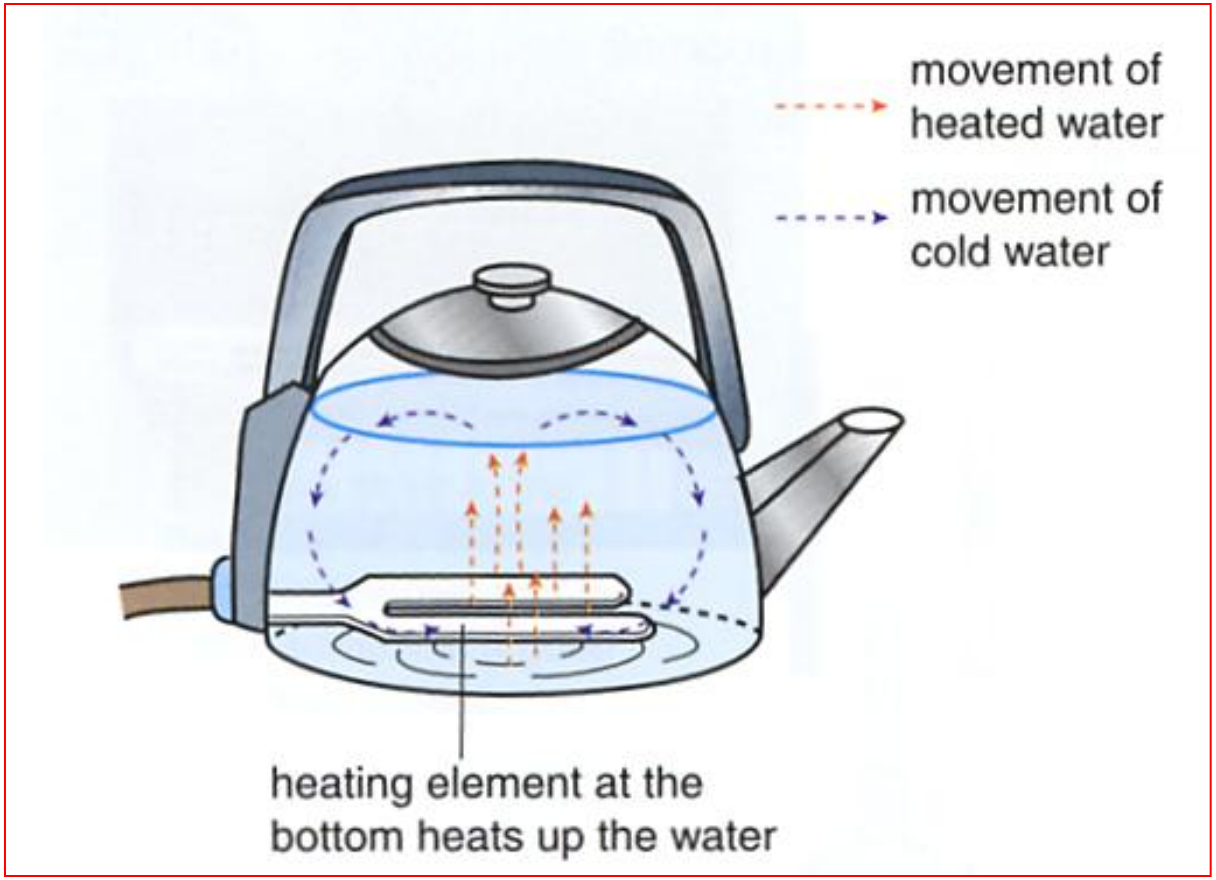
Land mass loses heat faster than water. Air above land cools down faster, and will flow towards water as air above water rises

Water body takes longer time to lose heat also. Air above water is warm. Will rise as it is less dense

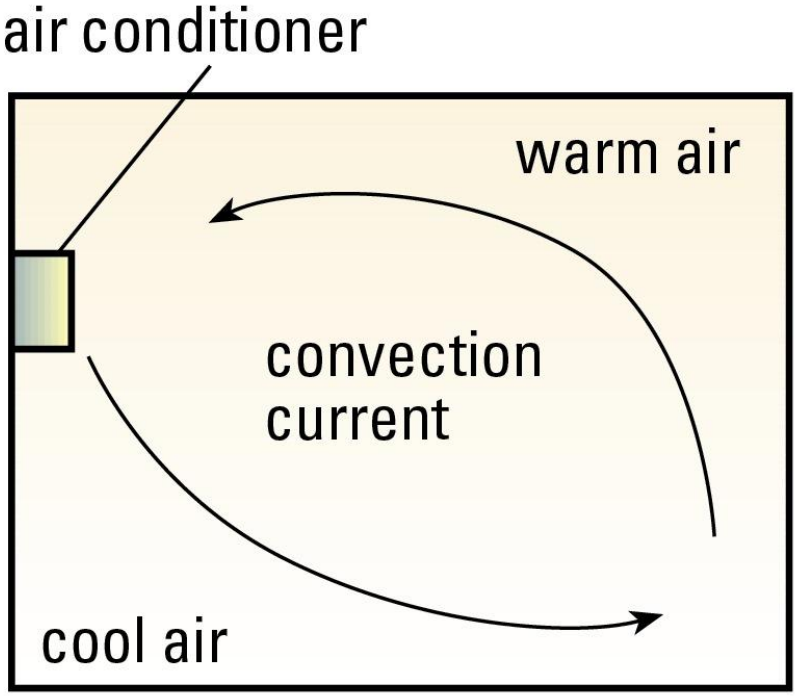
# Application of Convection

- Heating elements in kettles
  - Where is the heating element usually found?
- Air-conditioning
  - Where are air conditioners normally installed?
- Refrigerator
  - Where is the freezer located?

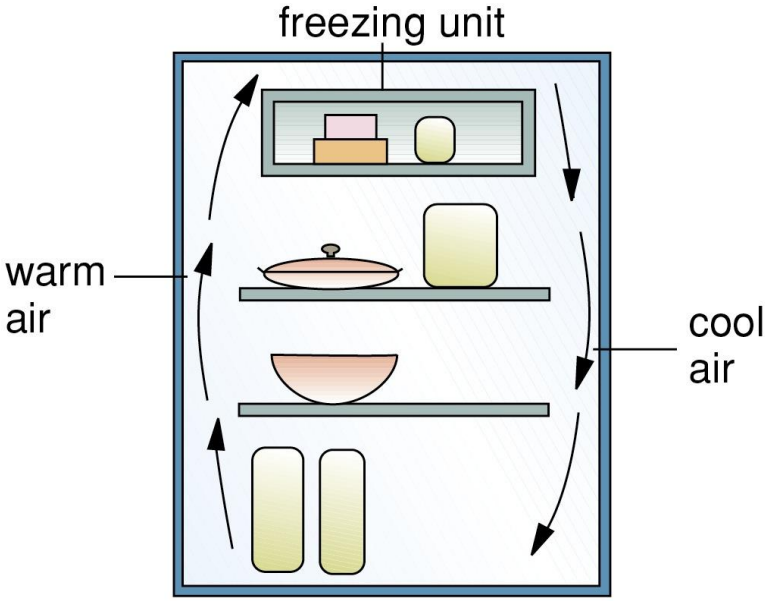
# Application of Convection



# Application of Convection




Air conditioners are installed near to the ceiling of rooms to facilitate setting up convection currents as cooler air sinks




Freezing unit is placed at top to cool the air and facilitate the setting up of convection currents.

# Convection & Conduction

## Differences

- Movement of molecules

  In conduction, molecules vibrate with more K.E. affecting neighbors. In convection, there is movement of molecules where warmer, less dense matter rises, causing cooler, denser matter to move in

## Similarities

- Both processes require matter!

Think… how do we receive heat from the sun? Since space is vacuum…

# Radiation

Radiation is a method of heat transfer by which a heat source transmits infra-red waves

- It does not require a medium.
- It can take place in vacuum.
- When absorbed, the energy of infra-red waves is transformed into thermal energy of the receiving body.
- All objects emits radiation.
- The hotter the object, the greater is the radiation.

# Radiation

## Absorption of infrared radiation

- Infrared radiation is absorbed by all objects and surfaces.
- The absorption of radiant heat causes a temperature rise.

## Emission of infrared radiation

- Infrared radiation is emitted by all objects and surfaces.
- This emission causes the temperature of the objects themselves to fall.

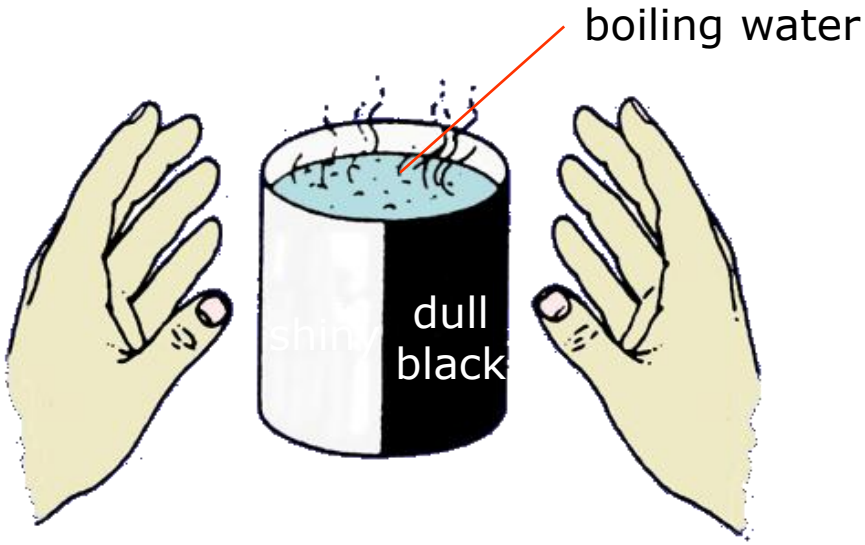
- In general, good emitter of radiation is also a good absorber of radiation.
- Conversely, poor emitter of radiation is also a poor absorber of radiation.

# Factors affecting Radiation

- Color & texture of surface
- Surface temperature
- Surface area

# Factors Affecting Radiation

## Colour & Texture of Surface




which side feels hotter?

**Dull black surfaces are good emitters of radiation than shiny ones**

http://schools.moe.edu.sg/canberra/science/genscience/scienceflashfiles/frame_hotpotato_flash3.htm

# Factors Affecting Radiation

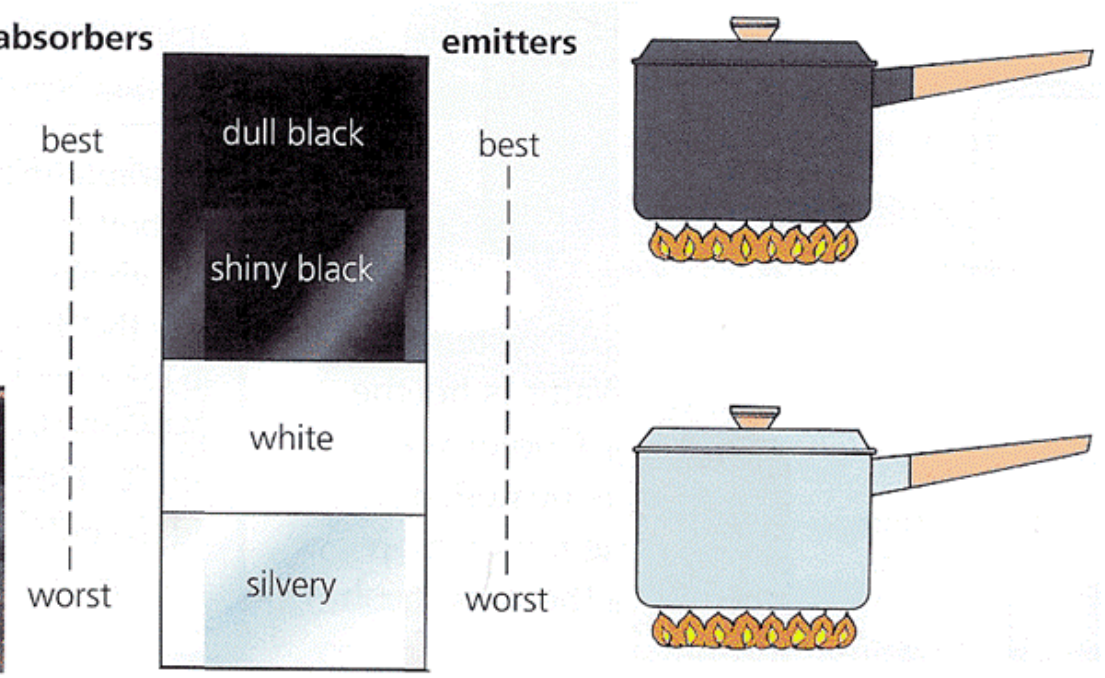
## Colour & Texture of Surface


Eg. Darker clothes-feel hotter because absorbs more heat than light coloured clothes

Shiny Teapot – bad emitters of heat

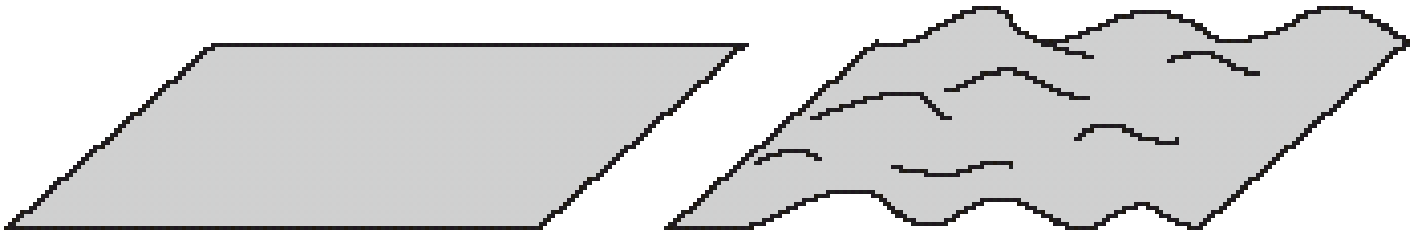
# Factors Affecting Radiation

## Colour & Texture of Surface



# Factors Affecting Radiation

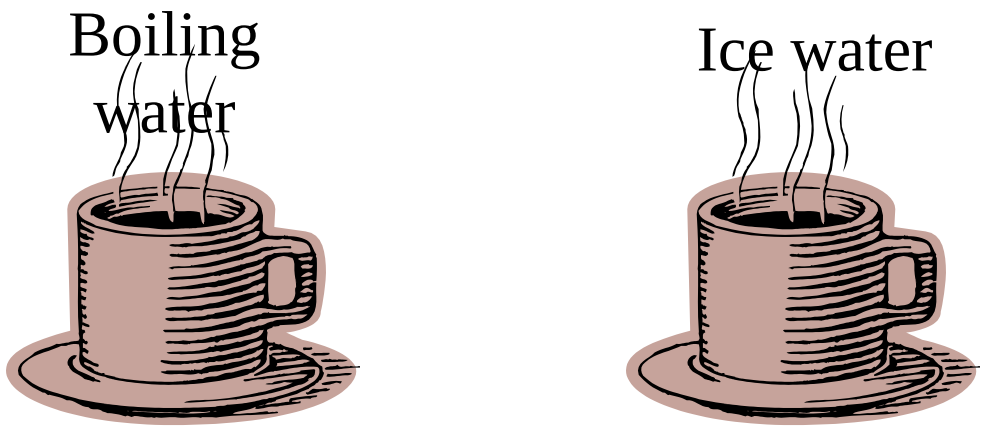
## Colour & Texture of Surface



Rough objects are better absorber and emitter of radiation than smooth objects. (because of its greater surface area)

# Factors Affecting Radiation

## Surface Temperature




Which cup radiates more heat?

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

# Factors Affecting Radiation

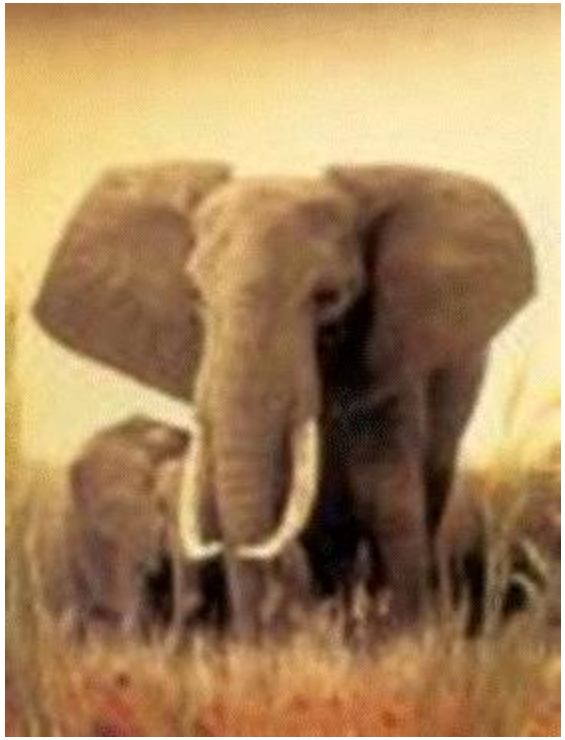
## Surface Area

Imagine you are lost in North Pole, with no winter clothes, how do you keep yourself warm?

**The greater the surface area of the object, the faster is the rate of heat transfer from it**

# Factors Affecting Radiation

## Surface Area



the big ears of the African elephant provide a large surface area for the giant mammal to cool off quickly in hot weather

# Factors affecting Radiation

- Color & texture of surface
  - Dull, black surface better heat emitter/absorber of radiation
  - Shiny, white surface poor heat emitter/absorber of radiation

- Surface temperature
  - Higher temperature, higher heat transfer

- Surface area
  - Larger surface area, larger area to emit heat – so emit radiation at higher rate.

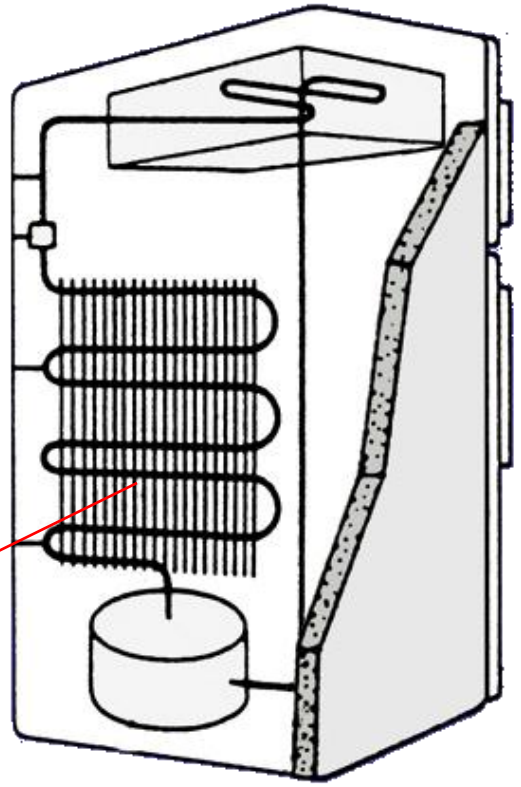
# Application of Radiation

## uses of good and poor emitters of radiation

Good emitters are used in situations where heat has to be quickly emitted.

| Good Emitters | Poor Emitters |
|---|---|
| Cooling fins at the back of a refrigerator painted dull black | A shiny metal teapot |

Keep liquid warmer for longer time



cooling fins at the back of a refrigerator painted dull black

refrigerator

# Application of Radiation

## uses of good and poor absorbers of radiation

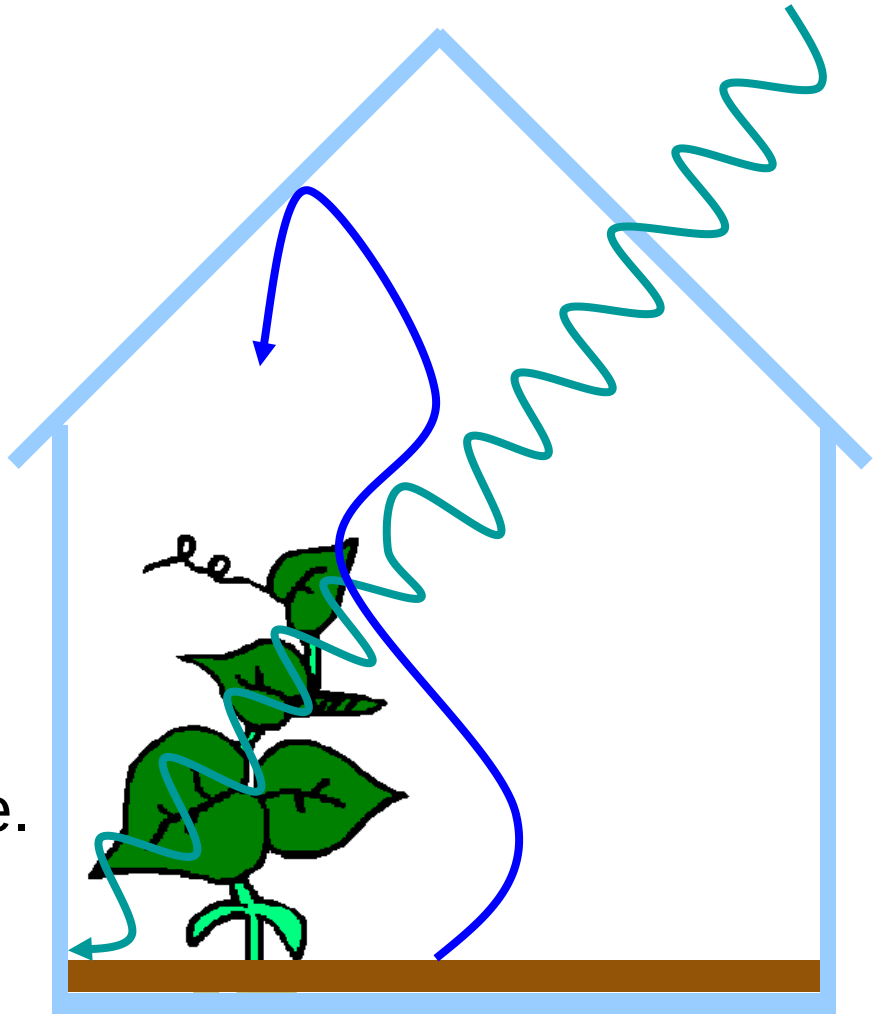
Good absorbers are used in situations where heat has to be quickly absorbed.

| Good Absorbers | Poor Absorbers |
|---|---|
| Solar heating panels are painted in dull black paint | Houses in hot countries and factory roofs are painted in white, light-coloured paint, aluminium paint |
| | Light colours are chosen for clothes and cars in hot weather |

solar panels

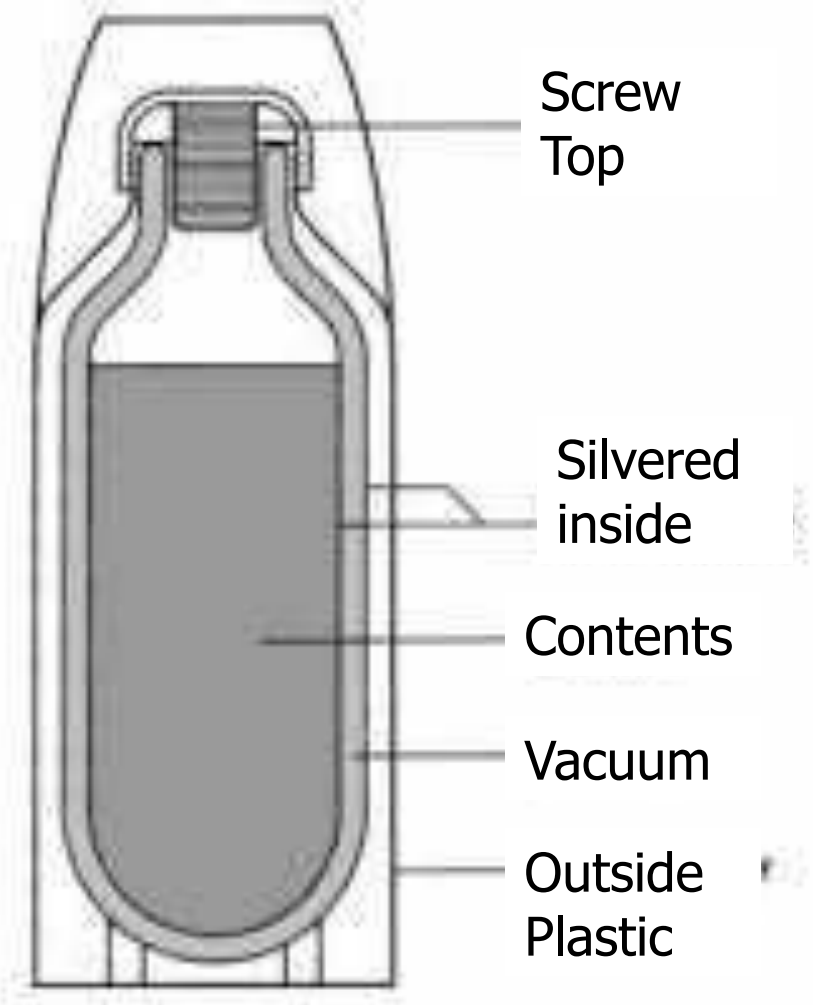
# Application of Radiation

- Greenhouse
  - Glass allow IR radiation from sun (short wavelength because of higher temp.) to pass through
  - Do not allow IR radiation from soil (long wavelength because of low temp.) to pass.
  - Heat trapped in greenhouse. Good for plant growth

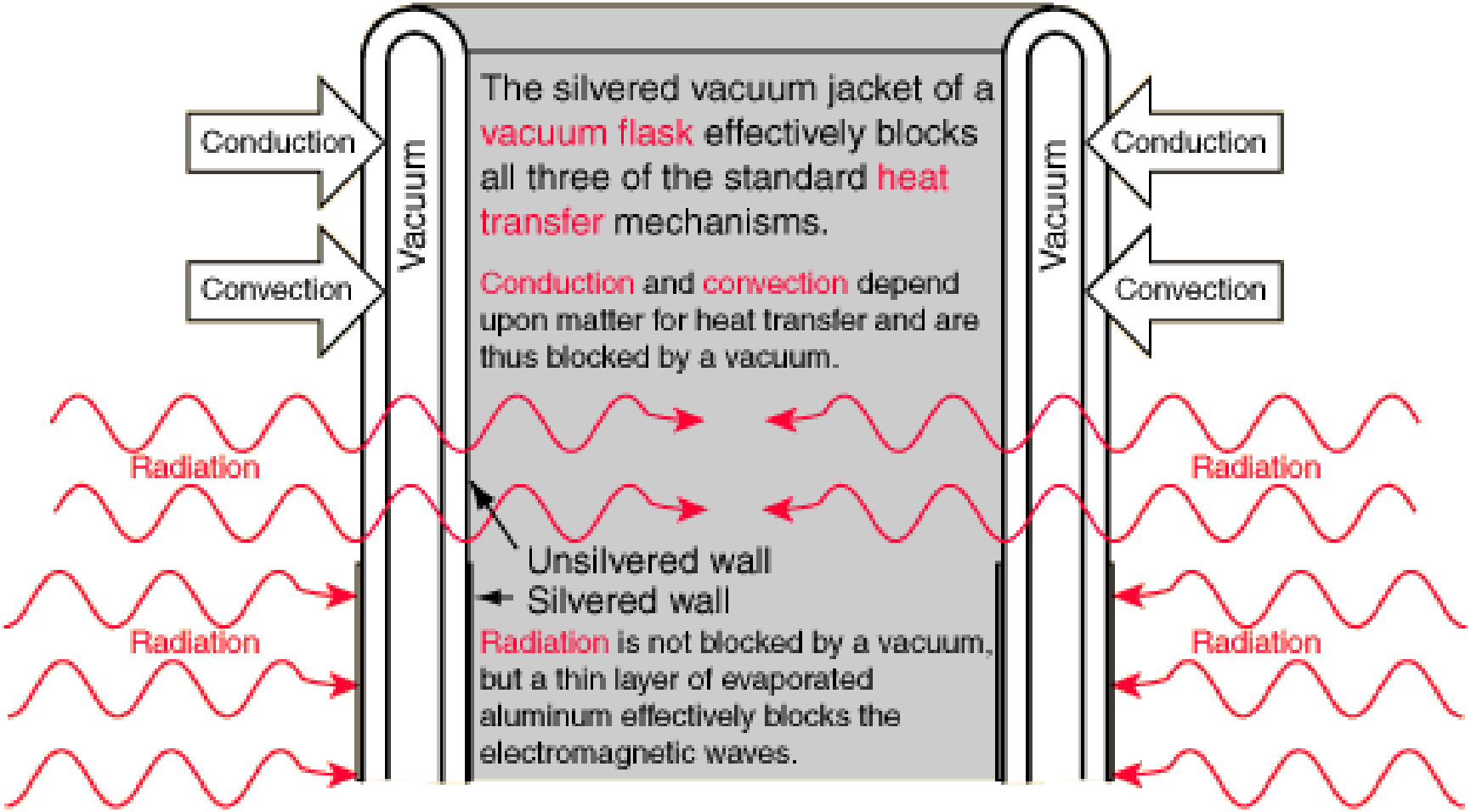


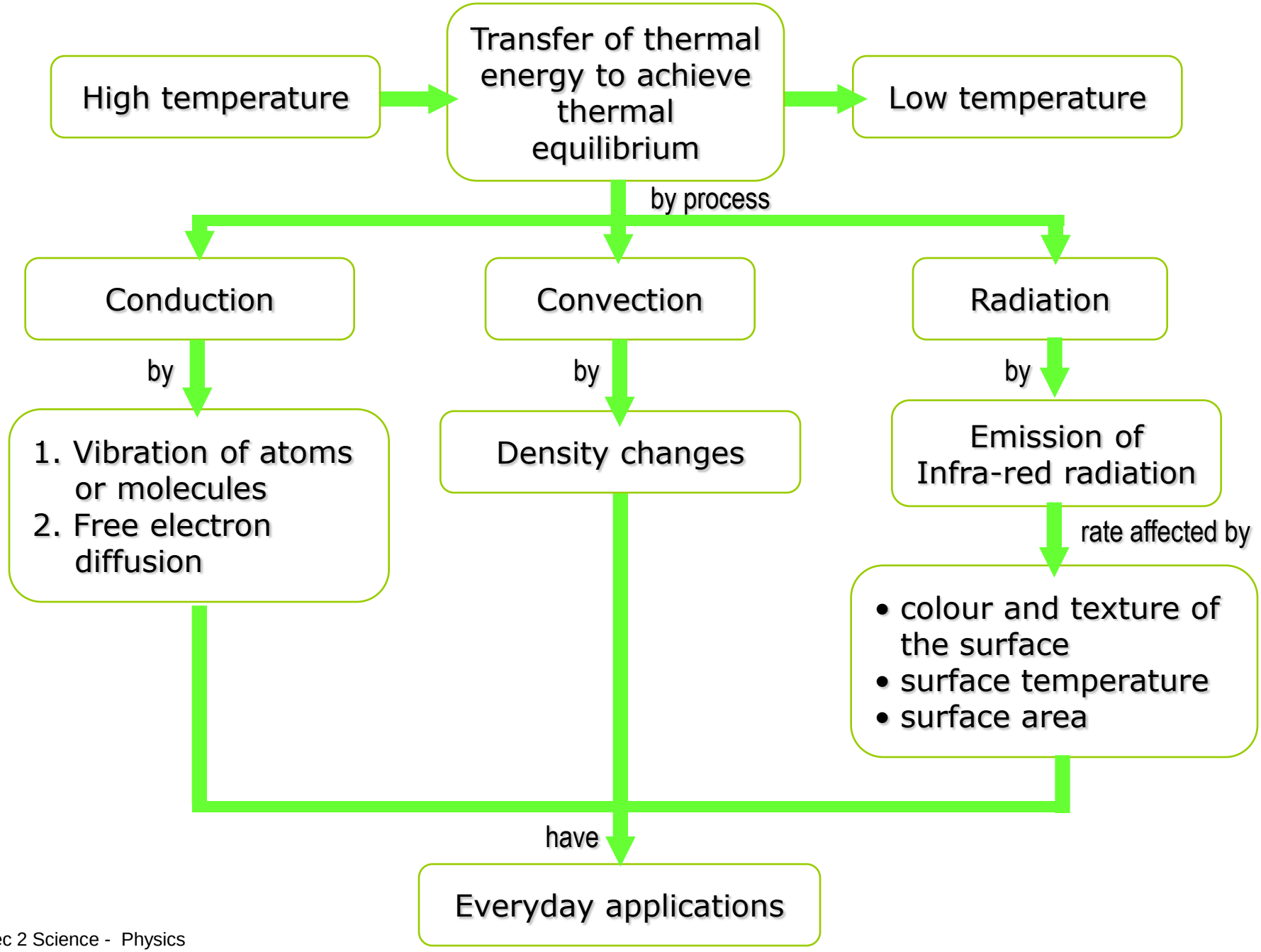
# Application of Radiation

- Vacuum flask
  - Layer of vacuum prevent convection and conduction. NOT radiation.
  - Silvered glass wall minimize heat loss due to radiation
  - Plastic screw top minimize evaporation and convection from flask mouth



# Application of Radiation




High temperature
Transfer of thermal energy to achieve thermal equilibrium
Low temperature
by process
Conduction
Convection
Radiation
by
by
by
1. Vibration of atoms or molecules
2. Free electron diffusion
Density changes
Emission of Infra-red radiation
rate affected by
• colour and texture of the surface
• surface temperature
• surface area
have
Everyday applications