Heat Transfer

Objectives

- Distinguish the three types of heat transfer (radiation, conduction, convection).
- Explain the difference between thermal insulators and conductors.
- Understand and apply the concept of adiabatic processes.

Energy in the Earth Systems

- Energy in the Earth Systems can exist in a number of forms. A few examples are:

Thermal (heat) energy found in Earth

Chemical energy stored in the bonds of fossil fuels

Mechanical (motion) energy like that found in ocean tides

Specific Forms of Energy

(Each has both PE & KE)

1. **Chemical** energy

The energy associated with chemical changes (*energy is also involved with physical changes*)

- a. Endothermic $\Delta H = +$ → heat flows **into** the reaction mixture from the surroundings
- b. Exothermic $\Delta H = -$ → heat flows **from** the reaction mixture into the surroundings
- c. Activation energy → The energy needed before a chemical reaction can take place (e.g. In order to downhill ski, energy must be available to take you to the top of the hill)

2. Mechanical energy

when energy exerts a force

- 3. **Electrical** energy
  the flow of
  electrons (e-)

4. Light energy

(electromagnetic **radiation**)

- a. gamma … *highest energy, highest frequency, shortest wavelength*
- b. X-ray
- c. UV
- d. visible (VIBGYOR) … *400 nm to 700 nm*
- e. infrared
- f. microwave
- g. radio… *lowest energy, lowest frequency, longest wavelength (> 1 m)*

5. Sound energy → sonar, ultrasound

6. Magnetic energy → magnetic field (NMR diagnostic techniques) MRI

7. **Heat** energy → form of energy that takes into account the quantity of matter

8. Activation energy → The energy needed before a chemical reaction can take place (e.g. In order to downhill ski, energy must be available to take you to the top of the hill)

9. **Nuclear** Energy → fission (splitting atoms), fusion (combining atoms)

Energy Units

- 1. **Joule** (j) → *When a force of 1 Newton is applied through a distance of 1 meter, 1 joule of work is done*
  - *E (joules) = f (Newtons) x d (meters)*
- 2. **Calorie** → *The amount of energy required to raise 1 gram of water, one degree Celsius.*
  - *1 calorie = 4.18 joules*
  - *1 j = 2.39 X 10^{-1} cal*
  - *1000 calories = 1 Calorie (kilocalorie)*

Units of Measurement

Temperature Scales

Temperature

A measure of the average kinetic energy (motion) of molecules in a substance.

Most people equate temperature with how “hot” or “cold” an object is. *But an Alaskan or an Egyptian would define hot and cold differently than you and I.*

80 ºF (27 ºC) would be “hot” to an Alaskan But “cool” to an Egyptian

Temperature Scales

Temperature

A measure of the average kinetic energy (motion) of molecules in a substance.

Most substances expand with an increase in temperature and contract as the temperature decreases. (e.g. sidewalks in winter versus summer).

This explains how thermometers work (*the liquid inside expands & contracts*).

Temperature

The measure of heat intensity: describes the average kinetic energy (KE) of the molecules in a system

- B. Conversions
  - 1. Fahrenheit and Celsius
    - F = 9/5 C + 32
    - C = 5/9 (F - 32)
  - 2. Kelvin vs. Celsius
    - K = C + 273
    - 1 K increment = 1 C

Fill In Values

C	K
0	
	0
100	
	100

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Fill In Values

C	K
0	273
-273	0
100	373
-173	100

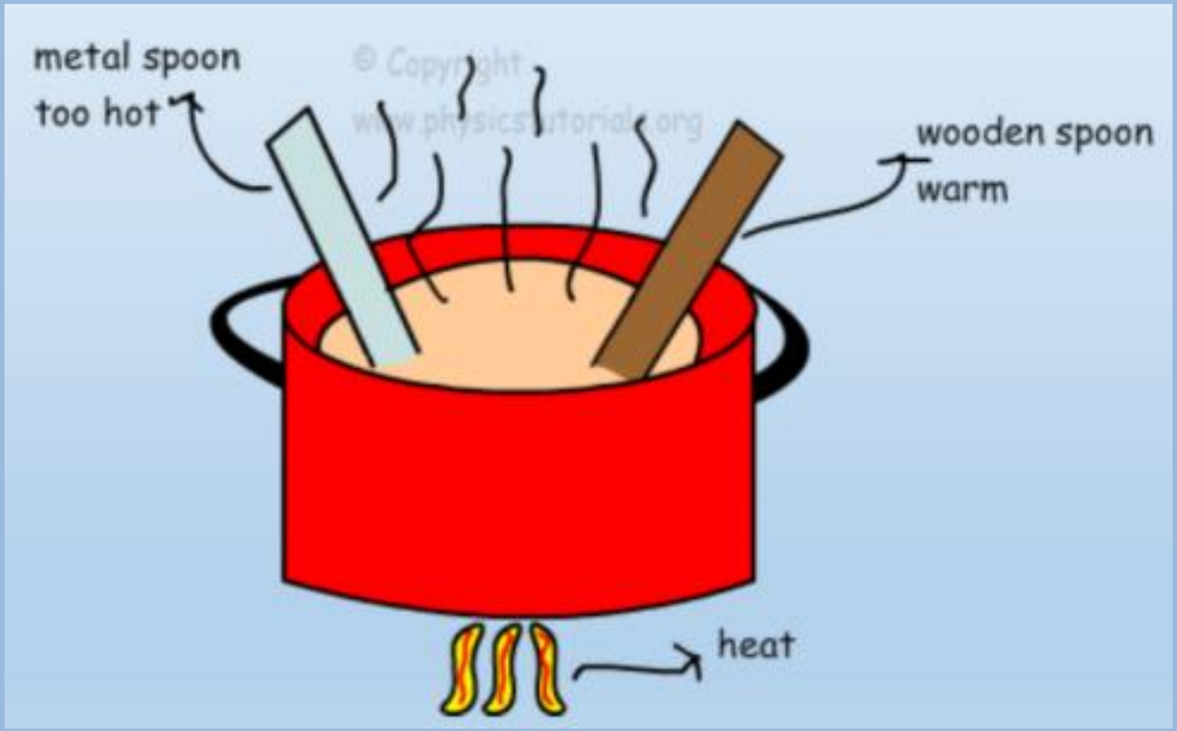
Heat Flow

- Thermal **expansion** occurs when particles of matter move farther apart as temperature increases, therefore, **volume increases**.

- As temperature decreases, there is thermal **contraction** of particles, therefore, **volume decreases**, because they slow down, collide less, and exert less force.

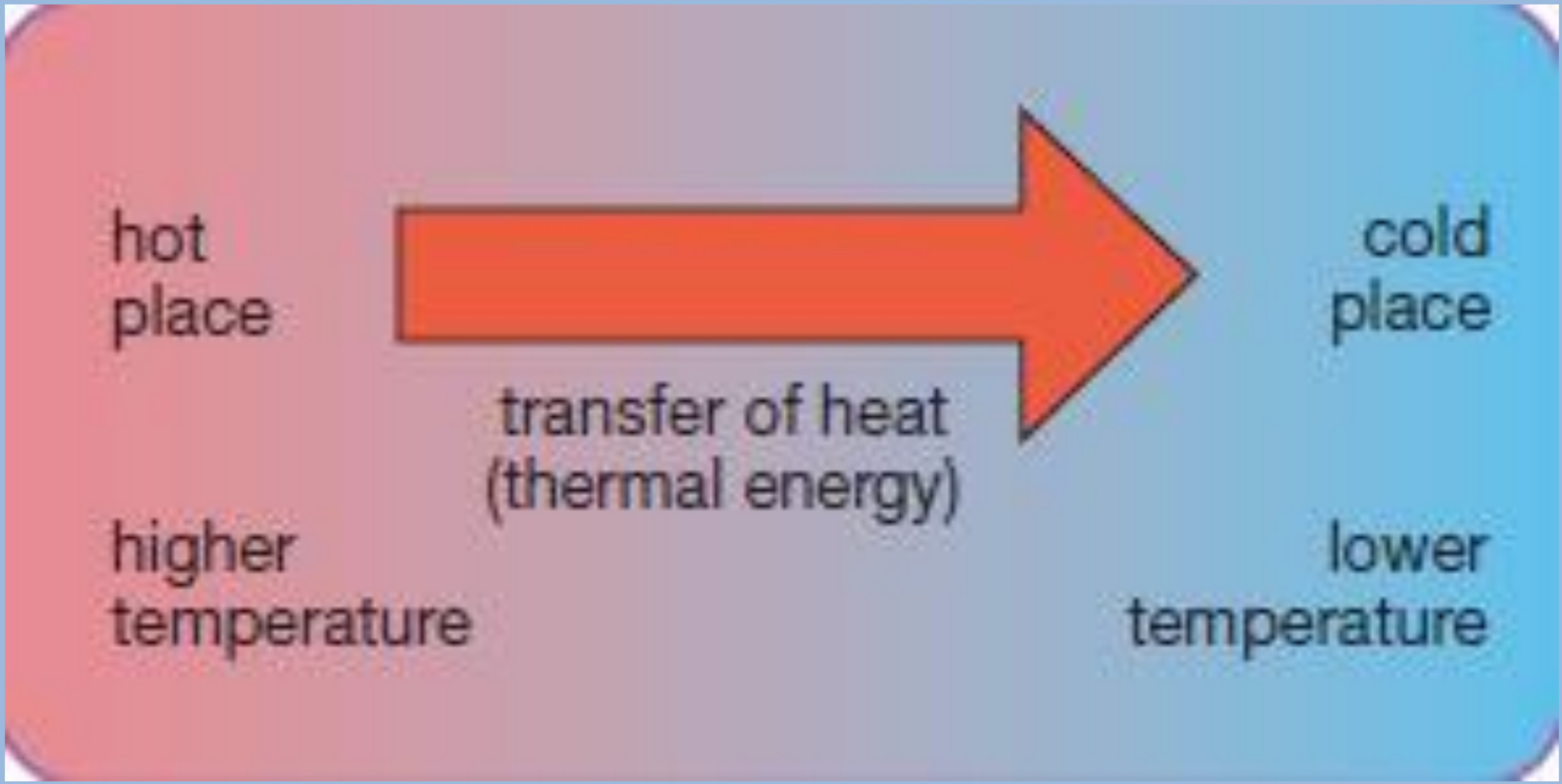
Heat Flow

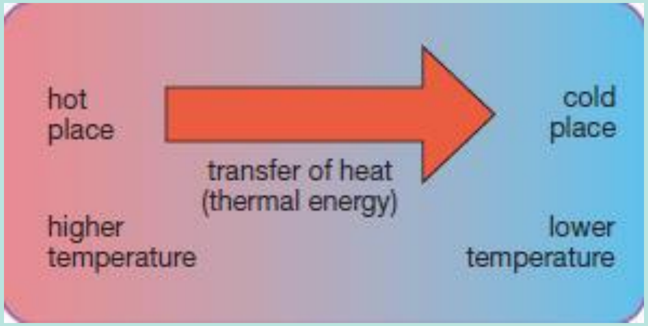
- Temperature relates to the **specific heat** of a substance.



- **The metal spoon heats up faster than the wooden spoon.**

Heat Transfer





Heat Flow

- **Heat flows spontaneously from hot objects to cold objects.**
- **The second law of thermodynamics (entropy) states that thermal energy can flow from colder objects to hotter objects only if work is done on the system.**
  - This is because matter goes from order to disorder spontaneously. Hotter objects have particles moving much faster (more random) than cooler objects. Therefore, hotter objects spread out faster than cooler objects.

Heat Flow

Thermal energy depends on the mass, temperature, and phase (solid, liquid, or gas) of an object.

e.g. A cup of tea and a teapot full of tea can have the same temperature, but the number of particles (related to mass) and the phase (s, l, g) affect the heat flow.

On the Kelvin scale, **absolute zero** is defined as a temperature of 0 kelvins.

Thermal Energy

Thermal energy depends on mass and temperature.

A. The tea is at a higher temperature than the lemonade.

B. The lemonade has more thermal energy because it has many more particles.

Thermal (Heat) Energy Transfer

Like matter, energy can be transformed from one form to another AND can move from one sphere to another

Thermal (Heat) Energy is transferred in one of three ways:

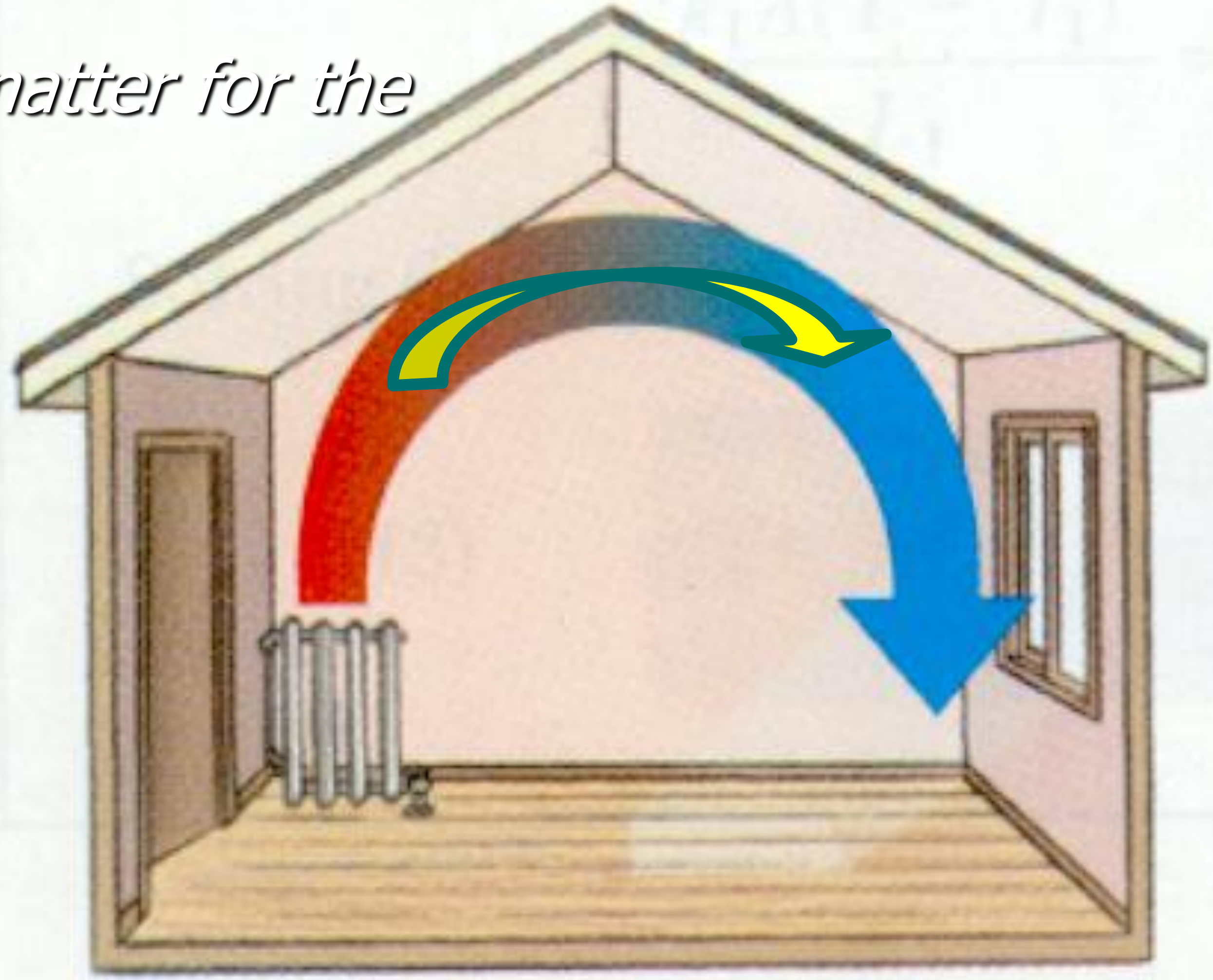
Conduction

Convection

Radiation

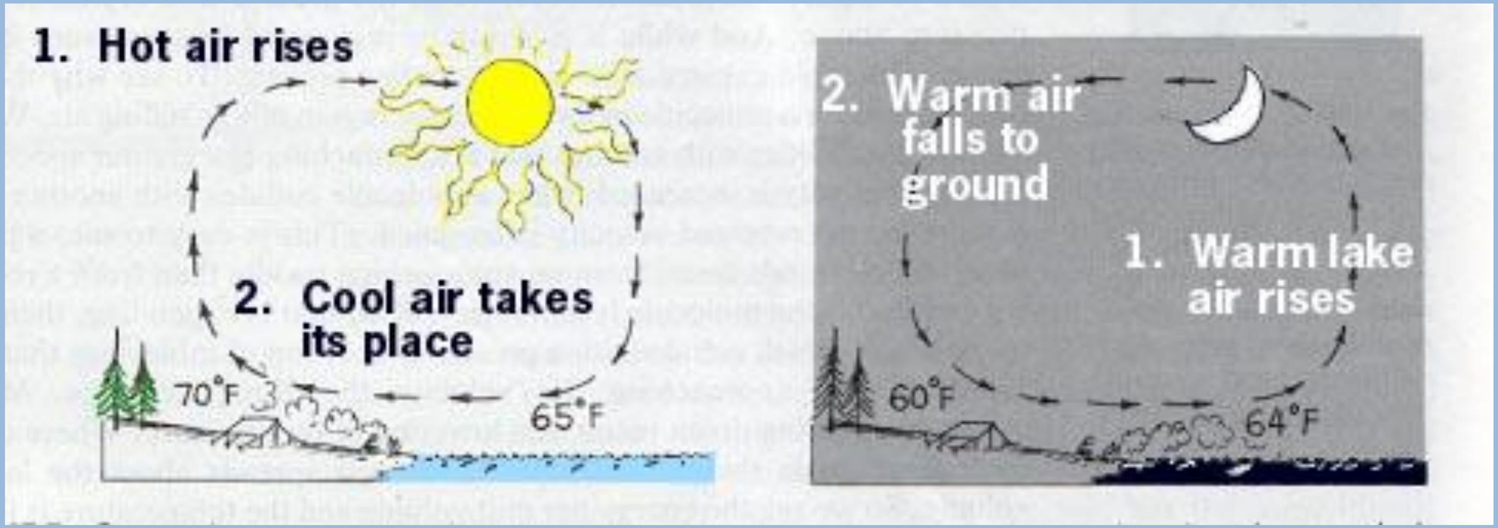
Convection

Requires matter for the transfer



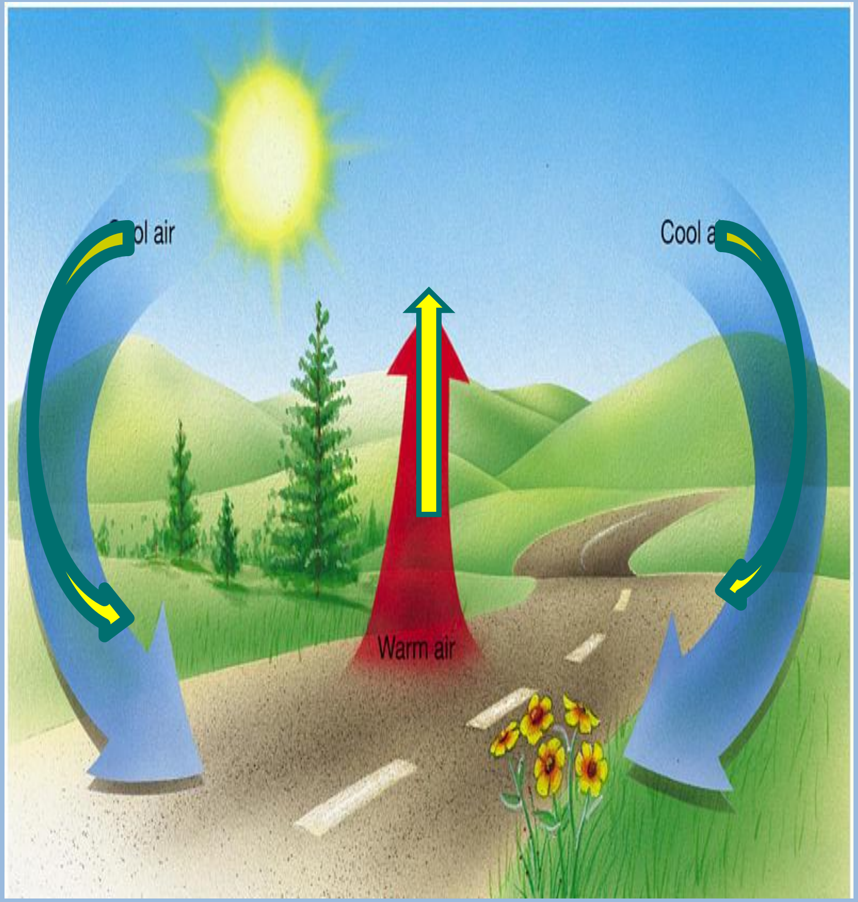
Heat Transfer

- A. Convection
  - (*requires matter for the transfer*)



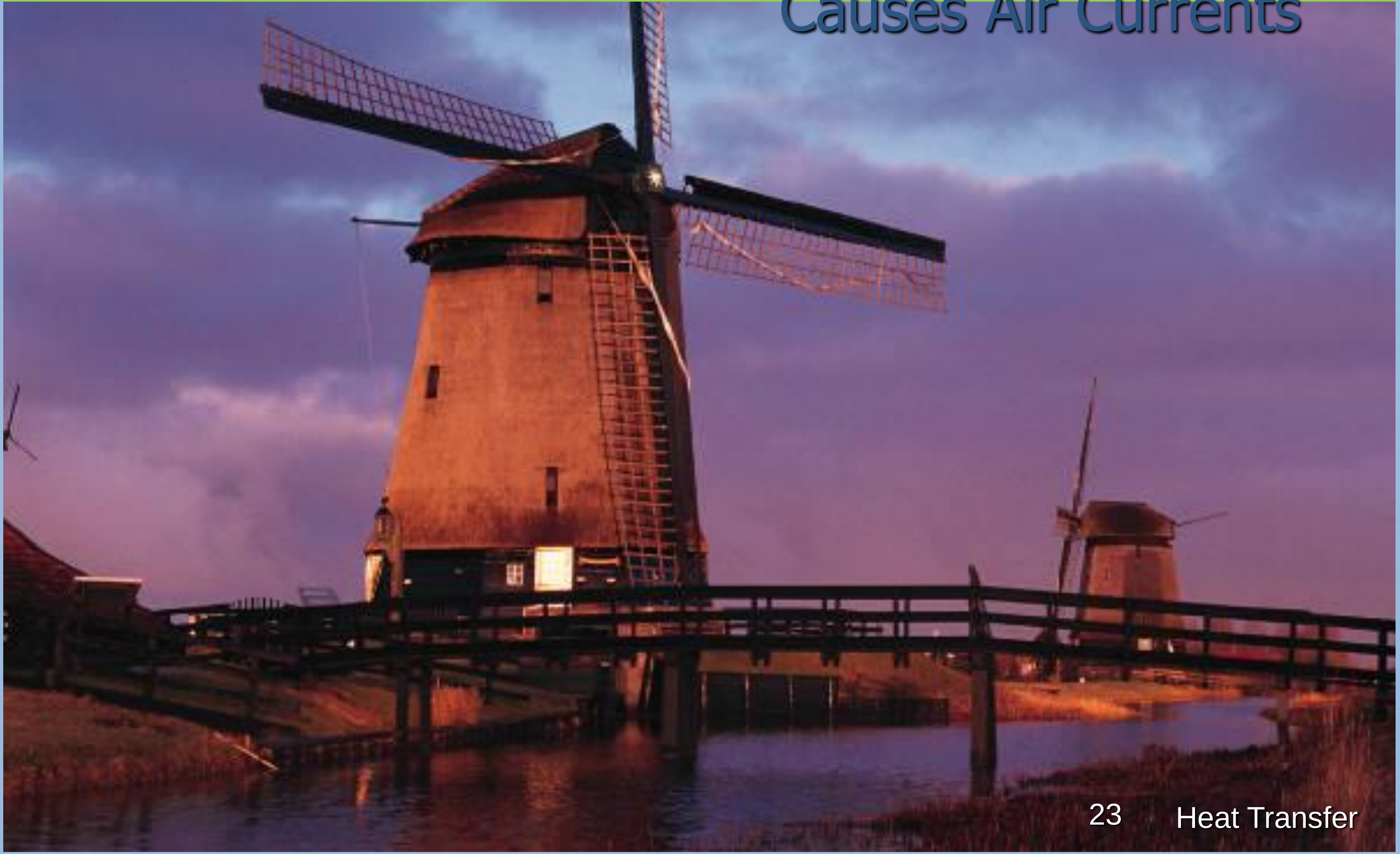
Convection

- Energy is transferred due to differences in density or temperature.
- The cooler material will sink, warmer material will rise
- This is true for heat <u>IN</u> and <u>ON</u> the Earth.

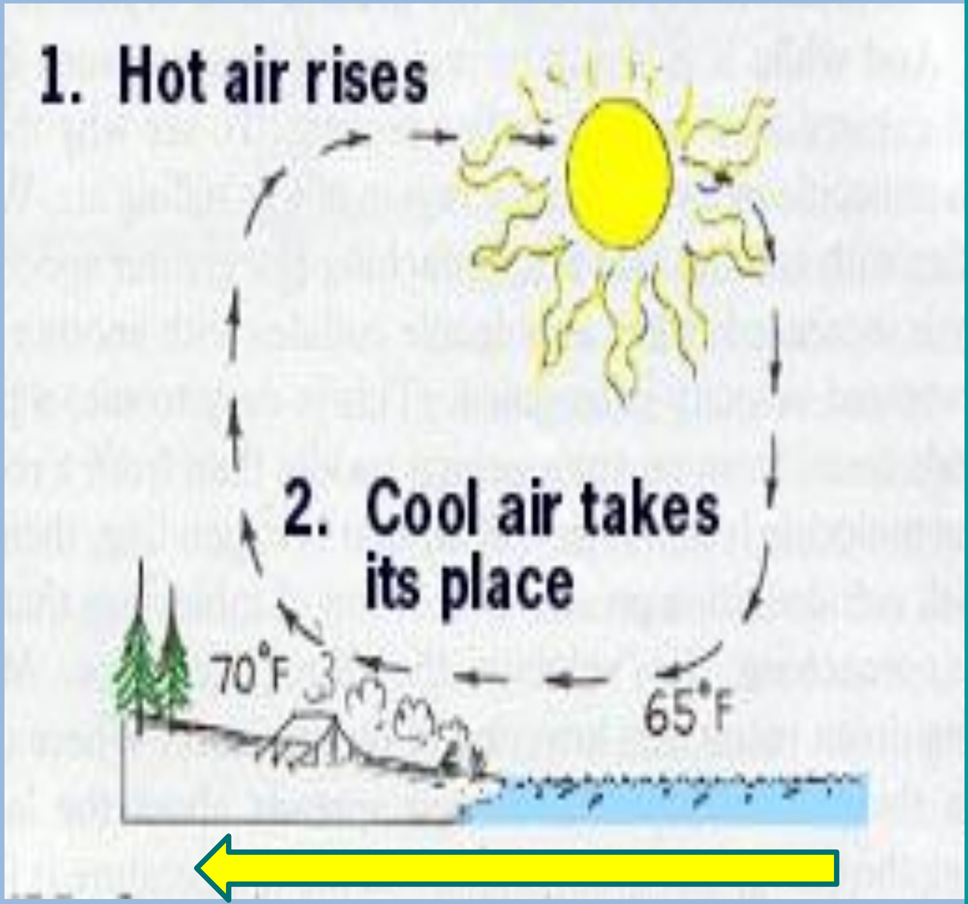


Convection

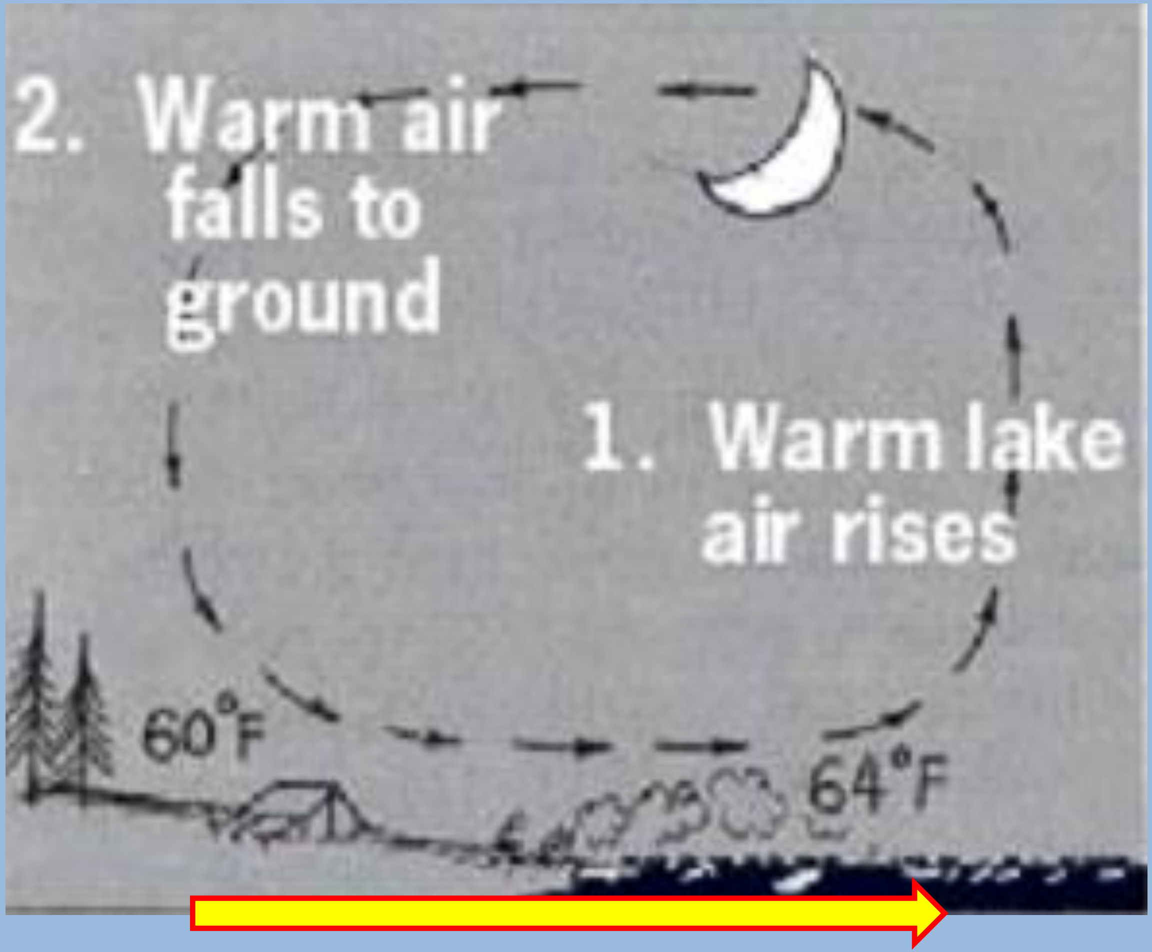
Causes Air Currents



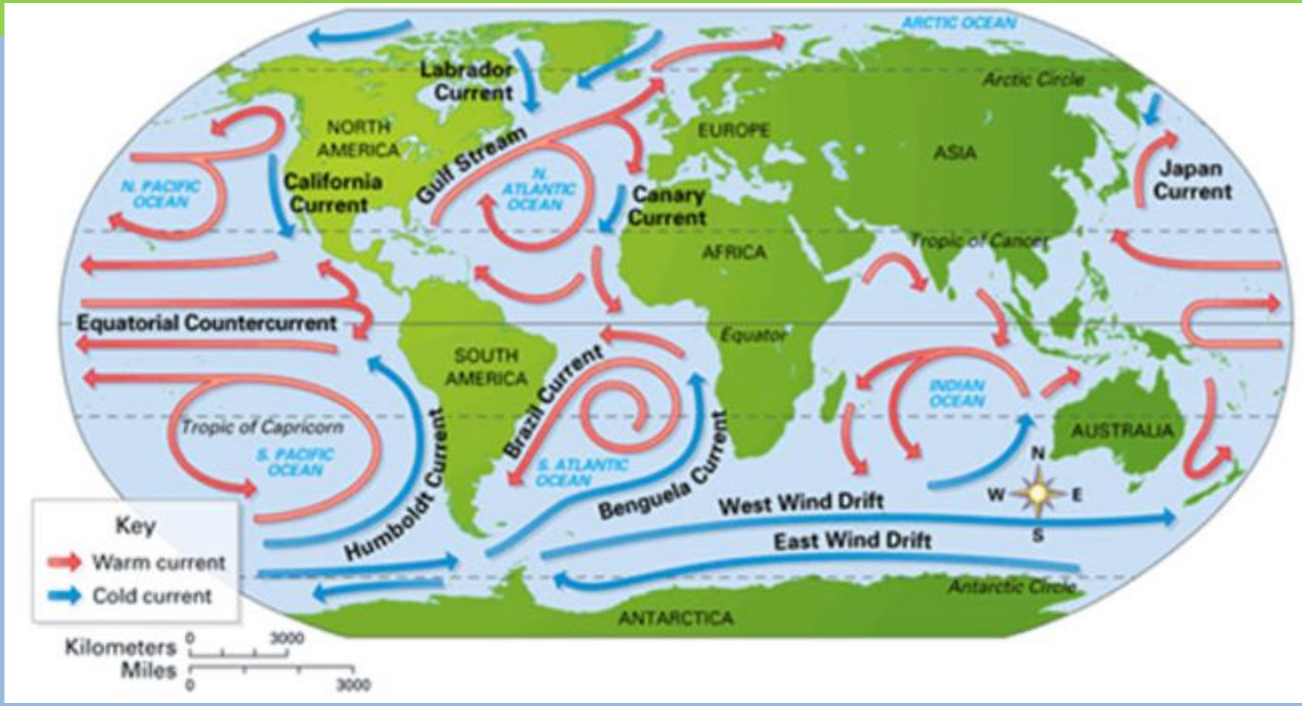
Convection



Convection

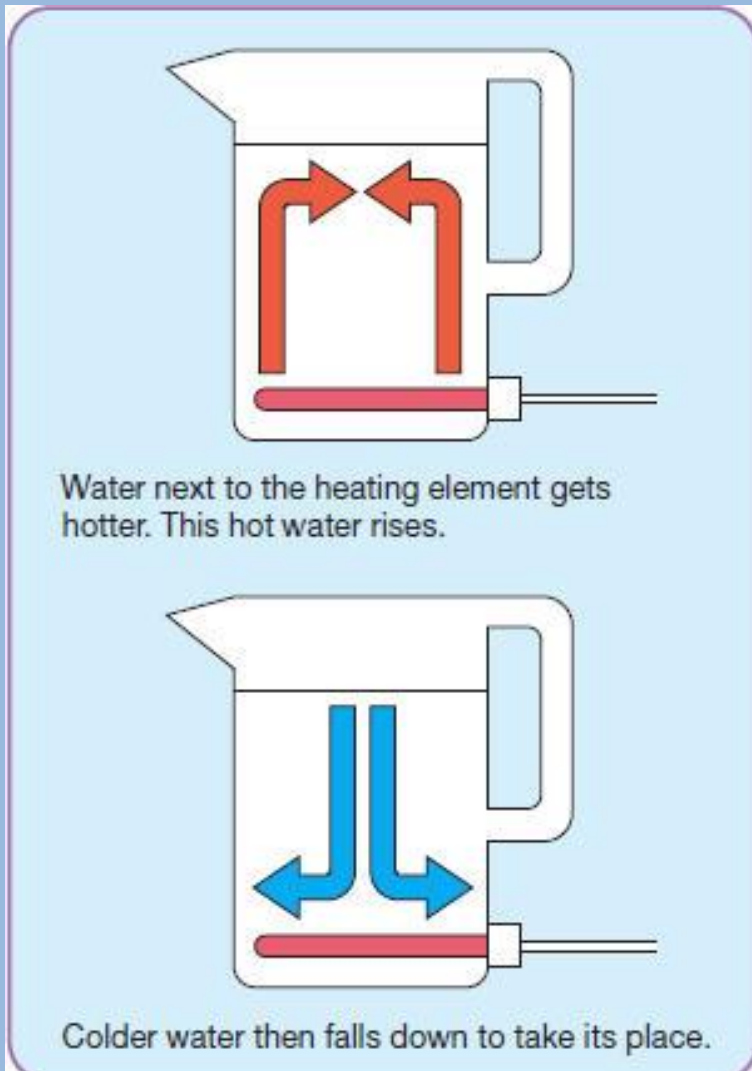


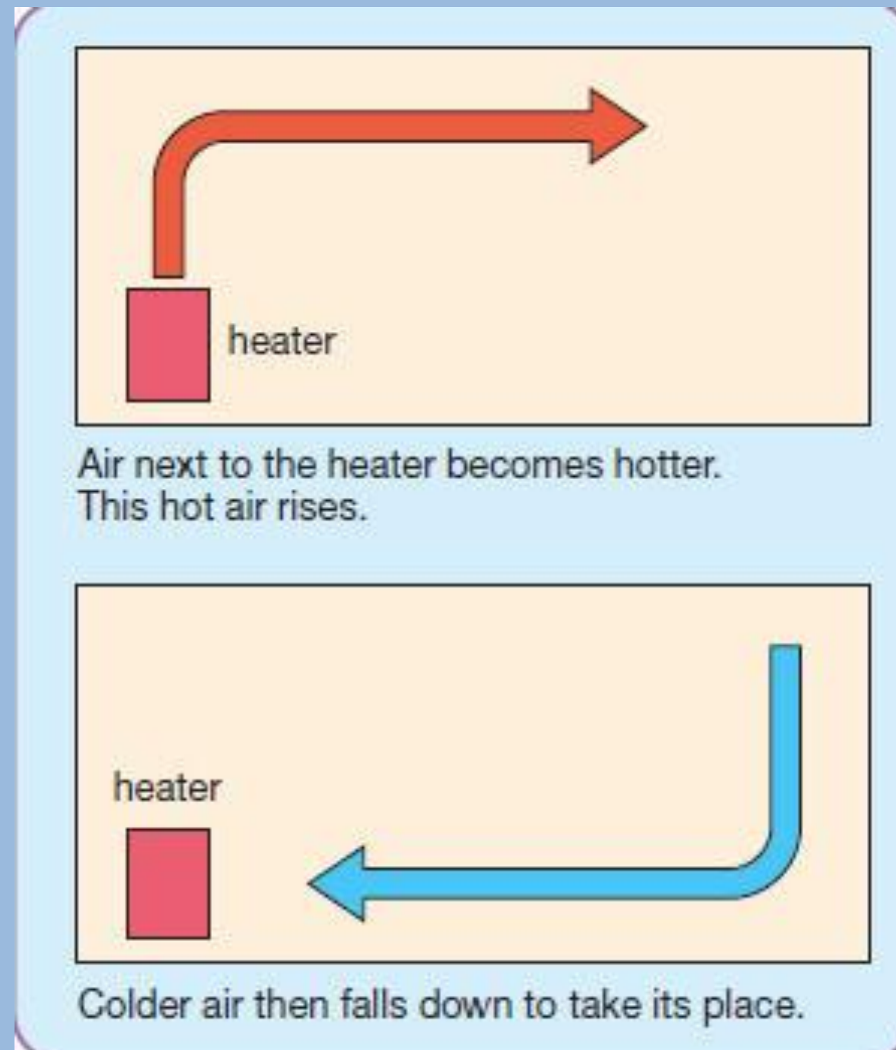
Convection



Ocean currents, Global wind patterns, and movement in the earth's crust all occur due to convection.

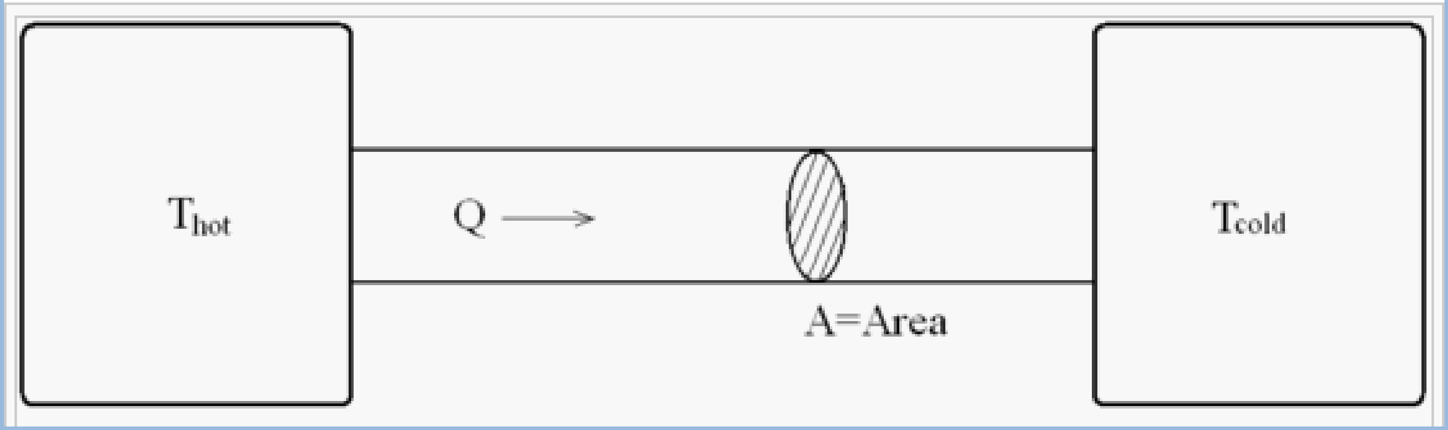
Convection


Water next to the heating element gets hotter. This hot water rises.
Colder water then falls down to take its place.


heater
Air next to the heater becomes hotter. This hot air rises.
heater
Colder air then falls down to take its place.

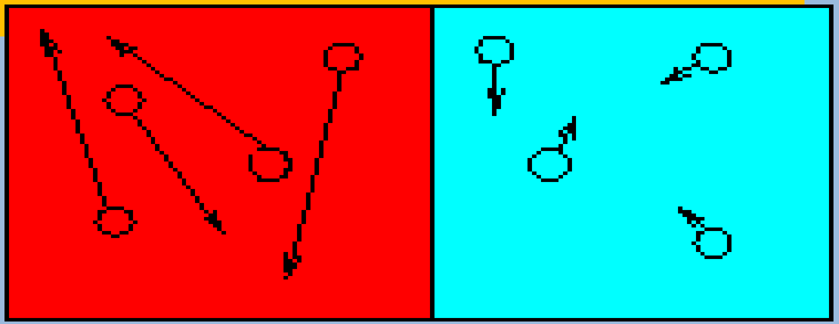
Heat Transfer

- B. **Conduction**
  - (*requires matter for the transfer*)



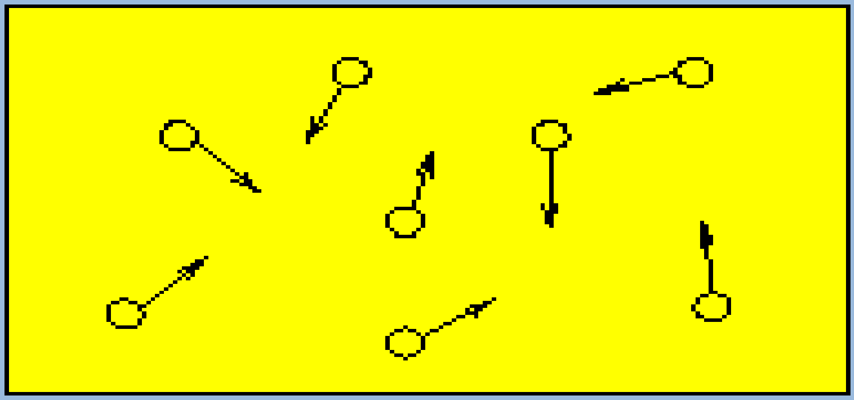
Conduction

Conduction – the transfer of heat by contact between molecules.



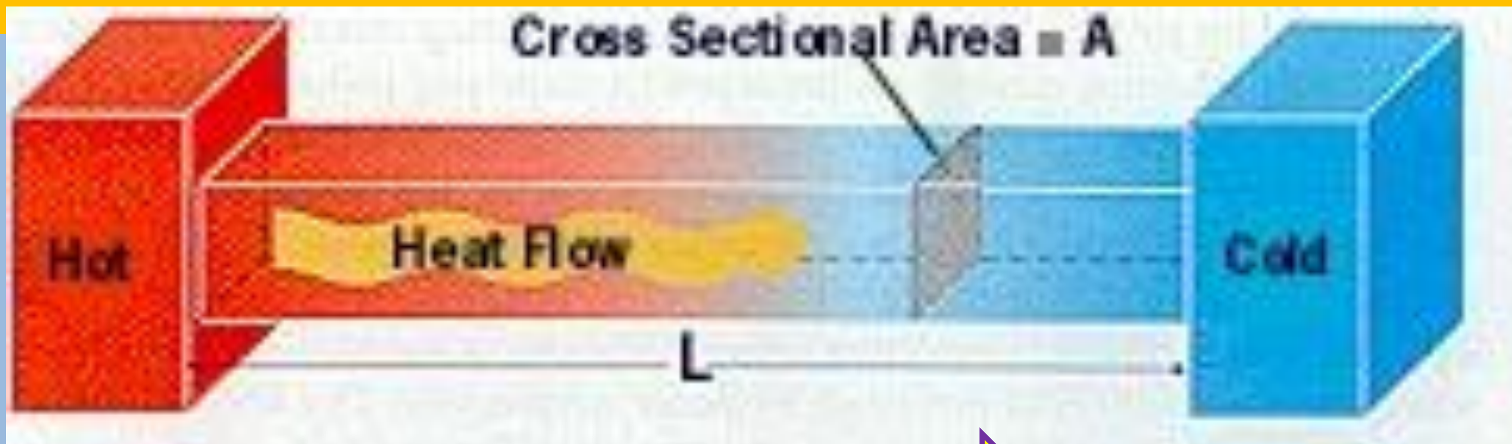
Fast (hot) atoms   Slow (cold) atoms

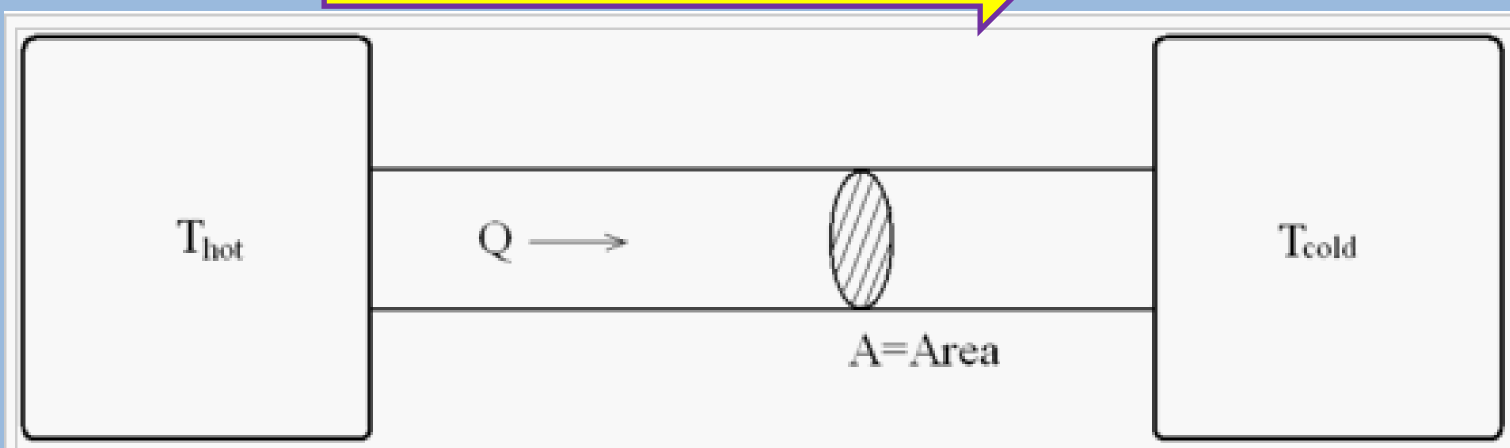
Conduction requires matter for the transfer



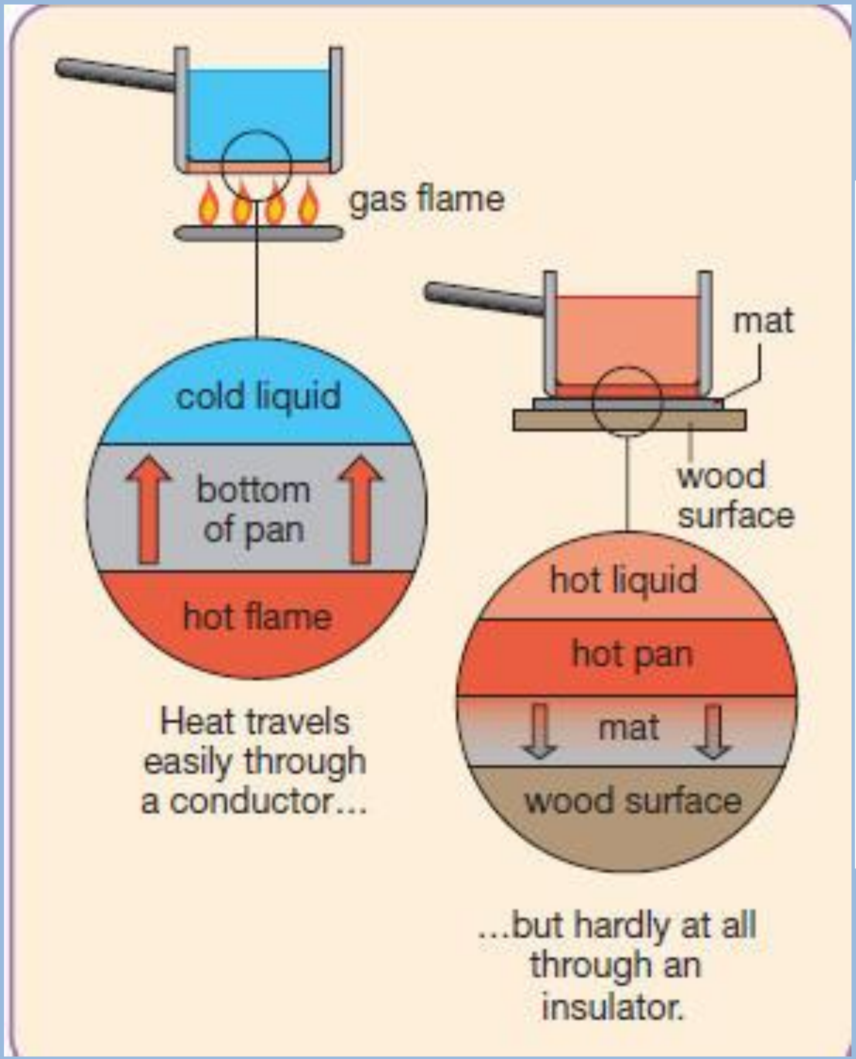
Common temperature

Conduction

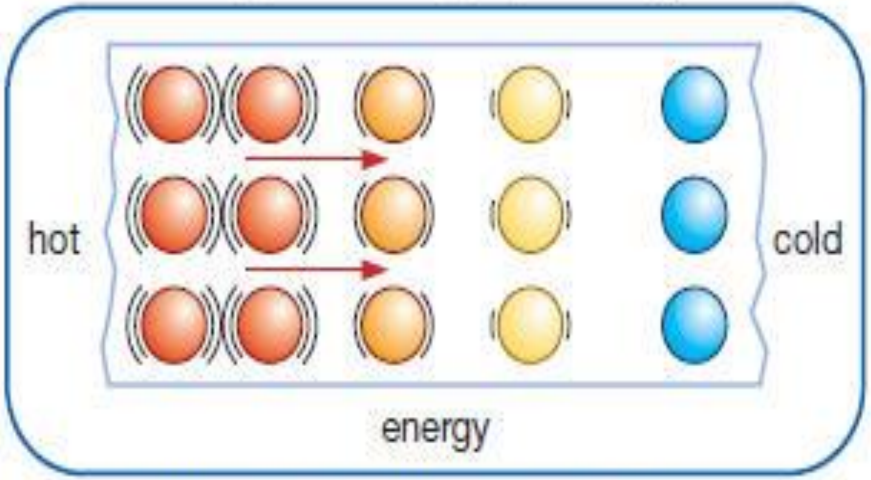

Cross Sectional Area = A
Hot
Heat Flow
Cold
L


T_{hot}
Q
T_{cold}
A=Area

Conduction



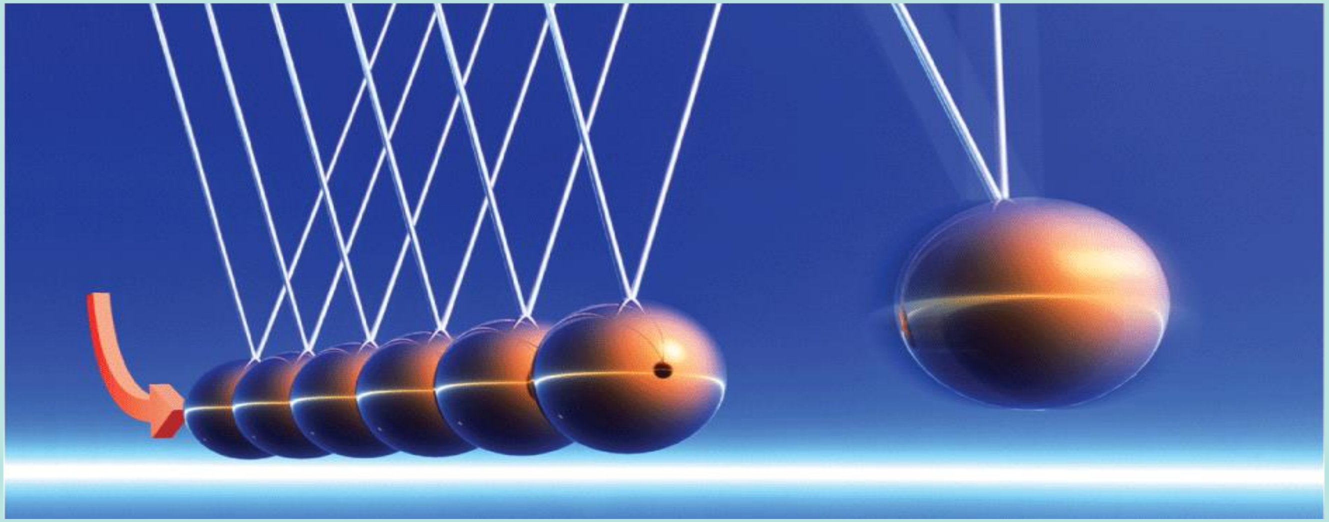
Conduction happens in solids, liquids and gases.



Particles with more energy pass on energy to neighbouring particles by colliding with them.

Conduction

- **Conduction in gases is slower than in liquids and solids because the particles in a gas collide less often.**
- Newton's cradle helps to visualize conduction. One ball strikes the rest, and most of the kinetic energy is transferred to one ball on the end.

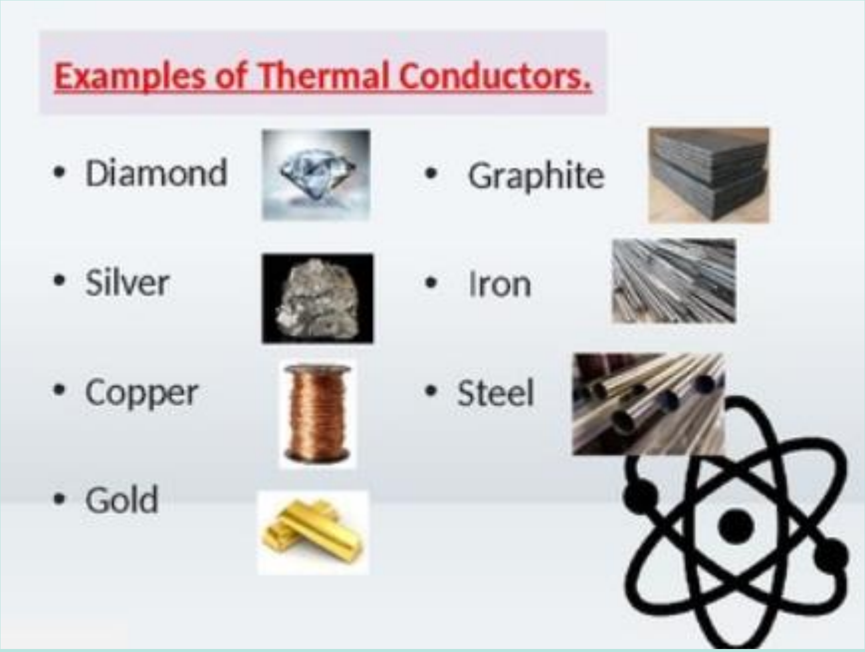


Conduction

Thermal Conductors

A **thermal conductor** is a material that conducts thermal energy well.

- Metals are good thermal conductors.

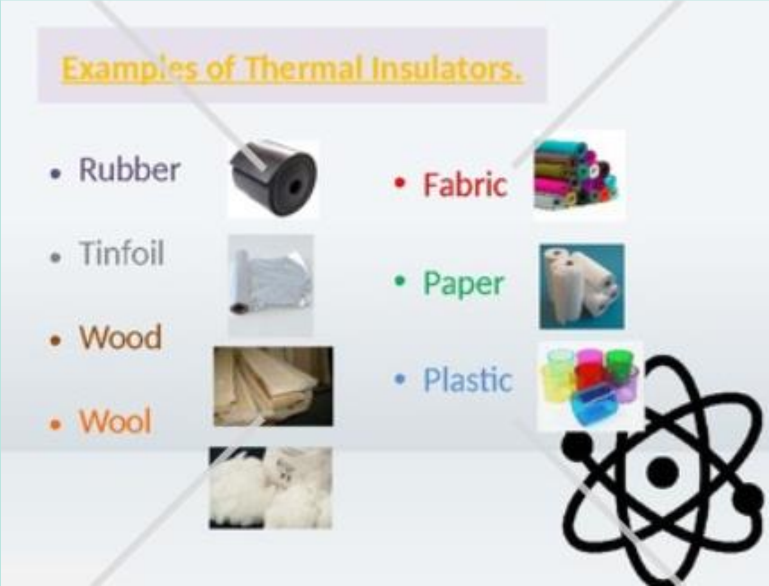


Conduction

Thermal Insulators

A material that conducts thermal energy poorly is called a **thermal insulator.**

Air is a very good insulator. Wool garments and plastic foam cups use trapped air to slow down conduction.



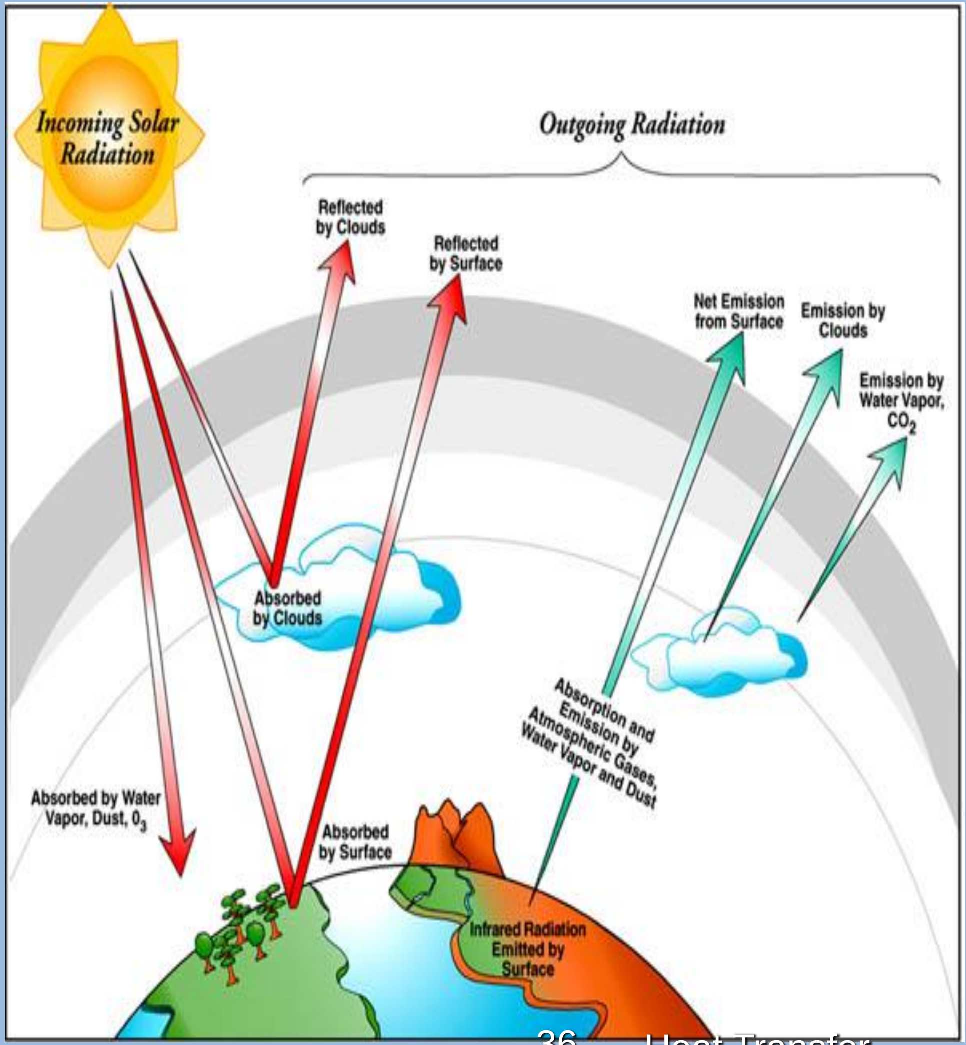
Heat Transfer

- C. Radiation
  - (*does NOT require matter for the transfer*)

Radiation

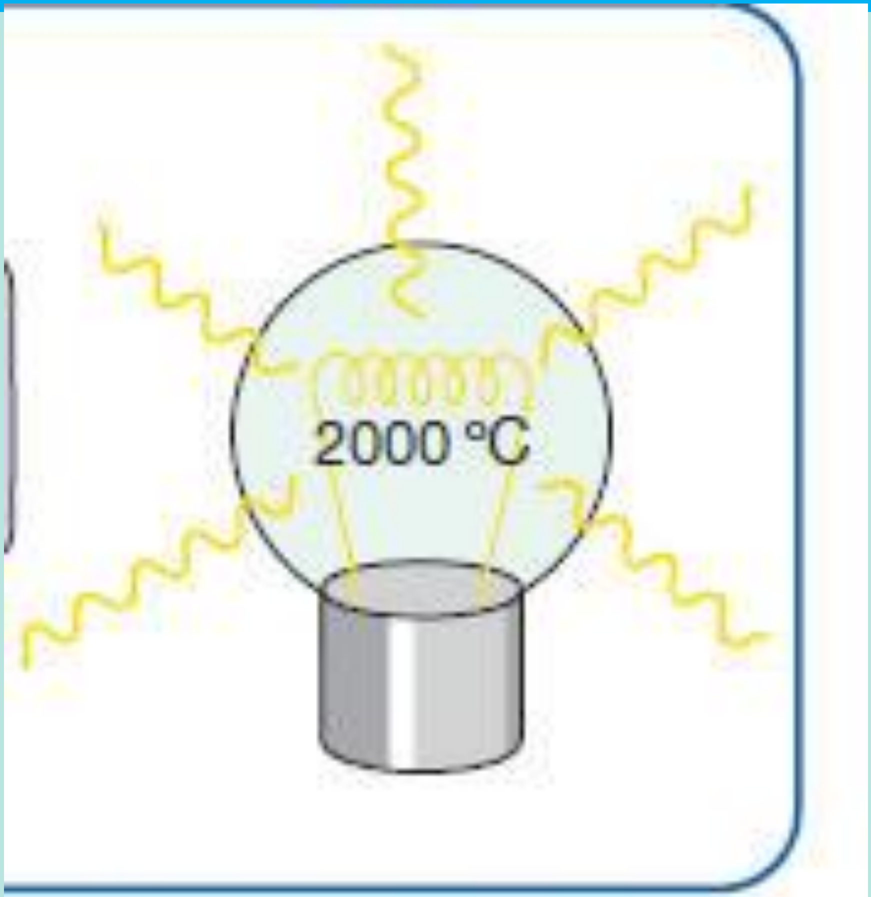
Energy that is "given off" by an object AND *does NOT require matter for the transfer*.

The Earth is most affected by the Sun's radiation (the heat the Sun gives off (radiates)).



Radiation

Radiation



A very hot lamp filament emits light as well as thermal radiation.

Examples of Radiation

- The warmth of a bonfire
- Stoves / Ovens radiate heat
- A “radiator” in a house
- Our bodies radiate heat

Radiation

Thermal energy is transferred from the fire to your face by radiation. No substance (solid, liquid or gas) is needed so the radiation can travel through empty space.

Thermal (Heat) Energy Transfer

Conduction

(*requires matter for the transfer*)

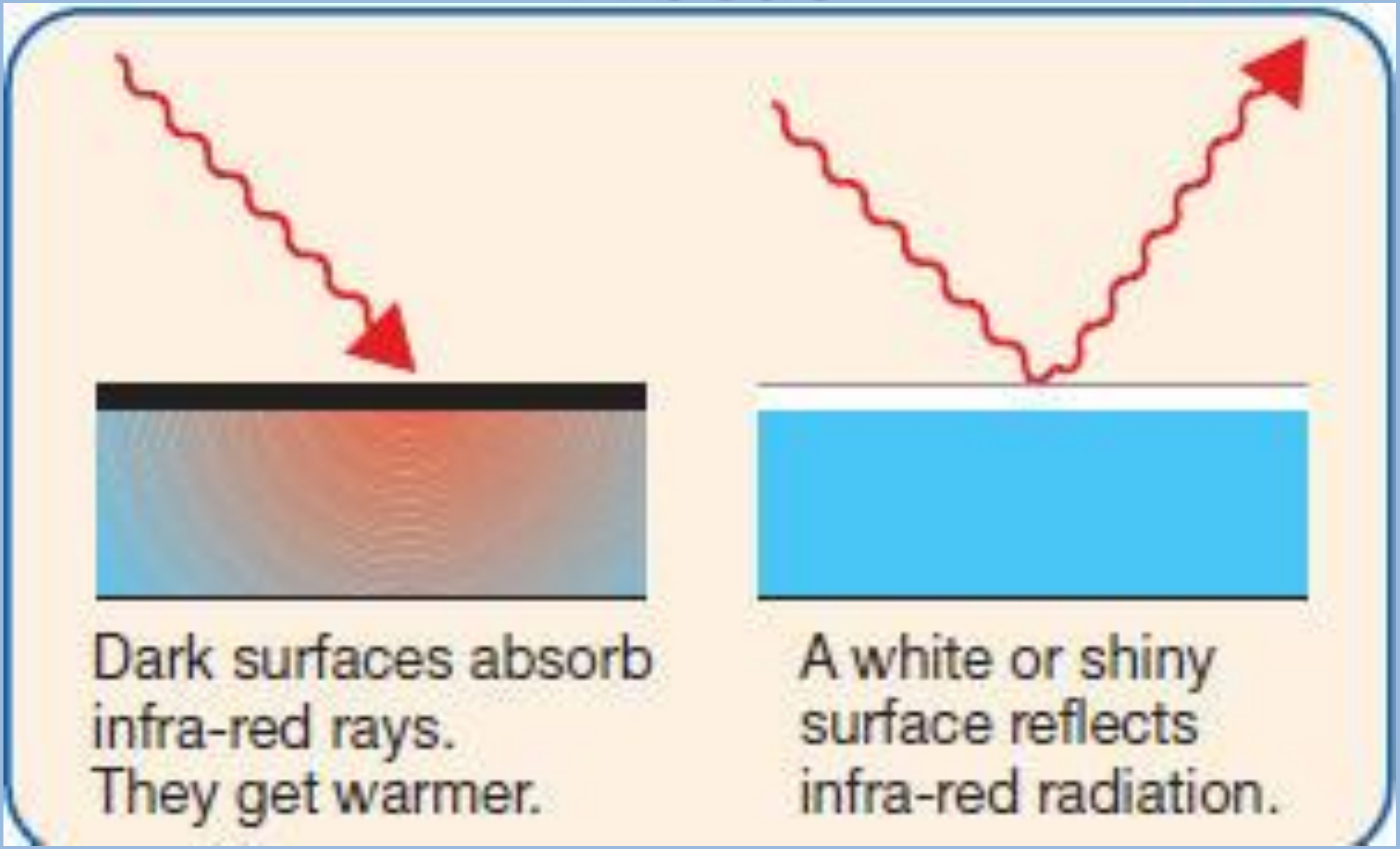
Convection

(*requires matter for the transfer*)

Radiation

(*does NOT require matter for the transfer*)

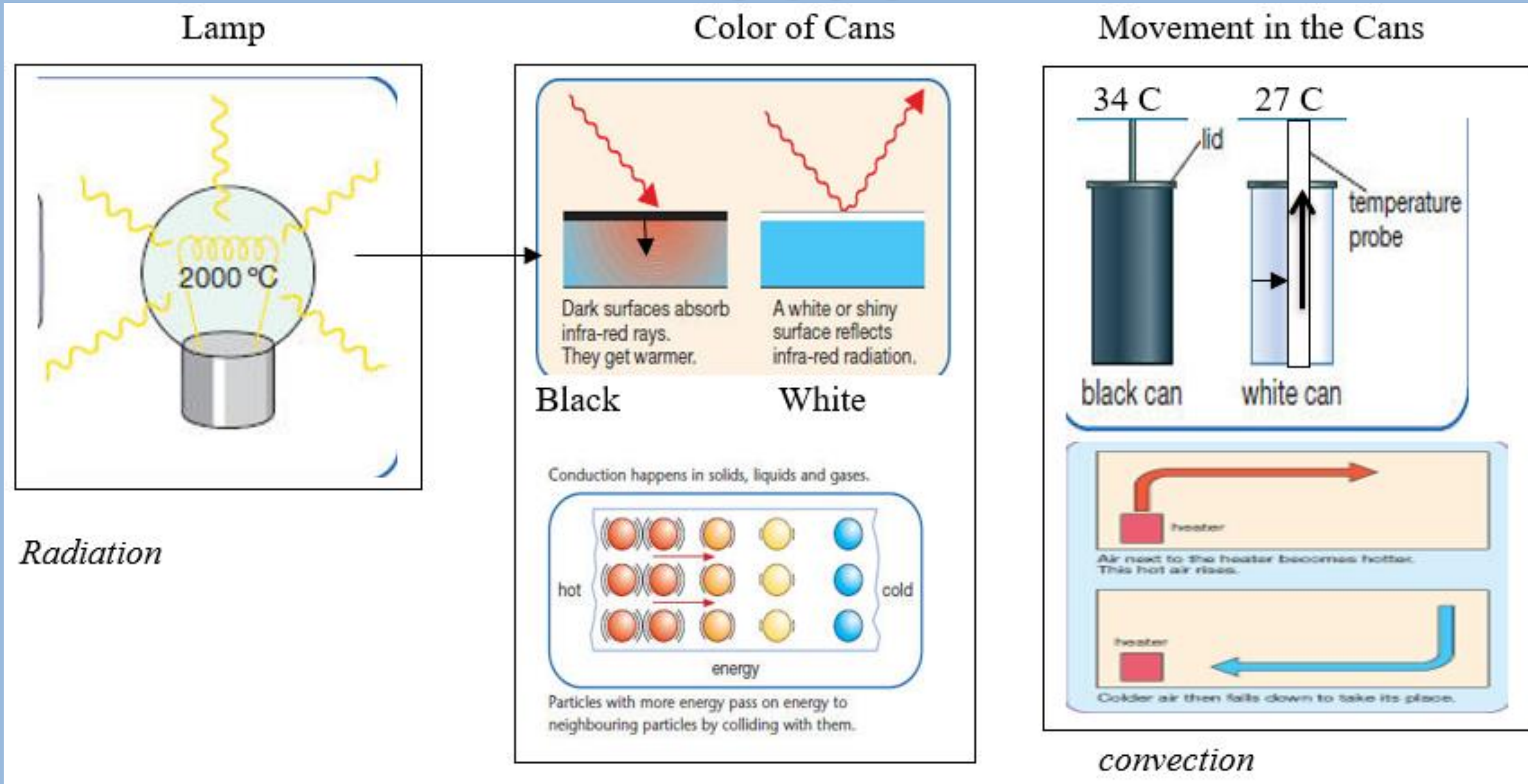
Albedo


Dark surfaces absorb infra-red rays. They get warmer.
A white or shiny surface reflects infra-red radiation.

Albedo

- The reflectivity of a surface to radiant energy or light.
- The higher the albedo the more it reflects radiation.
- The temperature increase of a surface depends on albedo.
  - A surface with higher albedo would not gain as much temperature as a surface with lower albedo.

Albedo

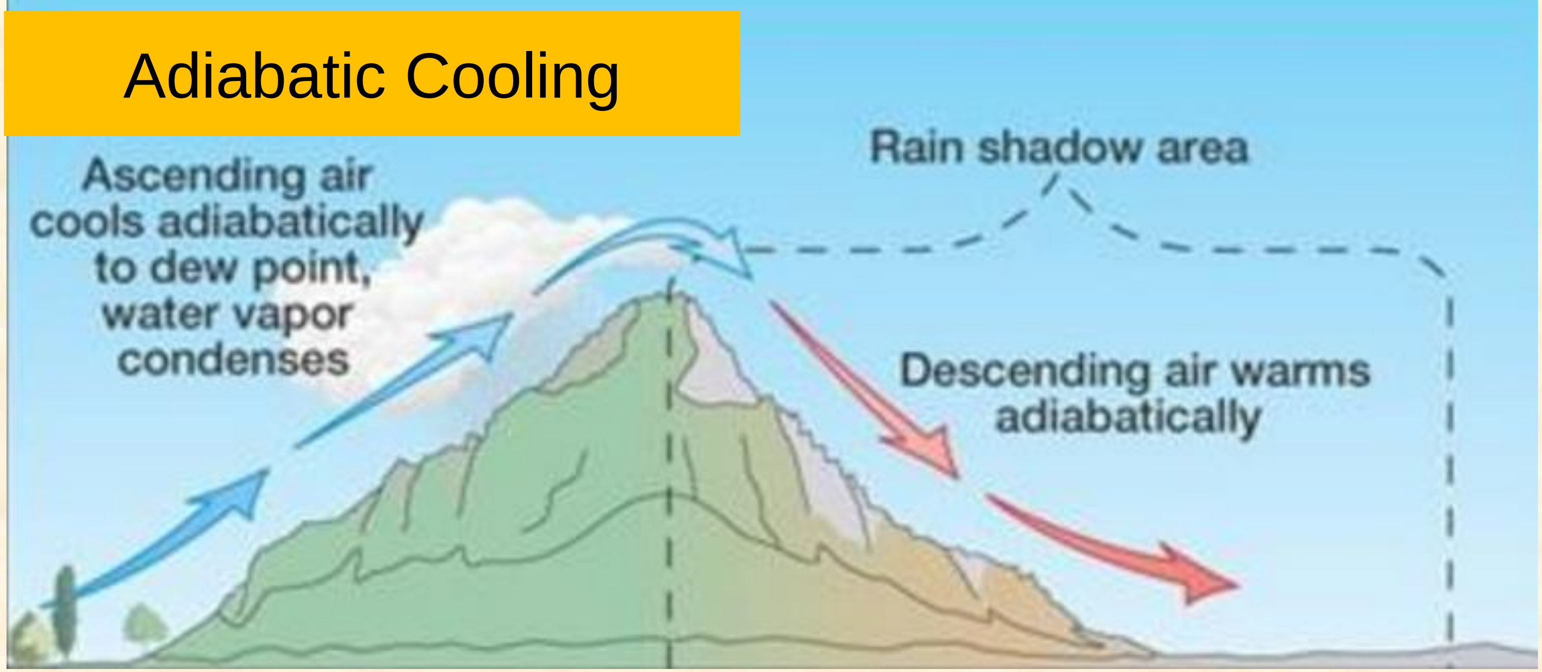


- The white can has the greatest albedo, meaning its surface reflects light from the lamp the most. In the experiment, we observed that the temperature inside the black can increased the most because it absorbed the radiation rather than reflected it as in the white can.

How Do Clouds Form? (Condensation)

- Clouds form when air is cooled (e.g. lower pressure, higher elevation) which condenses the water vapor in the atmosphere.
- Water vapor molecules attach to one another because they move slower in cooler air, and eventually attach to dust or smoke particles (condensation nuclei) in the atmosphere.
- Once enough water is present – a cloud is formed.

Adiabatic Cooling



- The adiabatic process occurs when air rises or descends. <u>No heat</u> is added to or withdrawn from air.
- Air pressure decreases with elevation (as air rises) and therefore expands.
- The expanding air loses kinetic energy as the molecules slow down, decreasing temperature.

http://somup.com/cF6h2LnVWV (1:05)

Heating Systems

- How do most heating systems distribute thermal energy?
- Most heating systems use convection to distribute thermal energy.

Heating Systems

A **central heating system** heats many rooms from one central location.

- The most commonly used energy sources for central heating systems are electrical energy, natural gas, oil, and coal.
- Heating systems differ in how they transfer thermal energy to the rest of the building.

Hot-Water Heating

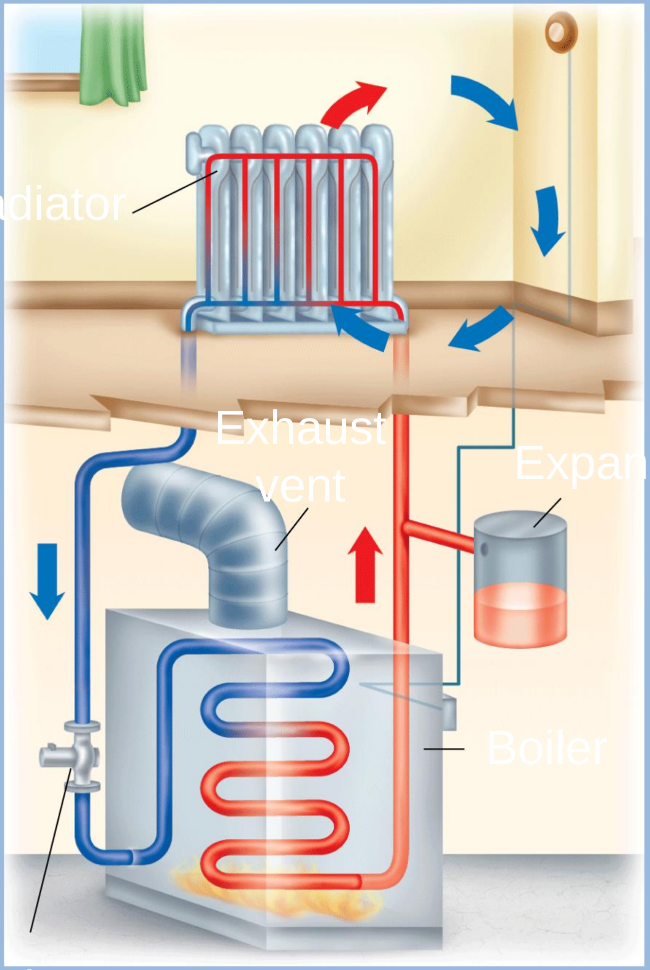
- At the boiler, heating oil or natural gas burns and heats the water.
- The circulating pump carries the hot water to radiators in each room.
- The hot water transfers thermal energy to the radiator by conduction.

Heating Systems

- The hot pipes heat the room air by conduction and radiation.
- Hot air rises and sets up a convection current in each room.
- The cooled water returns to the boiler.

Heating Systems

Within the pipes of this hot-water heating system, the water circulates in a convection current. In each room, the air moves in a convection current.



Steam Heating

Steam heating is very similar to hot-water heating except that steam is used instead of hot water.

- The transfer of heat from the steam-heated radiator to the room still occurs by conduction and radiation.
- Steam heating often is used in older buildings or when many buildings are heated from one central location.

Heating Systems

Electric Baseboard Heating

An electric baseboard heater uses electrical energy to heat a room.

- A conductor is used to convert electrical energy to thermal energy.
- The hot coil heats the air near it by conduction and radiation.
- Convection circulates the warm air to heat the room.

Heating Systems

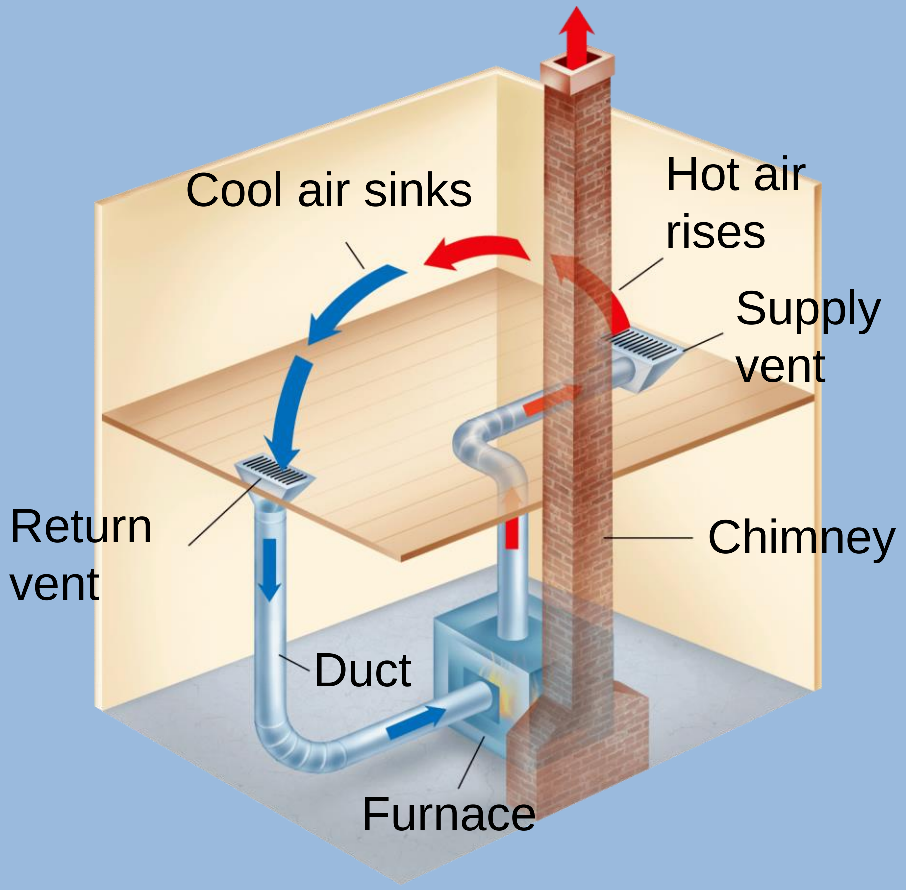
Forced-Air Heating

Forced-air heating systems use fans to circulate warm air through ducts to the rooms of a building.

- Convection circulates air in each room.
- Warm air entering the room rises toward the ceiling.
- Cool room air returns to the furnace through floor vents on the other side of the room.

Heating Systems

Hot air enters the room through a supply vent in the floor. The hot air rises as cooler, denser air in the room sinks.



Cooling Systems

- **How does a heat pump reverse the normal flow of heat?**

  A **heat pump** is a device that reverses the normal flow of thermal energy.

- **Heat pumps must do work on a refrigerant in order to reverse the normal flow of thermal energy.**

Cooling Systems

A **refrigerant** is a fluid that vaporizes and condenses inside the tubing of a heat pump.

- When the refrigerant absorbs heat, it vaporizes, or turns into a gas.
- When the refrigerant gives off heat, it condenses, or turns back into a liquid.

Cooling Systems

Refrigerators

A refrigerator is a heat pump—it transfers thermal energy from the cold food compartment to the warm room.

- A motor must do work to move refrigerant through tubing inside the refrigerator walls.
- Coils of tubing underneath or behind the refrigerator release heat absorbed from the food compartment and thermal energy produced by the work the motor does.

Cooling Systems

When a refrigerator door is open, some thermal energy from the room enters the refrigerator. More thermal energy leaves the refrigerator through the coils.

Cooling Systems

Air Conditioners

- The compressor in a room air conditioner raises the temperature and pressure of the refrigerant, turning it into a hot, high-pressure gas.
- The condenser coil is hotter than the outside air, so heat flows spontaneously to the outside air.
- The refrigerant cools and condenses into a liquid.

Cooling Systems

- The liquid refrigerant then flows through the expansion valve and decreases in temperature.
- As the cold refrigerant flows through the evaporator coil, it absorbs thermal energy from the warm room air.
- The fan sends cold air back into the room. The refrigerant becomes a vapor, and the process starts all over again.

Cooling Systems

In a window air conditioner, outside air is heated as a fan blows it through the condenser coil.