Temperature

CHAPTER

19

PHYS102~L8

Chapter 20

Heat and the First Law of Thermodynamics

CHAPTER OUTLINE

TOPICS TO BE COVERED

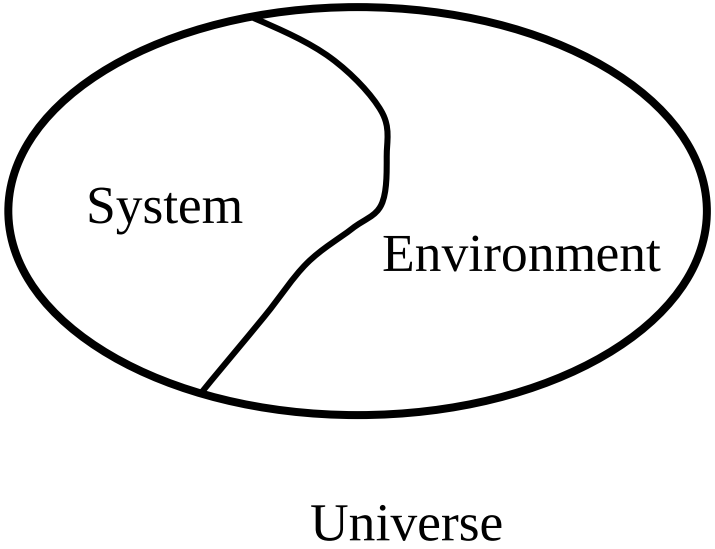
- Temperature
- Heat
- Thermal Equilibrium
- Thermometers
- Thermal scales
- Thermal expansion
- Thermal Capacity
- Specific Heat Capacity
- Latent Heat
- Energy Heat mechanisms

Thermodynamics

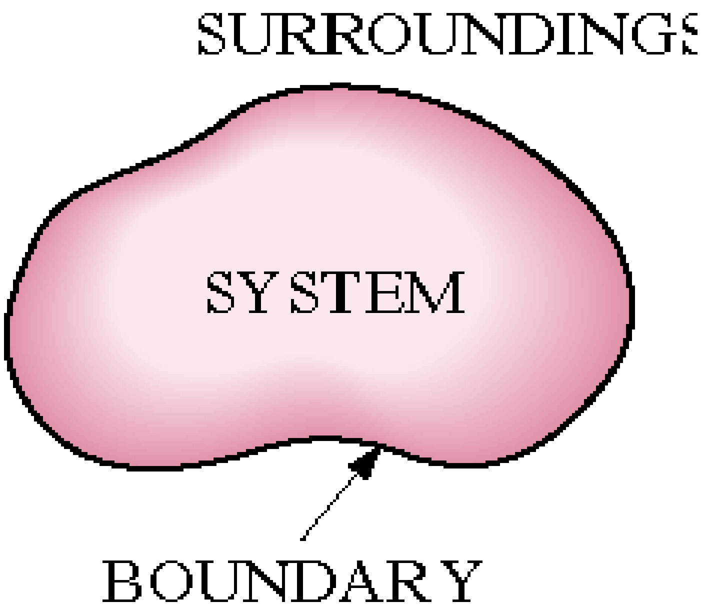
Thermodynamics is the study of the inter-relation between heat, work and internal energy of a system and its interaction with its environment..

Example systems

- Gas in a container
- Charging & discharging a battery
- Chemical reactions



Thermodynamic Systems



Thermodynamic System

- quantity of matter or a region of space chosen for study

Boundary

- real or imaginary layer that separates the system from its surroundings

Surroundings

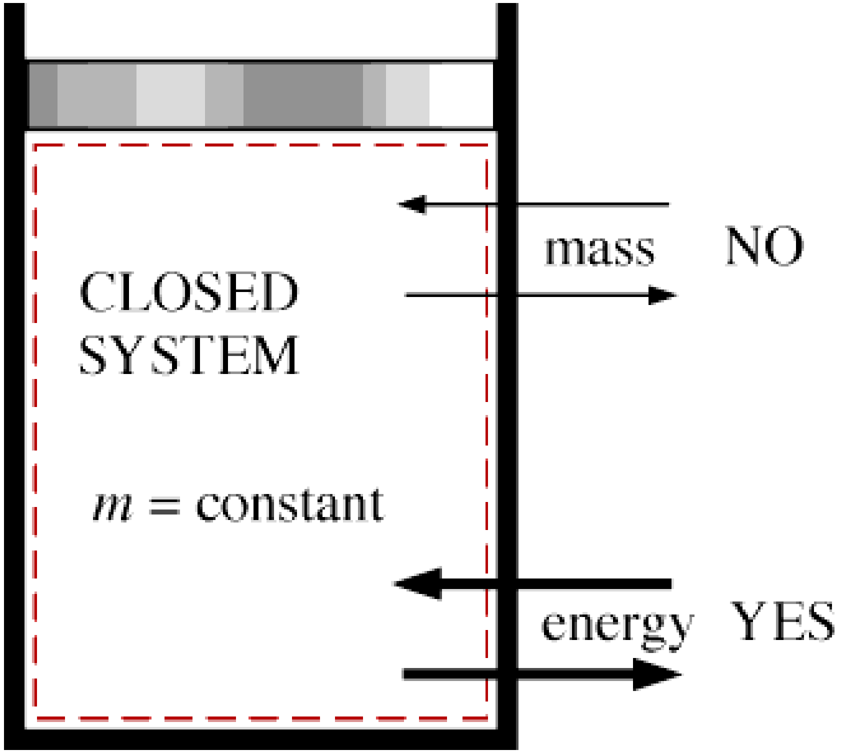
- physical space outside the system boundary

Types of Systems

- Closed
- Open
- isolated

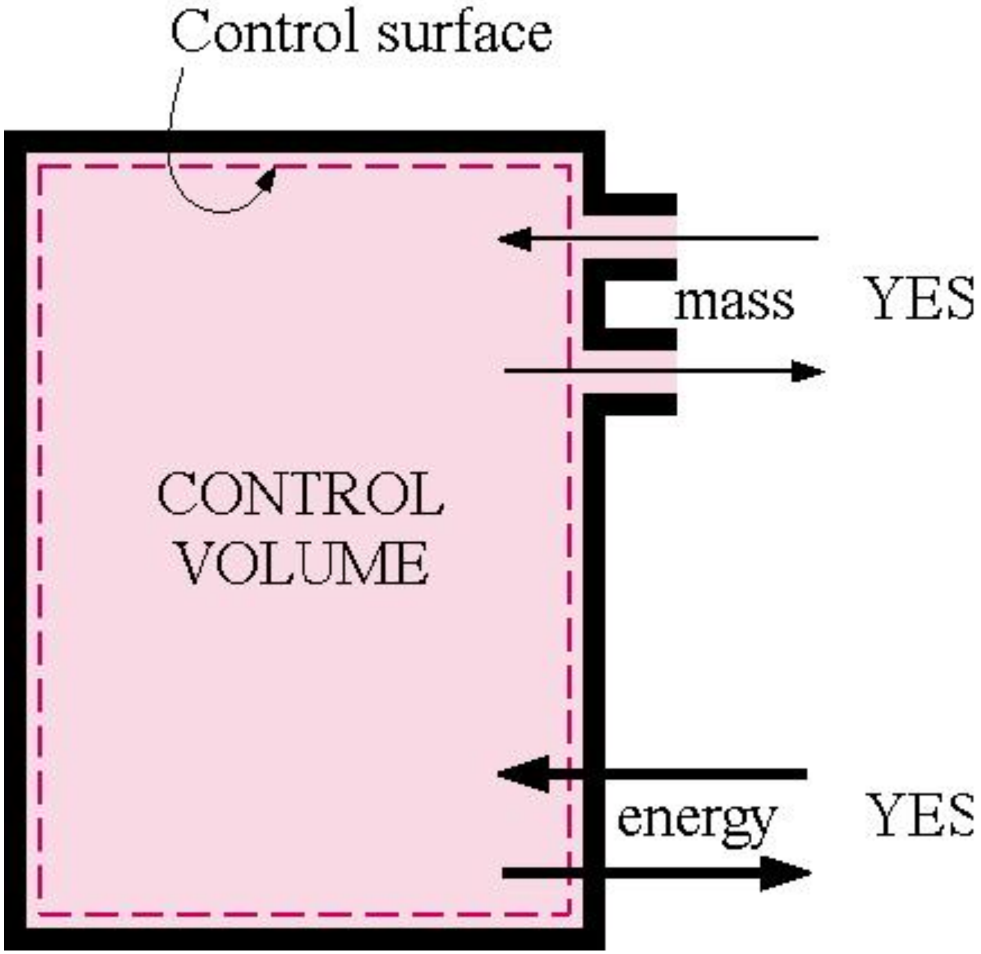
Closed Systems (fixed masses)

Energy, not mass, crosses closed-system boundaries



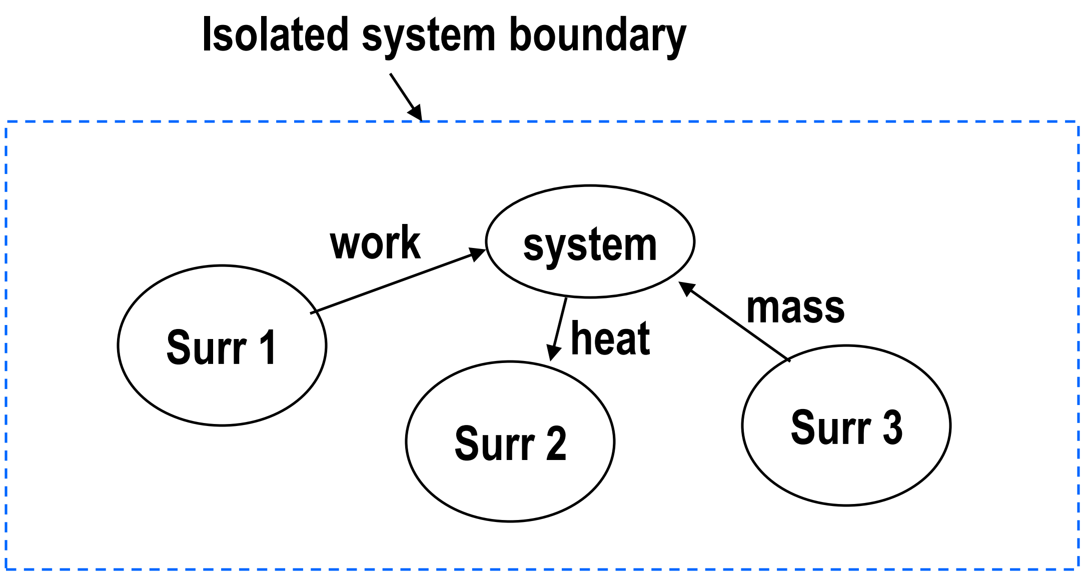
Open Systems (Control Volumes)

Mass and Energy Cross Control Volume Boundaries



Isolated System

- **Closed system where no heat or work (energy) may cross the system boundary**
  - typically a collection of the a main system (or several systems) and its surroundings is considered an isolated system



Thermodynamics States

A **state variable** describes the state of a system at time t, but it does not reveal how the system was put into that state.

Examples of state variables:

- P = pressure (Pa or N/m^2),
- T = temperature (K),
- V = volume (m^3),
- n = number of moles, and
- U = internal energy (J).

The thermodynamic variables

- It is common to call quantities such as P, V, and T the thermodynamic variables of an ideal gas. If the equation of state is known, then one of the variables can always be expressed as some function of the other two.
- **Thermodynamic variables** are the observable macroscopic variables of a system, such as P, V and T.
- If they are used to describe an equilibrium state of the system, they are known as ***state variables*****.**

Properties

- **Any characteristic of a system in equilibrium is called a property.**
- **Types of properties**
  - Extensive properties - vary directly with the size of the system

    Examples: volume, mass, total energy
  - Intensive properties - are independent of the size of the system

    Examples: temperature, pressure, color
- **Extensive properties per unit mass are intensive properties.**

specific volume $\quad v$ = Volume/Mass = V/m

density $\quad \rho$ = Mass/Volume = m/V

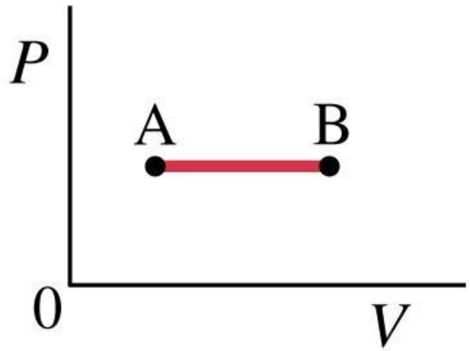
State & Equilibrium

- **State of a system**
  - system that is not undergoing any change
  - all properties of system are known & are not changing
  - if one property changes then the state of the system changes
- **Thermodynamic equilibrium**
  - “equilibrium” - state of balance
  - A system is in equilibrium if it maintains thermal (uniform temperature), mechanical (uniform pressure), phase (mass of two phases), and chemical equilibrium

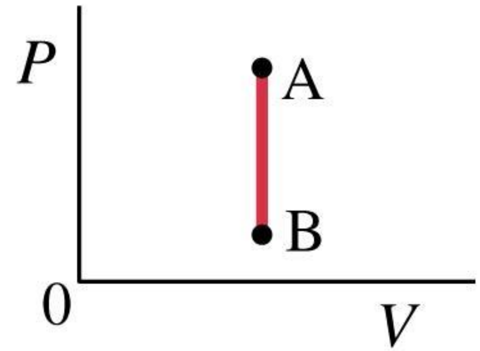
Processes & Paths

- **Process**
  - when a system changes from one equilibrium state to another one
  - some special processes:
    - isobaric process - constant pressure process
    - isothermal process - constant temperature process
    - isochoric process - constant volume process
- **Path**
  - series of states which a system passes through during a process

An isobaric process (a) occurs at constant pressure; an isovolumetric one (b) at constant volume.

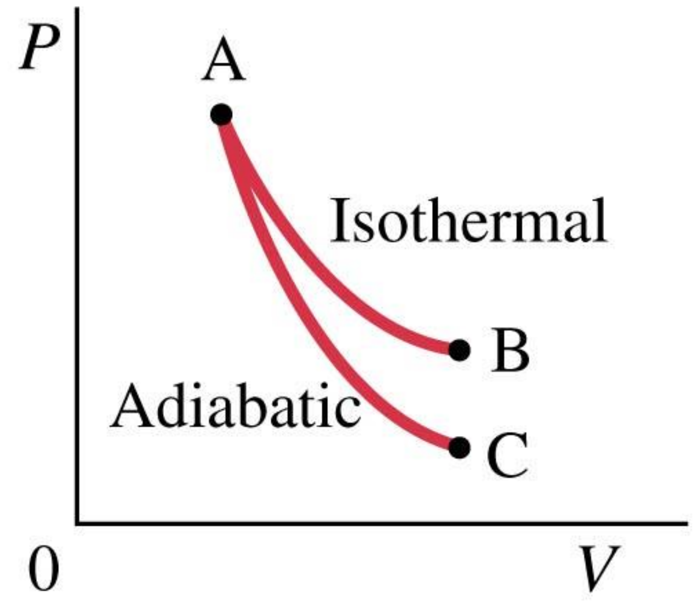


(a) Isobaric

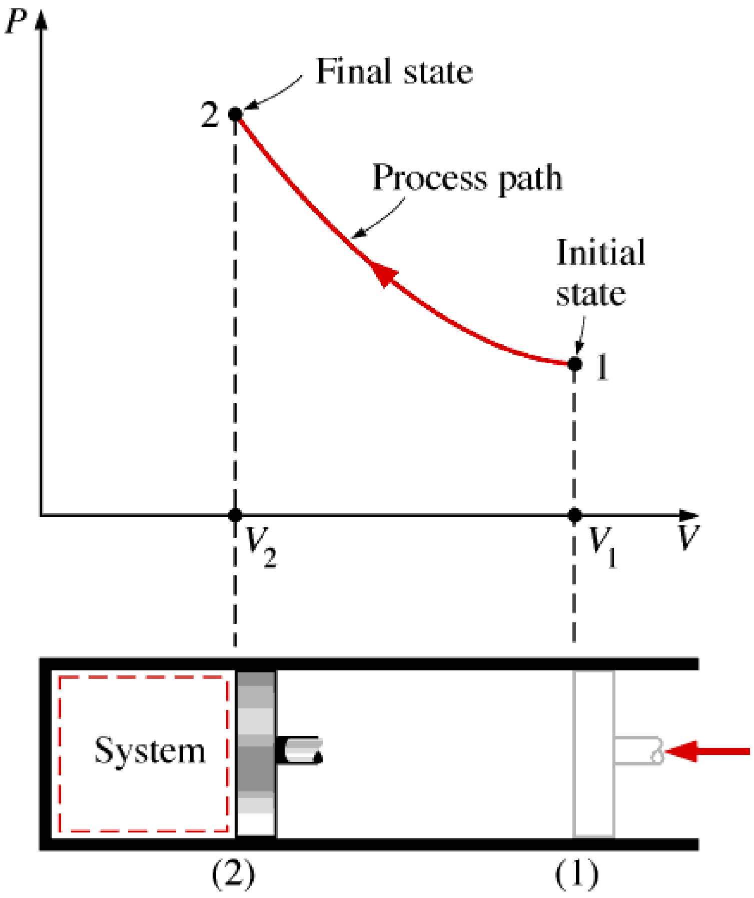


(b) Isovolumetric

An adiabatic process is one where there is no heat flow into or out of the system.

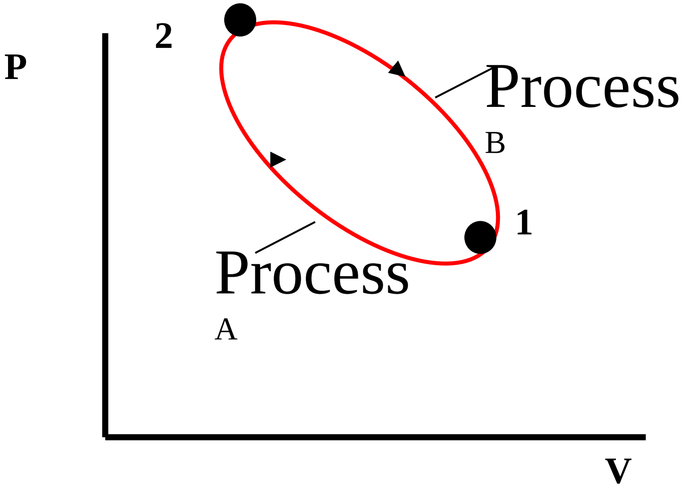


Compression Process



Cycles

- **Cycles**
  - A process (or a series of connected processes) with identical end states



1. Thermometers and Temperature scales

- We often associate the concept of temperature with how hot or cold an object feels when we touch it.
- The temperature is a measure of the average translational **kinetic energy** associated with the disordered motion of atoms and molecules.

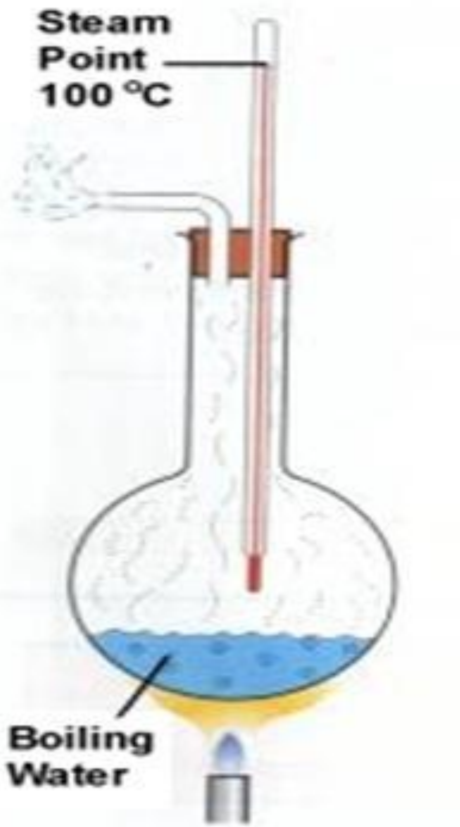
- **Thermometers** *are devices that are used to measure the temperature of a system.*
- All thermometers are based on the principle that some physical property of a system changes as the system’s temperature changes.

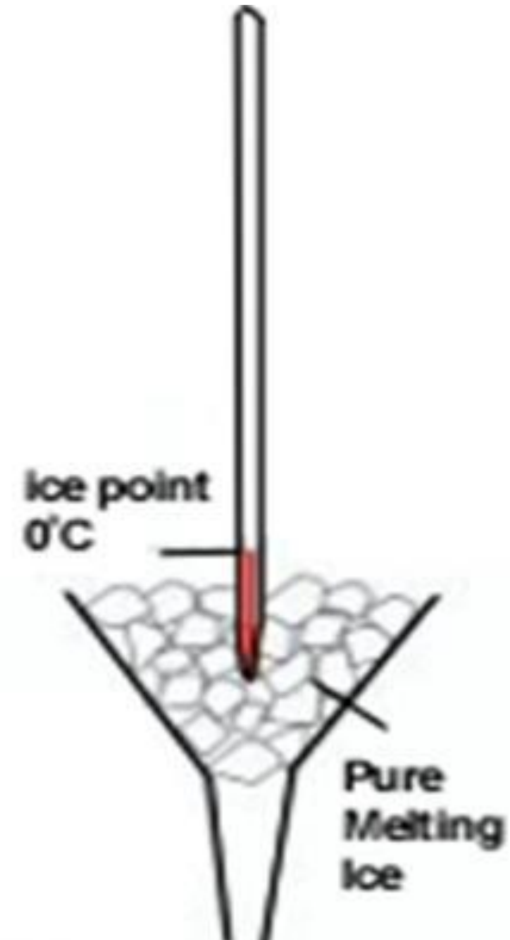
- Some physical properties that change with temperature are:
- (**1) the volume of a liquid,**
- **(2) the dimensions of a solid,**
- **(3) the pressure of a gas at constant volume,**
- **(4) the volume of a gas at constant pressure,**
- **(5) the electric resistance of a conductor, and**
- **(6) the color of an object.**

- Temperatures are measured in one of the three standard **temperature scales** (Celsius, Kelvin, and Fahrenheit).
- To define a temperature scale, **two fixed points** should be chosen.
- The interval between these two points is called the **fundamental interval.**
- The fixed points are usually chosen to be the **melting point of ice** and **the boiling point of water.**

Celsius Scale

- Temperature of an ice-water mixture is defined as 0º C
  - This is the *freezing point* of water
- Temperature of a water-steam mixture is defined as 100º C
  - This is the *boiling point* of water
- Distance between these points is divided into 100 equal segments to create the Celsius scale. Thus, each segment denotes a change in temperature of one Celsius degree.


Steam
Point
100 °C
Boiling
Water


ice point
0°C
Pure
Melting
ice

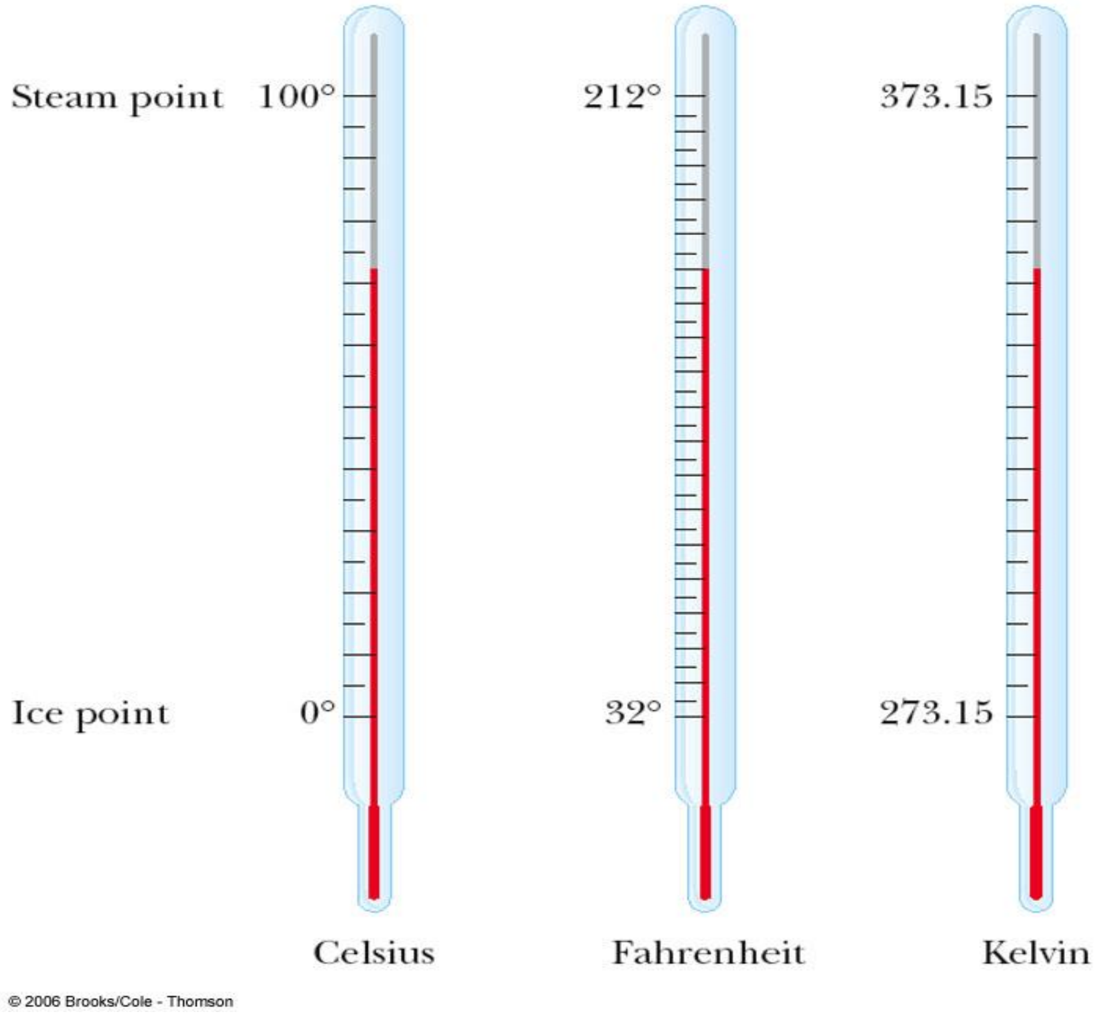
Kelvin Scale

- When the pressure of a gas goes to zero, its temperature is –273.15º C
- This temperature is called *absolute zero*
- This is the zero point of the Kelvin scale
  - –273.15º C = 0 K
- To convert: $T_C = T_K - 273.15$
  - The size of the degree in the Kelvin scale is the same as the size of a Celsius degree

Fahrenheit Scales

- Most common scale used in the US
- Temperature of the freezing point is 32º
- Temperature of the boiling point is 212º
- 180 divisions between the points

Comparing Temperature Scales



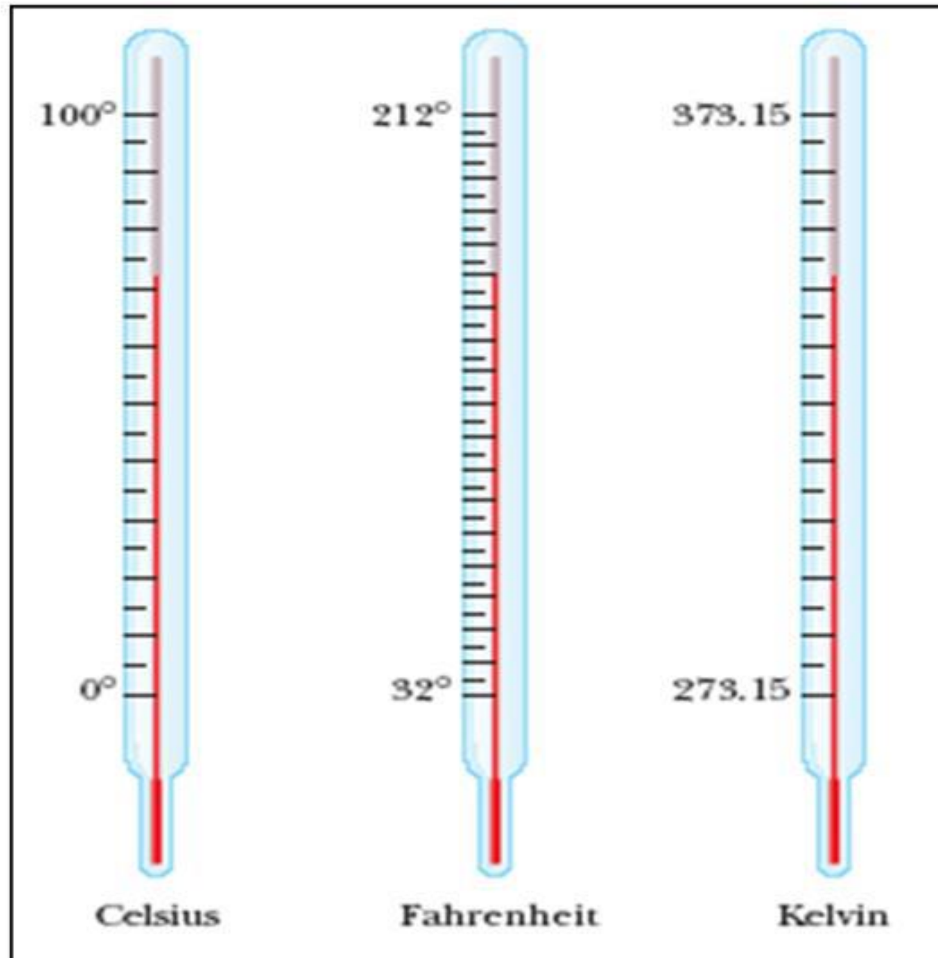
The Celsius, Fahrenheit, and Kelvin Temperature Scales

- Transformation between the scales is given by the formula:

- **T°K= t°C+273.15**
-
- **t°C= T°K - 273.15**

$$T_C = \frac{5}{9}(T_F - 32)$$

$$T_F = \frac{9}{5}\,T_C + 32$$



Converting Among Temperature Scales

$$T_C = T_K - 273.15$$

$$T_F = \frac{9}{5} T_C + 32$$

$$T_C = \frac{5}{9}\left(T_F - 32\right)$$

$$\Delta T_F = \frac{9}{5} \Delta T_C$$

- **Question one**

On a day when the temperature reaches 45°F, what is the temperature in degrees Celsius and in Kelvin?

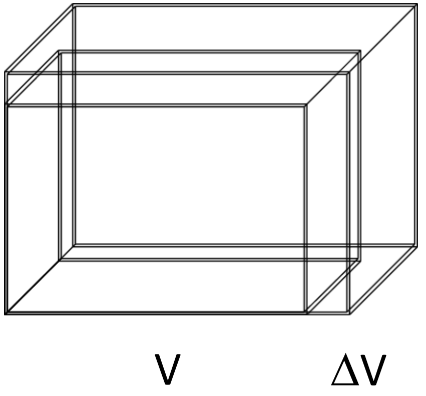
- **Question two**

A pan of water is heated from 40°C to 80°C. What is the change in its temperature on the Kelvin scale and on the Fahrenheit scale?

Thermal expansion of solids and liquids

- is the tendency of matter to change in length (or volume)in response to a change in temperature.

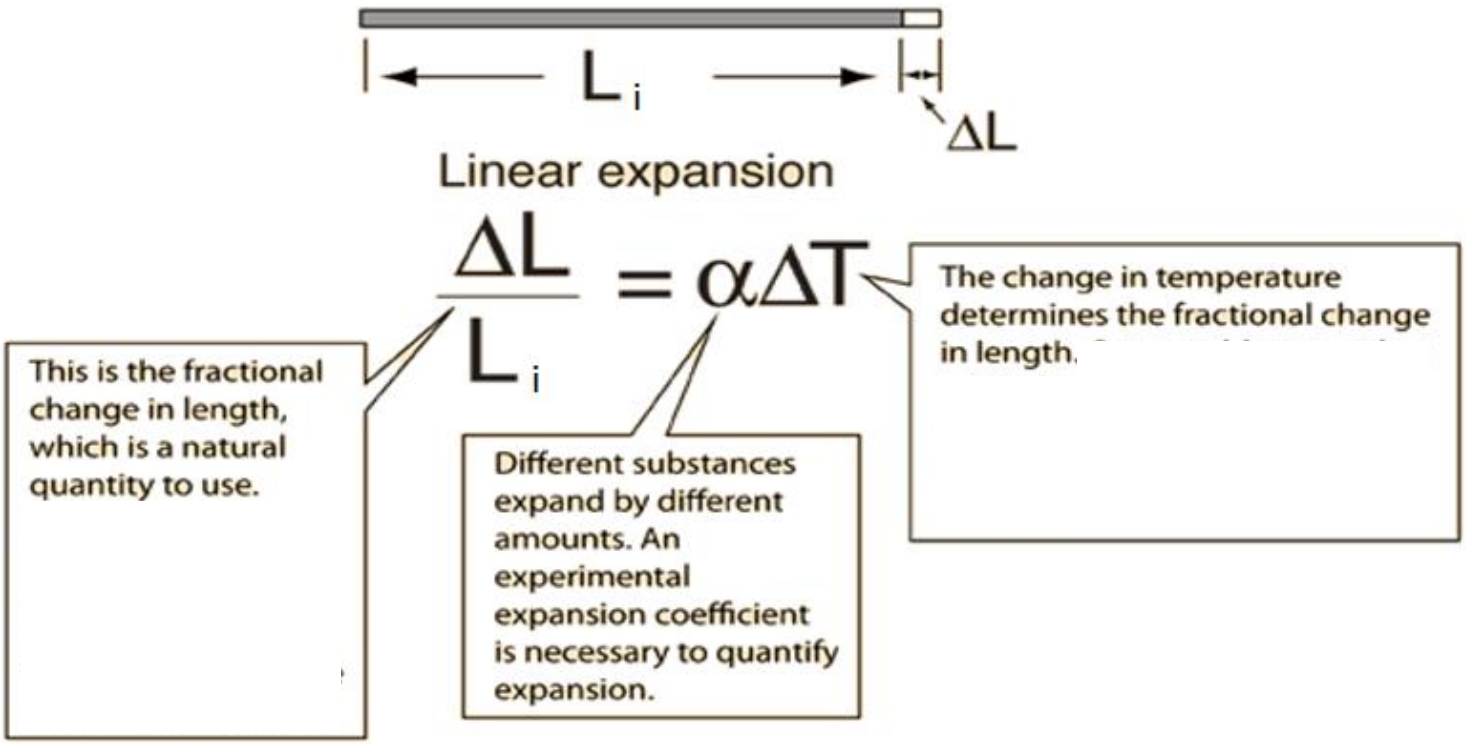
- This effect is limited in size, and only occurs within limited temperature ranges.



Types of thermal expansion

- ***linear Expansion*** $\Delta L = \alpha L_i \Delta T$

where α is the linear thermal expansion coefficient.



Types of thermal expansion

- ***Volume Expansion*** $\Delta V = \beta V_i \Delta T$

where β is the volume thermal expansion coefficient

$$\beta = \frac{\Delta V}{V_\circ \Delta T}$$

$\Delta V = Change\ in\ volume$

$V_\circ =$ Original volume

$\Delta T = change\ in\ temperature$

- The coefficient of linear expansion α is related to the coefficient of volume Expansion β by:

$$\beta = 3\,\alpha$$

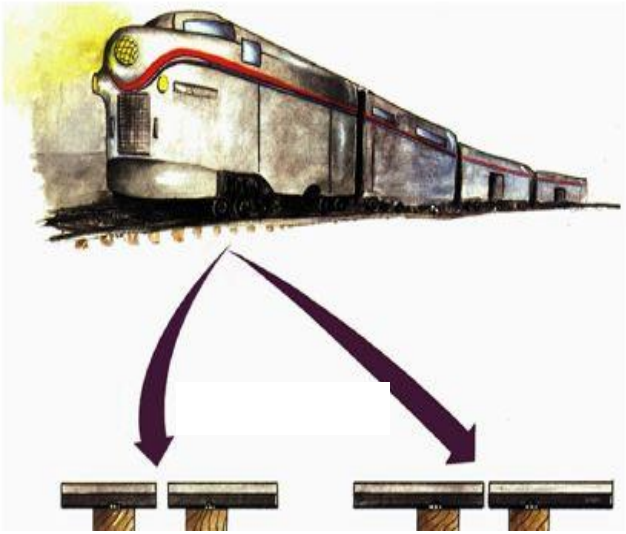
Coefficients of Thermal Expansion at 20 ºC

Substance	Linear Coefficient	Volumetric Coefficient
Aluminum	24×10^{-6}	72×10^{-6}
Brass	19×10^{-6}	57×10^{-6}
Copper	17×10^{-6}	51×10^{-6}
Glass(ordinary)	9×10^{-6}	27×10^{-6}
Glass (Pyrex)	3×10^{-6}	9×10^{-6}
Iron/Steel	12×10^{-6}	36×10^{-6}
Lead	29×10^{-6}	87×10^{-6}

Look at this pictures..

Example (2): Expansion of a Railroad Track

A segment of a steel railroad has a length of 30.000 m when temperature is 0.0 ºC. What is its length when the temperature is 40.0ºC?



Thermal Capacity (C)

- Thermal Capacity (Heat Capacity) (**C**) is the amount of energy required to raise the temperature of a substance by 1°C.

$$C = \frac{Q}{\Delta T}$$

- Measured in J /°C

- Water has a very high capacity.
  - It takes a lot of thermal energy for water's temperature to change
  - This is why the ocean isn't a thousand degrees
  - It's also why it takes some time for a pot of water to begin to boil
- Sand has a low capacity
  - Which is why beach sand gets really hot in the summer.

Specific Heat Capacity (c)

- Specific Heat (c) is the energy **per unit mass** required to raise the temperature of a substance by 1°C .

$$c = \frac{C}{m} = \frac{Q}{m\Delta T}$$

Measured in J / kg °C (in SI)

or cal / g .°C (in CGS)

- specific heat could measured by calorimeters.

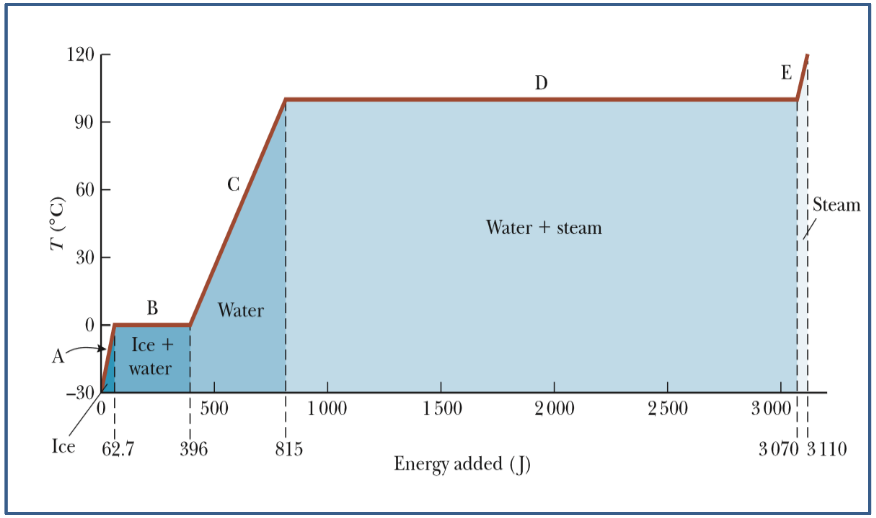
Latent Heat

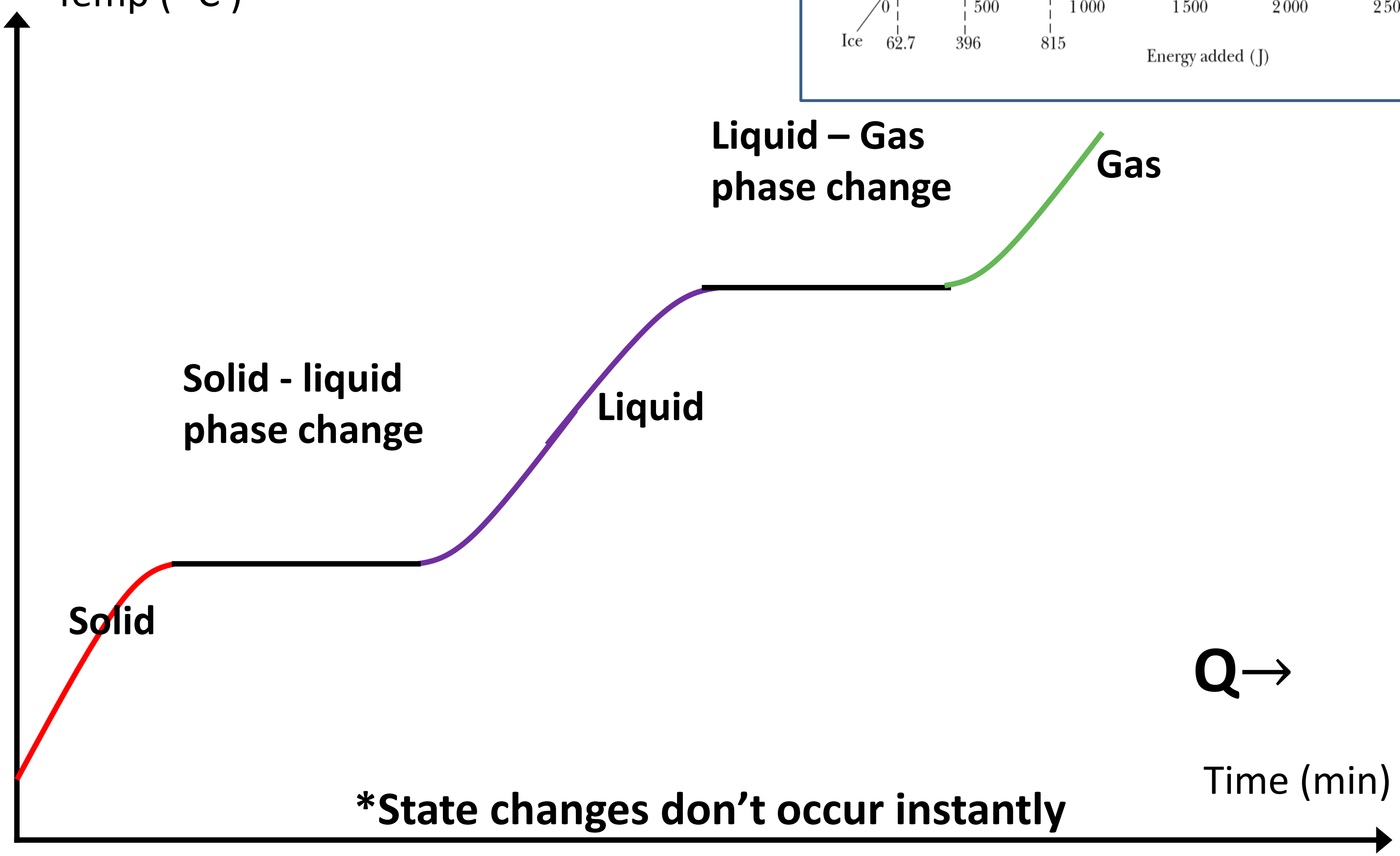
- When a phase (solid, liquid, and gas) change occurs, a lot of energy was absorbed by the substance without its temperature changing.
  - Due to latent heat
    - Not Specific Heat.
- latent heat is the amount of heat needed to change the state of matter from one phase to other without a change in temperature.

$L = \frac{Q}{m}$, L is called latent heat (the "hidden" heat)

- Latent Heat of Fusion is the amount of heat needed to change the state of matter from **solid** to **liquid** without a change in temperature.
- Latent Heat of Vaporization is the amount of heat needed to change the state of matter from **liquid** to **gas** without a change in temperature.

Heating Curve

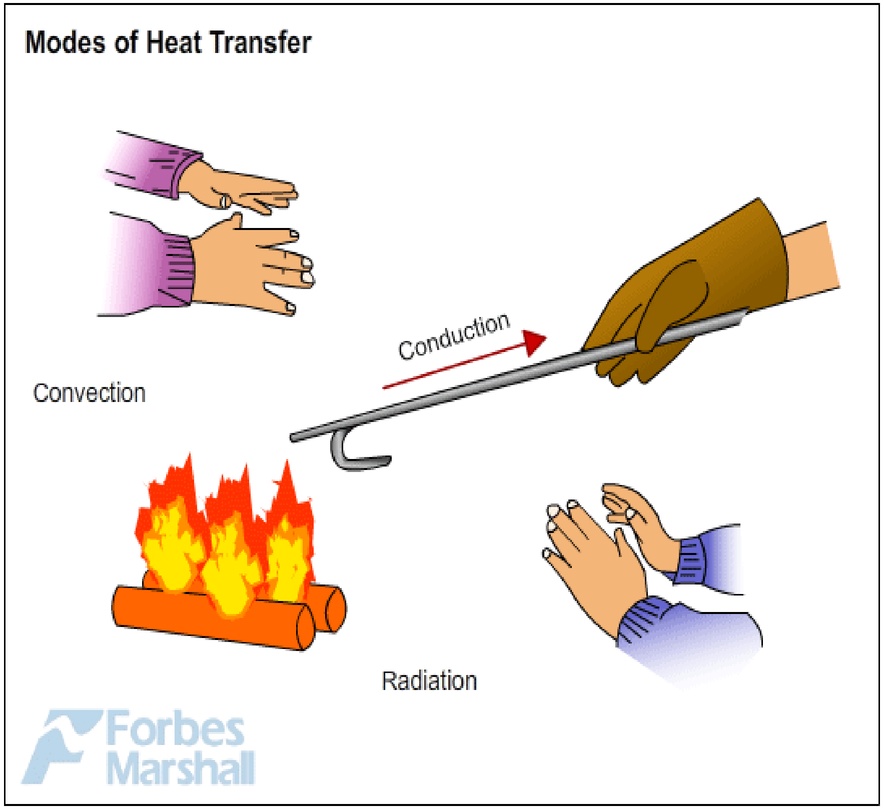




Heat energy transfer mechanisms

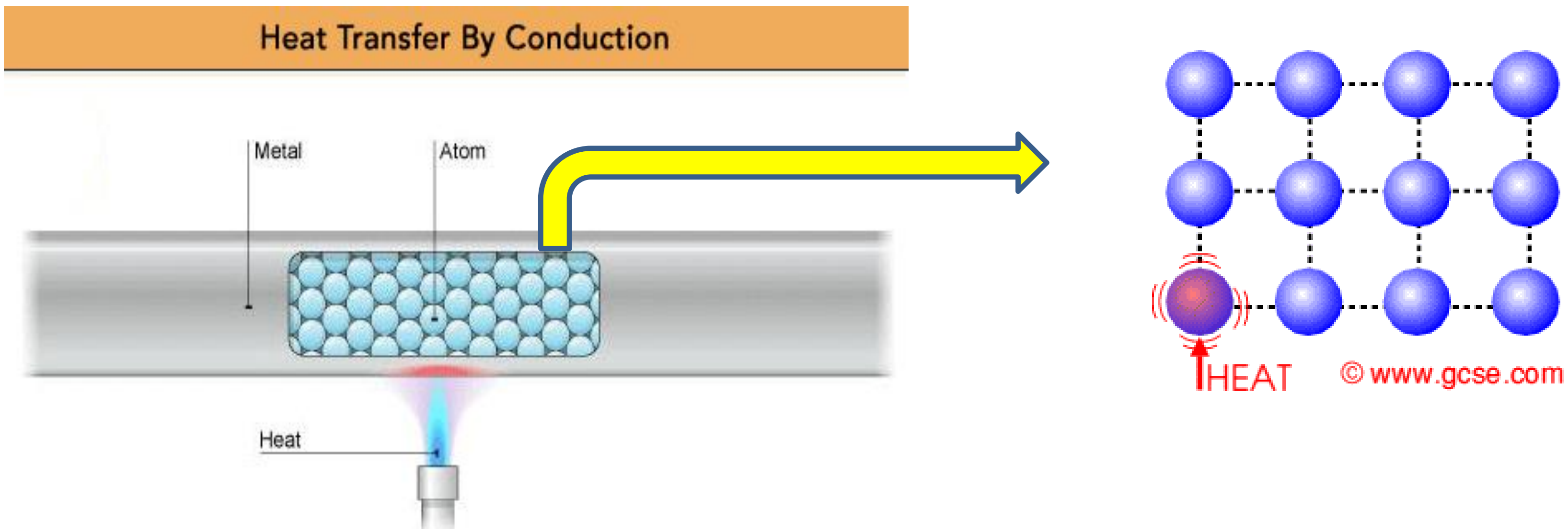
- ***3 mechanisms***
- Conduction
  - Heat (not the molecules) transfer through material (solid).
- Convection
  - Heat transfer by movement of hot material (fluid)
- Radiation
  - Heat transfer by electromagnetic waves.

Illustrative Video:
http://goo.gl/e6kHJo



1- Thermal Conduction

When you heat a metal strip at one end, the heat travels to the other end.



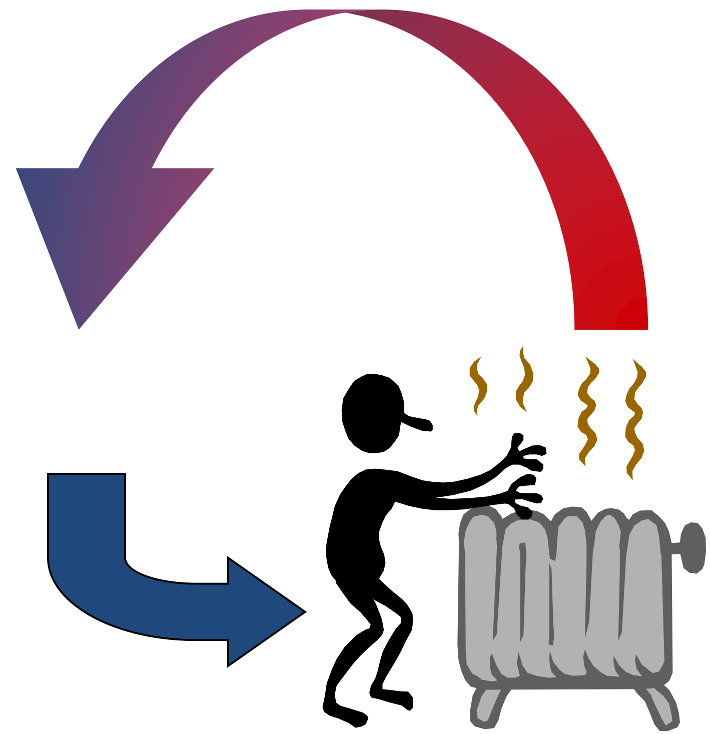
As you heat the metal, the particles vibrate, these vibrations make the adjacent particles vibrate, and so on and so on, the vibrations are passed along the metal and so is the heat.

2- Convection of heat

“Hot air rises” (and takes its heat with it!)

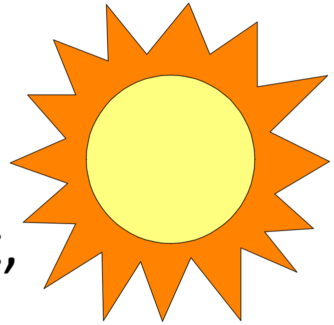
-Radiators

When the radiator heats the air, it becomes less dense and rises
Cool air moves in to replace the air that rose
This generates the air flow
So radiators don’t need a fan to stir the air and to distribute heat throughout a room.
The rising air cools until its density matches that of the surrounding air.

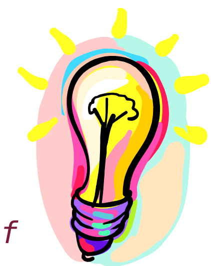


A warm substance transfers energy from one location to another.

3-Radiation



- Thermal Energy Travels as electromagnetic waves (Light, microwaves, radio waves, x-rays)
- Every object above absolute zero is emitting electromagnetic waves (radiation) regardless of temperature.



- Things also absorb radiation.
- Good emitters are also good absorbers.

because metals expand with a rise in temperature, Thermal expansion is the tendency of materials to expand when exposed to heat.

- When an object is in equilibrium with its surroundings, it radiates and absorbs energy at the same rate, and its temperature remains constant.
- When an object is hotter than its surroundings, it radiates more energy than it absorbs, and its temperature decreases. Whereas an object that is cooler than its surroundings absorbs more energy than it radiates, and its temperature increases.

Problems:

A pan of water is heated from 25°C to 80°C. What is the change in its temperature on the Kelvin scale and on the Fahrenheit scale?

Using the specific heat capacity of water(4200 J/kg^0 C) , how much energy is needed to increase the temperature of 600 g of water by 80^0 C in a kettle?

The temperature of a silver bar rises by 10.0°C when it absorbs 1.23 kJ of energy by heat. The mass of the bar is 525 g. Determine the specific heat of silver.

1. **Why is it advisable to allow telephone lines to sag when stringing them between pokes in summer?**
2. **What is the change in length of a metal rod with an initial length of 6 meters, a coefficient of thermal expansion 0.00009 /K and a temperature change of 15 K?**

because metals expand with a rise in temperature,Thermal expansion is the tendency of materials to expand when exposed to heat.

Homework

1. Liquid nitrogen has a boiling point of -195.81°C at atmospheric pressure. Express this temperature (a) in degrees Fahrenheit and (b) in kelvins.

- 2. Convert the following to equivalent temperatures on the Celsius and Kelvin scales:

(a) the normal human body temperature, 98.6°F;

(b) the air temperature on a cold day, 5.00°F.

Homework

3. The temperature difference between the inside and the outside of an automobile engine is 450°C. Express this temperature difference on

(a) the Fahrenheit scale and (b) the Kelvin scale.

4. The melting point of gold is 1064°C, and the boiling point is 2660°C. (a) Express these temperatures in kelvins. (b) Compute the difference between these temperatures in Celsius degrees and kelvins.