CHAPTER

1

Thermodynamics

Fundamental Concepts

For second year students only

What is thermodynamic

- The science of energy, that concerned with the ways in which energy is stored within a body.

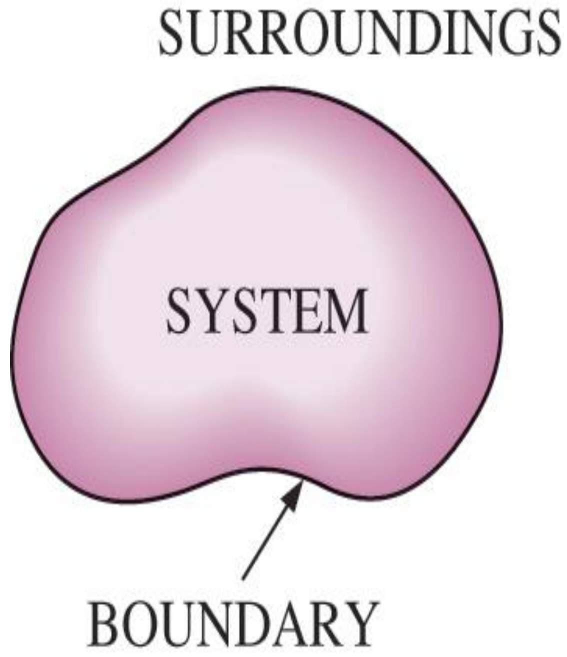
- Also can be define as the study of energy and conservation of energy from one to anther.

- The applications of thermodynamic laws and principles are found in all fields of energy technology notably in steam, nuclear power planet, internal composition engines, air conduction, refrigeration and direct energy conservation devices.

  - Energy transformations – mostly involve heat and work movements.

System, surroundings and boundary

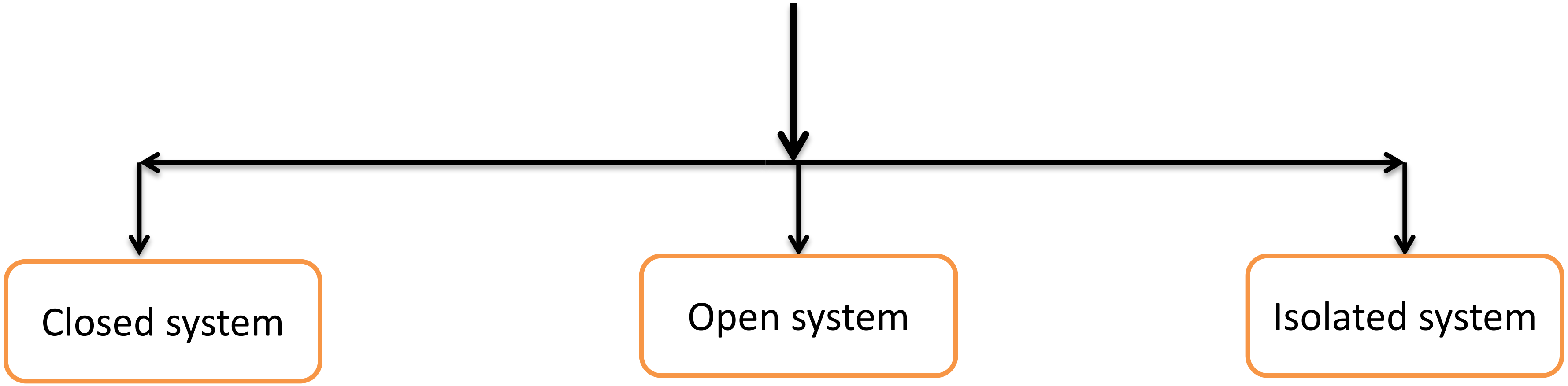
- **System:** A quantity of matter or a region in space chosen for study.
- **Surroundings:** The mass or region outside the system
- **Boundary:** The real or imaginary surface that separates the system from its surroundings.



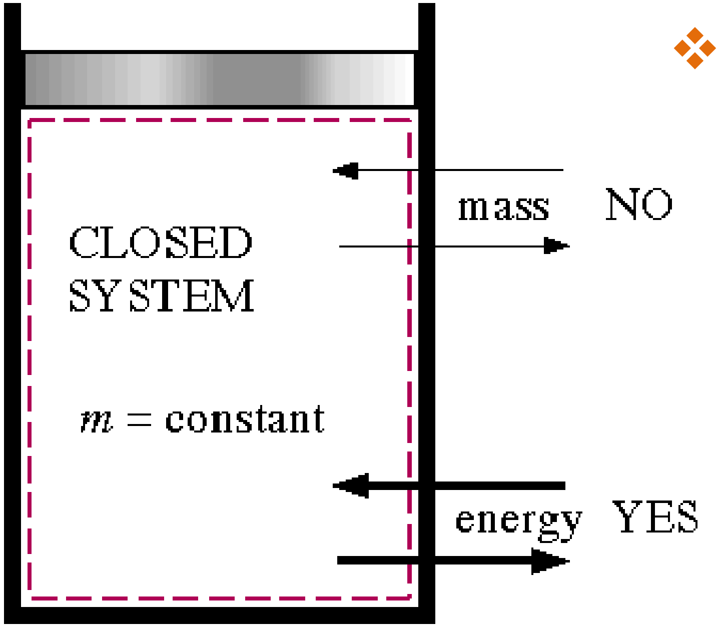
BOUNDARY :

- **Fixed / Movable**
- **Shared by both, SYSTEM and SURROUNDINGS**
- **No Thickness**
  No Mass / Volume

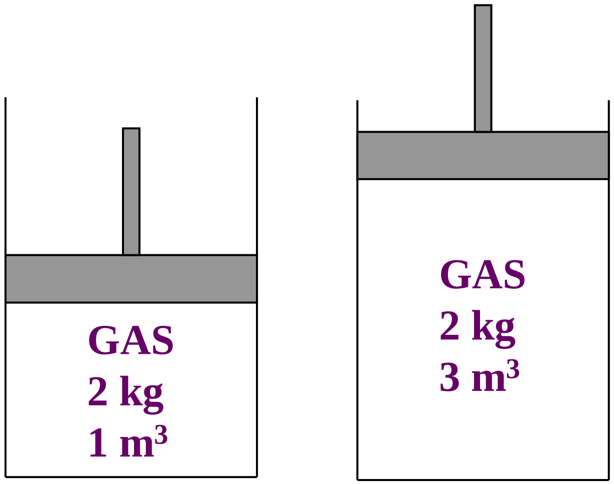
Type of system



Closed system

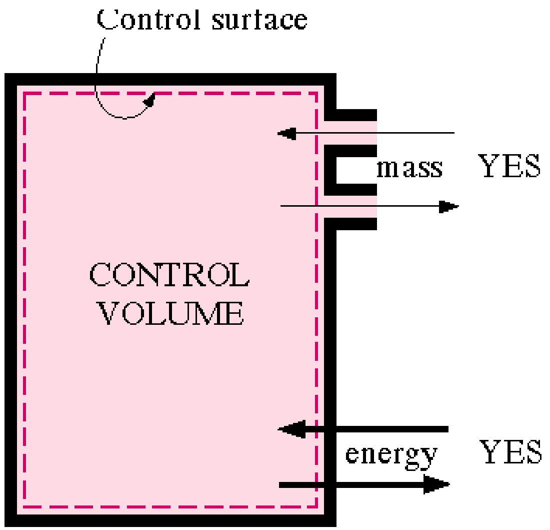


- Closed system – only energy can cross the selected boundary



CLOSED System with Moving Boundary

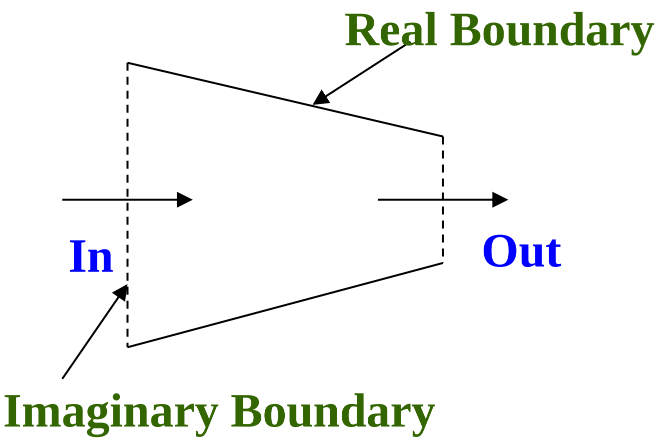
Open system



- Open system – both mass and energy can cross the selected boundary

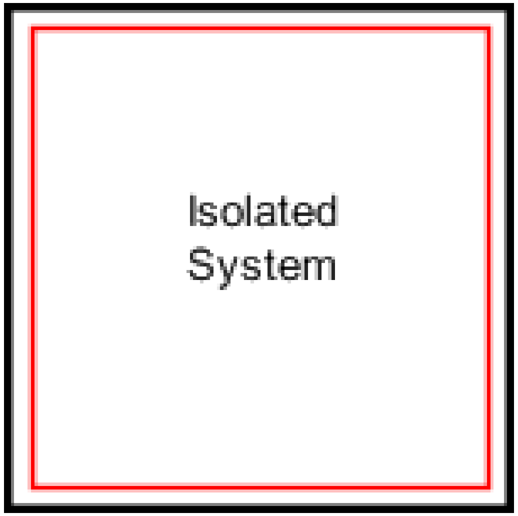
BOUNDARY of OPEN System is known as CONTROL SURFACE

Also known as CONTROL VOLUME



e.g. Water Heater, Car Radiator, Turbine, Compressor

Isolated system



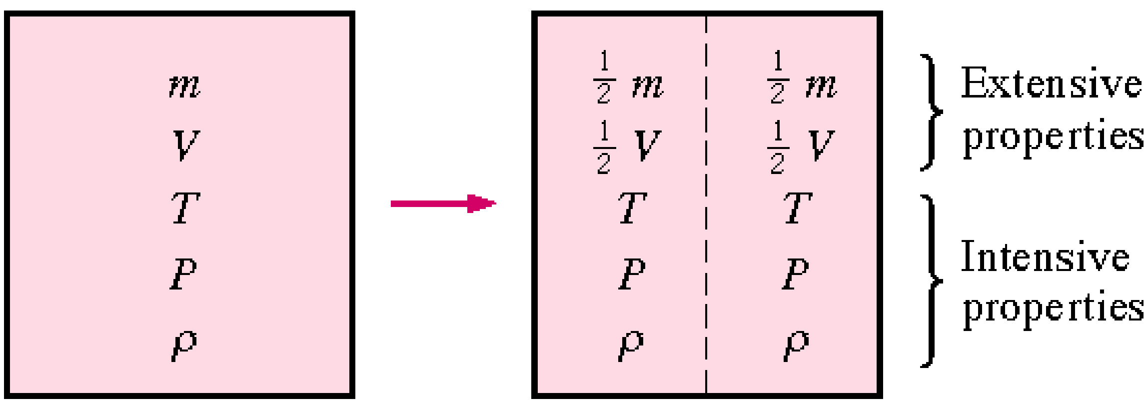
- **Isolated system** – neither mass nor energy can cross the selected boundary
- Example (approximate): coffee in a closed, well-insulated thermos bottle

Properties of a system

Any characteristic of a System is known as its PROPERTY.
Properties may be classified to intensive or extensive.

- **Intensive – Are independent of the amount of mass:**
  e.g: Velocity (v), Elevation (h), Temperature & Pressure

- **Extensive – varies directly with the mass**
  e.g: volume, energy, enthalpy where the extensive property is increased with increase mass



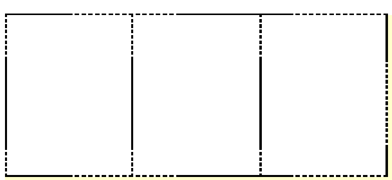
Properties of a system

Specific properties – The ratio of any extensive property of a system to that of the mass of the system is called an average specific value of that property (also known as intensives property)

Specific Volume	$V/m = v$	m^3/kg
Total Energy	$E/m = e$	J/kg
Internal Energy	$U/m = u$	J/kg

Classes of properties

Box with 3 sections after equilibrium



Extensive: Total :

$V = V_1 + V_2 + V_3$

$E = E_1 + E_2 + E_3$

$m = m_1 + m_2 + m_3$

Intensive: not size independent

$v = v_1 = v_2 = v_3 = V/m$

$e = e_1 = e_2 = e_3 = E/m$

T, P

-**Specific Volume** :-(v) is the total volume of that substance divided by the total mass of that substance , it is measured in (m^3/Kg)

$$v = \frac{V}{M} \frac{m^3}{kg}$$

-**Density (ρ)** :- is the total mass of that substance divided by the total volume . it is measured in (Kg/m^3).

$$\rho = \frac{M}{V} \quad Kg/m^3$$

Energy : can be define as the capability to produce an effect.
There are numerous forms of energy such as kinetic, potential, thermal and electrical.

Internal energy : is defined as the sum of all forms of energy of a system such as chemical, nuclear and latent energies.

State, Equilibrium and Process

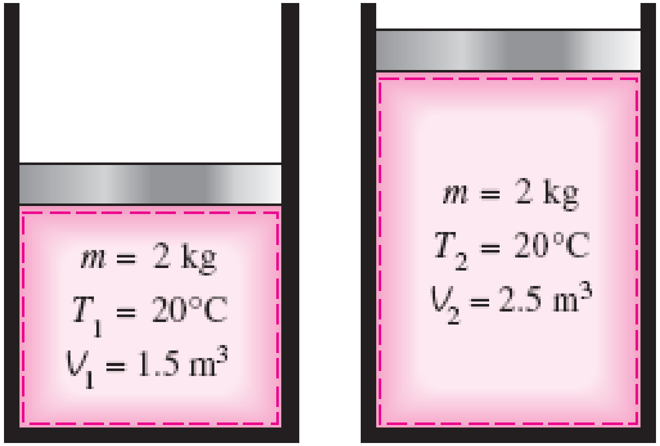
❖ State – a set of properties that describes the conditions of a system. Eg. Mass m, Temperature T, volume V

A system will be in state of thermodynamic equilibrium, if the condition for the following three types of equilibrium are satisfied:

a-isothermal in equilibrium (uniform temp.)

b-mechanical equilibrium (uniform pressure)

c-chemical equilibrium (uniform composition)



(a) State 1 (b) State 2

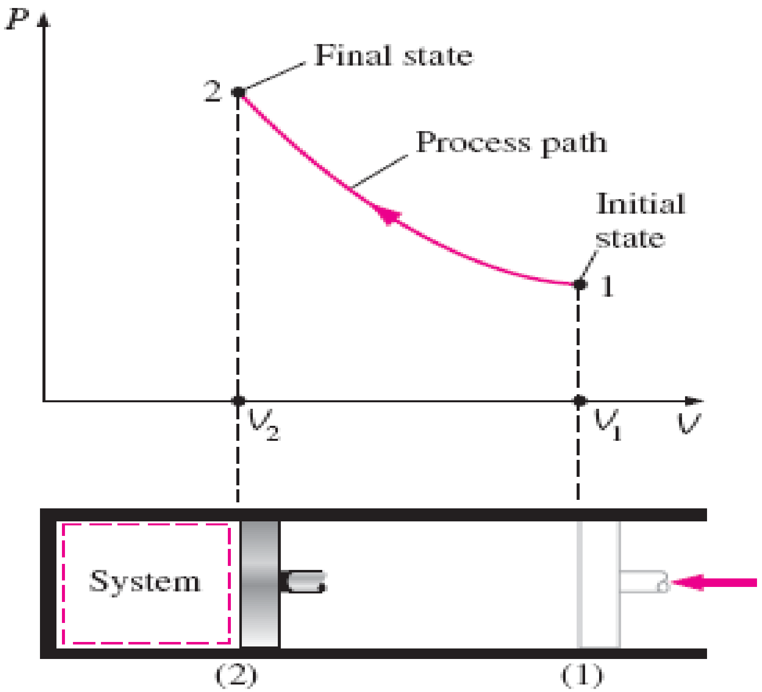
- **Phase** :- is the homogeneous part of the substance having the same intensive properties it can be either solid , liquid or gas (vapor)

- **Homogeneous and Heterogeneous** :- A substance exist at a single phase called a homogeneous , while one consists of two or more phase is called ((Heterogeneous)).

- Process – change from one equilibrium state to another.
- Also can be define as the change in state when one or more of the properties of a system change as example compression gas and heating process.

Several process are described by the fact that one property remain constant

Process	Property held constant
isobaric	pressure
isothermal	temperature
isochoric	volume
isentropic	entropy

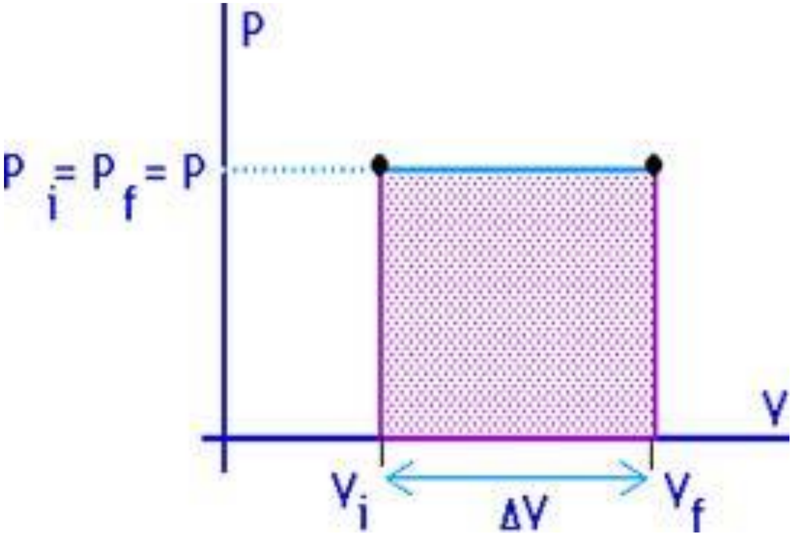


Cycle : a system is said to have undergone a cycle if it returns to it initial state at the end of the process

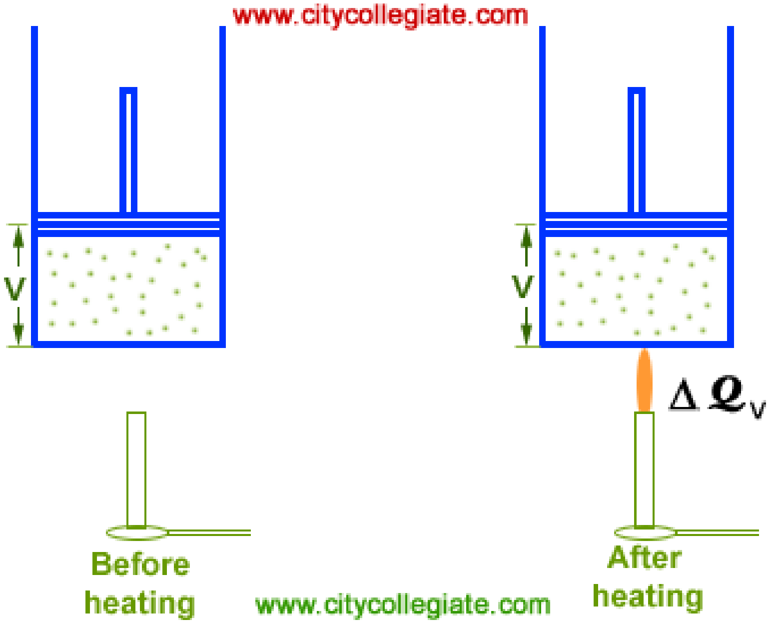
The prefix *iso-* is often used to designate a process for which a particular property remains constant.

Isobaric process: A process during which the pressure *P* remains constant.

Pressure is Constant (**ΔP = 0**)



Isochoric (or isometric) process: A process during which the specific volume *v* remains constant



Isothermal process: A process during which the temperature *T* remains constant.

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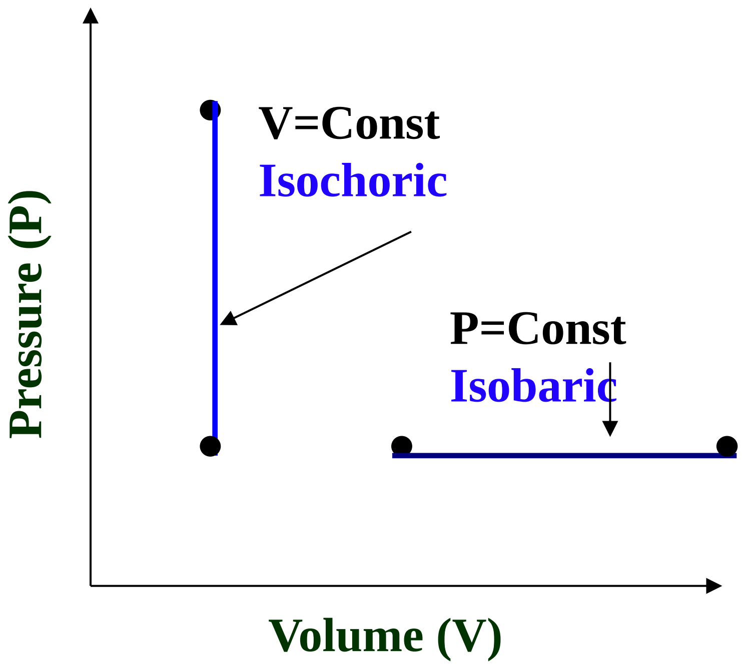
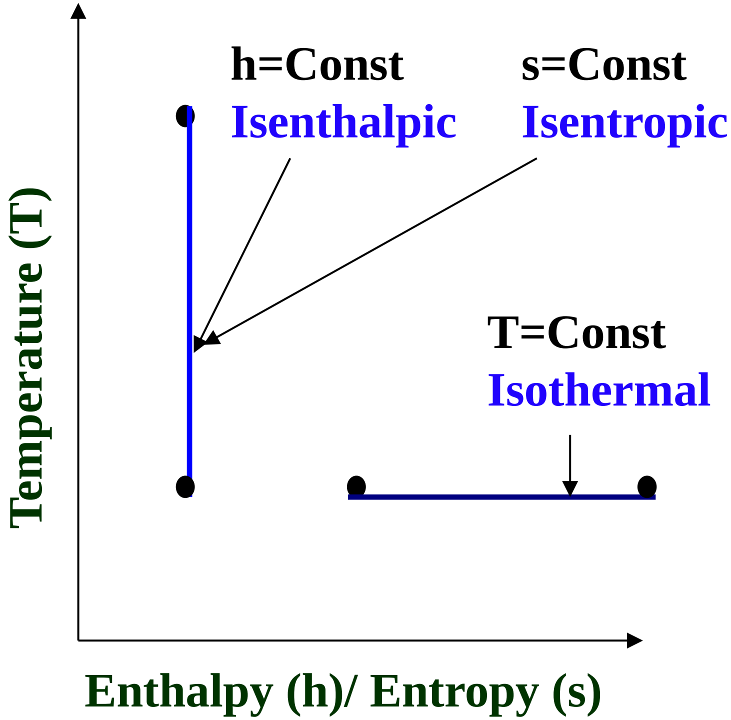
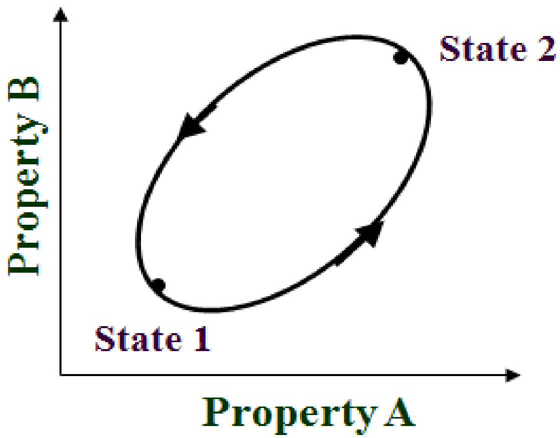
Process	Property held constant
isobaric	Pressure (P)
isothermal	Temperature (T)
isochoric	Volume (V)
Isentropic	Entropy (s)
Isenthalpic	Enthalpy (h)





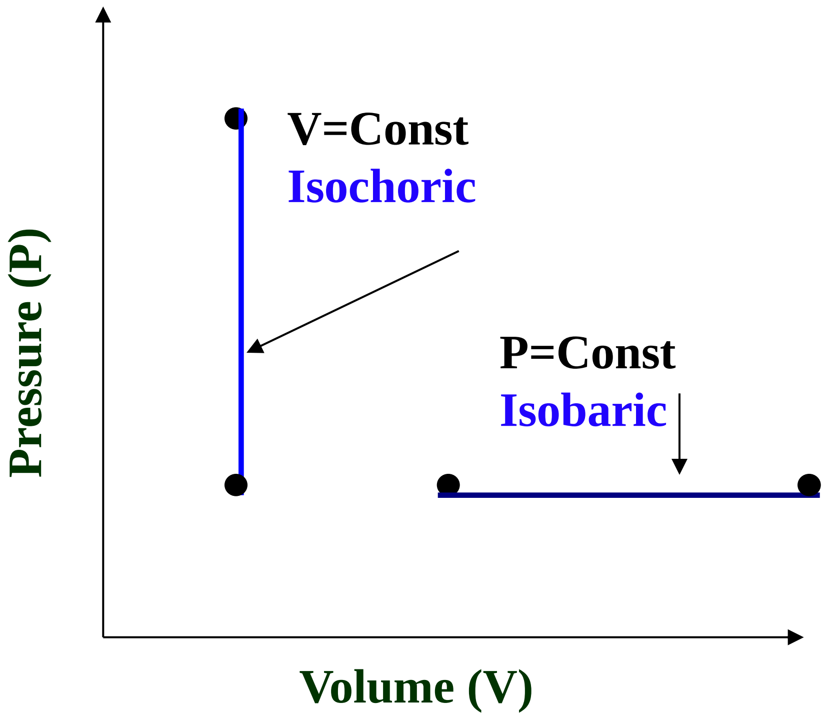
- **Cyclic process** - when a system in a given initial state goes through various processes and finally return to its initial state, the system has undergone a cyclic process or cycle.

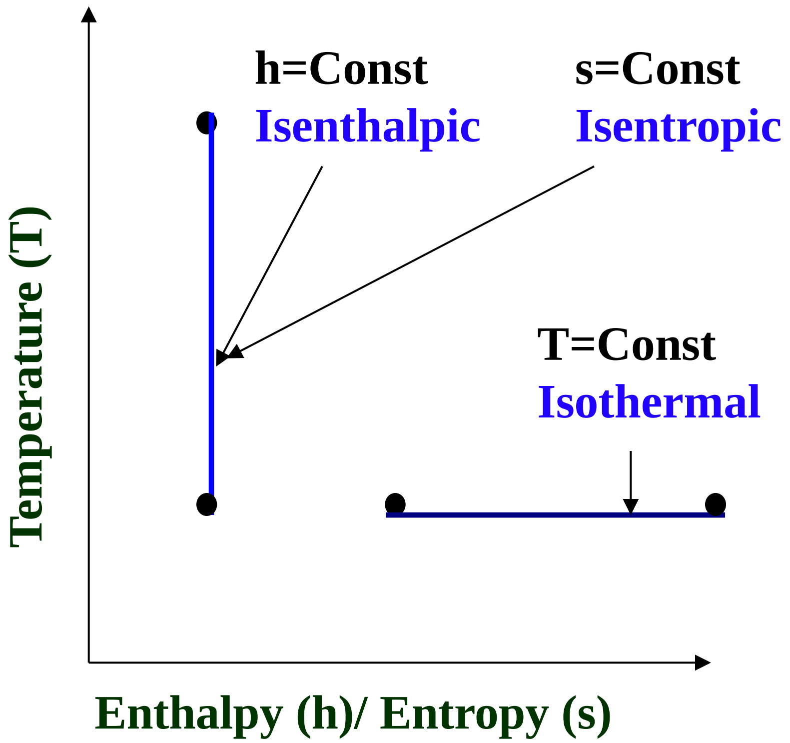


- **Reversible process** - it is defined as a process that, once having take place it can be reversed. In doing so, it leaves no change in the system or boundary. This is only possible when net Heat and net Work Exchange between the system and the surroundings is ZERO for the Process.

- **Irreversible process** - a process that cannot return both the system and surrounding to their original conditions

- **Adiabatic process** - a process that has no heat transfer into or out of the system. It can be considered to be perfectly insulated.
- **Isentropic process** - a process where the entropy of the fluid remains constant.
- **Polytropic process** - when a gas undergoes a reversible process in which there is heat transfer, it is represented with a straight line, PV^n = constant.
- **Throttling process** - a process in which there is no change in enthalpy, no work is done and the process is adiabatic.


V=Const
Isochoric
P=Const
Isobaric
Pressure (P)
Volume (V)


h=Const
Isenthalpic
s=Const
Isentropic
T=Const
Isothermal
Temperature (T)
Enthalpy (h)/ Entropy (s)

Temperature

Is a measure of the molecular activity of substance.
Or it measure of hotness \ cold
Properties of materials change with temperature.

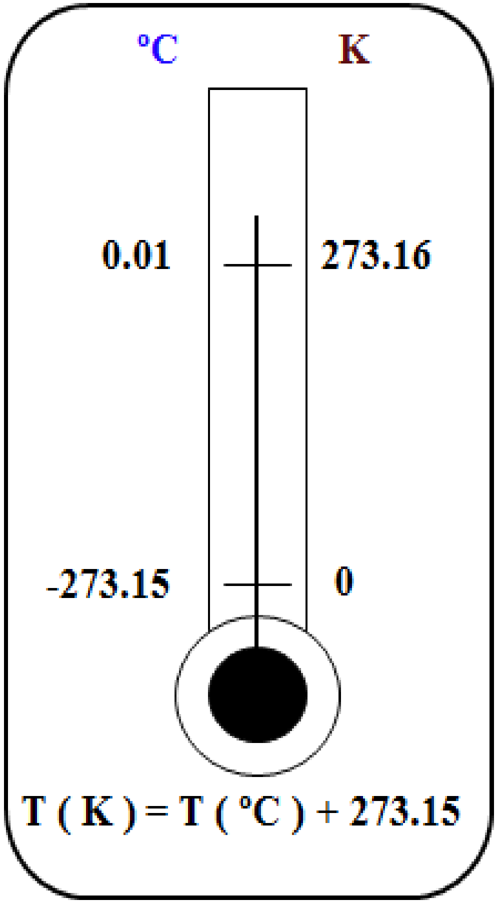
1. **Celsius Scale (ºC) – SI System**
2. **Fahrenheit Scale (ºF) – English System**
3. **Kelvin Scale (K) – SI System**
4. **Rankine Scale (R) – English System**

Celsius Scale and Fahrenheit Scale – Based on 2 easily reproducible fixed states,

viz. *Freezing* and *Boiling* points of water.

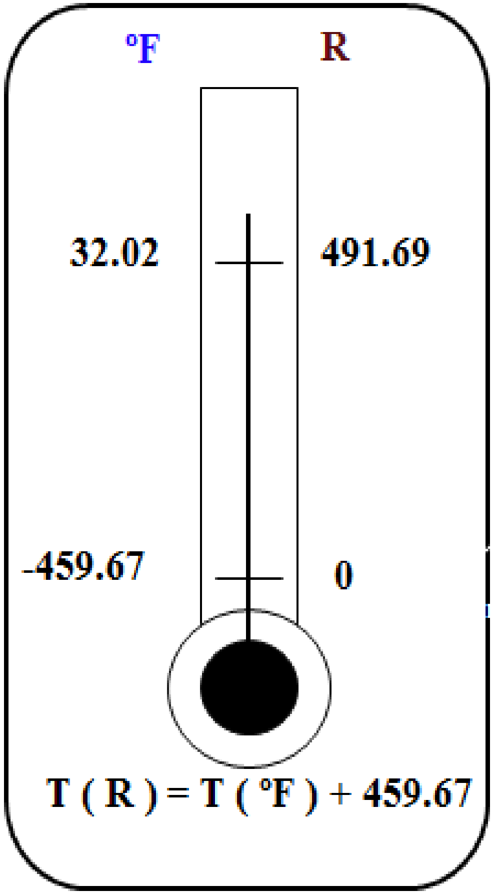
i.e. Ice Point and Steam Point

Conversion Factors :



$$T\,(\,^\circ F\,) = 1.8\,T\,(\,^\circ C\,) + 32$$

$$T\,(\,R\,) = 1.8\,T\,(\,K\,)$$



EXAMPLE 1–4 Expressing Temperature Rise in Different Units

During a heating process, the temperature of a system rises by 10°C. Express this rise in temperature in K, °F, and R.

Solution The temperature rise of a system is to be expressed in different units.

Analysis This problem deals with temperature changes, which are identical in Kelvin and Celsius scales. Then,

$$\Delta T(\text{K}) = \Delta T(^\circ\text{C}) = \mathbf{10\ K}$$

The temperature changes in Fahrenheit and Rankine scales are also identical and are related to the changes in Celsius and Kelvin scales through Eqs. 1–11 and 1–14:

$$\Delta T(\text{R}) = 1.8\ \Delta T(\text{K}) = (1.8)(10) = \mathbf{18\ R}$$

and

$$\Delta T(^\circ\text{F}) = \Delta T(\text{R}) = \mathbf{18^\circ F}$$

Discussion Note that the units °C and K are interchangeable when dealing with temperature differences.

Example -2-

What is the Kalvin equivalent of 80F.

Solution :

$$°C \quad = \frac{1}{1.8}(°F\text{-}32) = \frac{1}{1.8}(80\text{-}32)$$

$$= 26.7\ °C$$

$$T_{(k)} = T(°C) + 273$$

$$= 26.7 + 273 = 299.7\ K°$$

Pressure

Definition : Normal Force exerted by a fluid per unit Area.

SI Units :

1 Pa = 1 N/m^2

1 kPa = 10^3 Pa

1 MPa = 10^6 Pa = 10^3 kPa

1 bar = 10^5 Pa = 0.1 MPa = 100 kPa

1 atm = 101325 Pa = 101.325 kPa = 1.01325 bar

1 kgf/cm^2 = 9.81 N/m^2 = 9.81 X 10^4 N/m^2 = 0.981 bar = 0.9679 atm

English Units :

psi = Pound per square inch (lbf/in^2)

1 atm = 14.696 psi

1 kgf/cm^2 = 14.223 psi

Absolute Pressure : Actual Pressure at a given position.

Measured relative to absolute vacuum i.e. absolute zero pressure.

Pressure Gauges are generally designed to indicate ZERO at local atmospheric pressure.

Hence, the difference is known as Gauge Pressure.

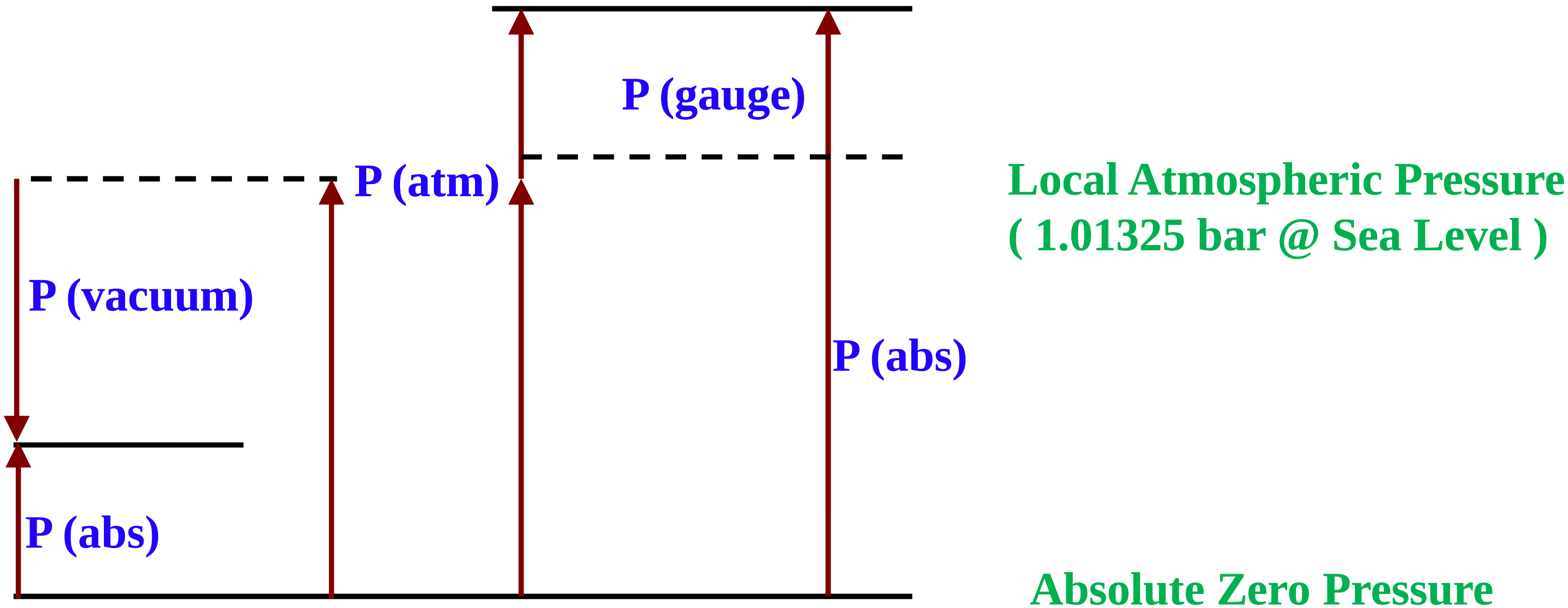
i.e. P (gauge) = P (abs) – P (atm)

Pressure less than local atmospheric pressure is known as Vacuum Pressure.

i.e. P (vacuum) = P (atm) – P (abs)

P (gauge) = P (abs) – P (atm)

P (vacuum) = P (atm) – P (abs)



EXAMPLE 1–5 Absolute Pressure of a Vacuum Chamber

A vacuum gage connected to a chamber reads 5.8 psi at a location where the atmospheric pressure is 14.5 psi. Determine the absolute pressure in the chamber.

Solution The gage pressure of a vacuum chamber is given. The absolute pressure in the chamber is to be determined.

Analysis The absolute pressure is easily determined from Eq. 1–16 to be

$$P_{abs} = P_{atm} - P_{vac} = 14.5 - 5.8 = \mathbf{8.7\ psi}$$

Discussion Note that the local value of the atmospheric pressure is used when determining the absolute pressure.

-**<u>Energy</u>** **:-** is defined as the capacity of a system to perform work or produce heat. There are different types of energy:

1-**<u>Potential energy (P.E.)</u>** **:-** is defined as the energy of position , it is defined as :-

$$P.E = mgz$$

m= mass (Kg) , g=gravitational acc. (m/sec^2)

z= height of body (m)   P.E. in Joule (J)

2-<u>Kinetic Energy (K.E.)</u>:- is defined as the energy of motion, it is defined as:-

$$K.E. = \frac{1}{2} mv^2 \qquad (J)$$

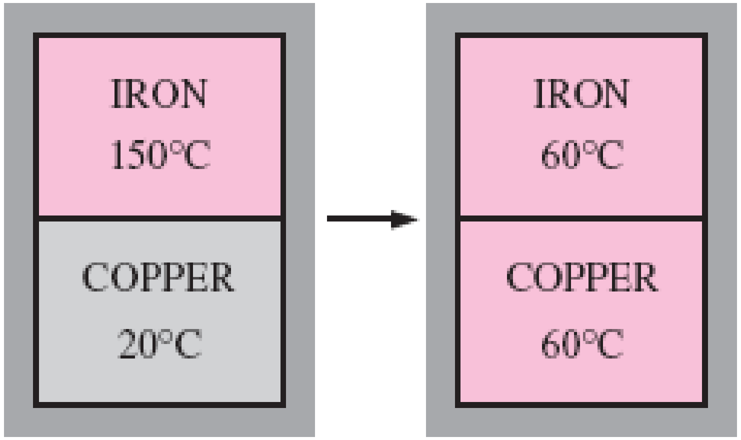
V=speed of body (m/sec.)

3-<u>Internal Energy (u)</u> :- is the energy of mass composition fund a mentally , it is due to the rotation , vibration , translate interactions among the molecules of the substance.

4-<u>Specific Enthalpy (H)</u>:- is defined as ((H=u+pV)) , where u is the specific internal energy (J) of the system being studied ,p is the pressure of the system (Pa) and (V)is the specific volume of the system (m^3/kg) .it is usually used in connection with ((open)) system problem in thermodynamic , it is a property like pressure , Temp. and volume but it cannot be measured directly .

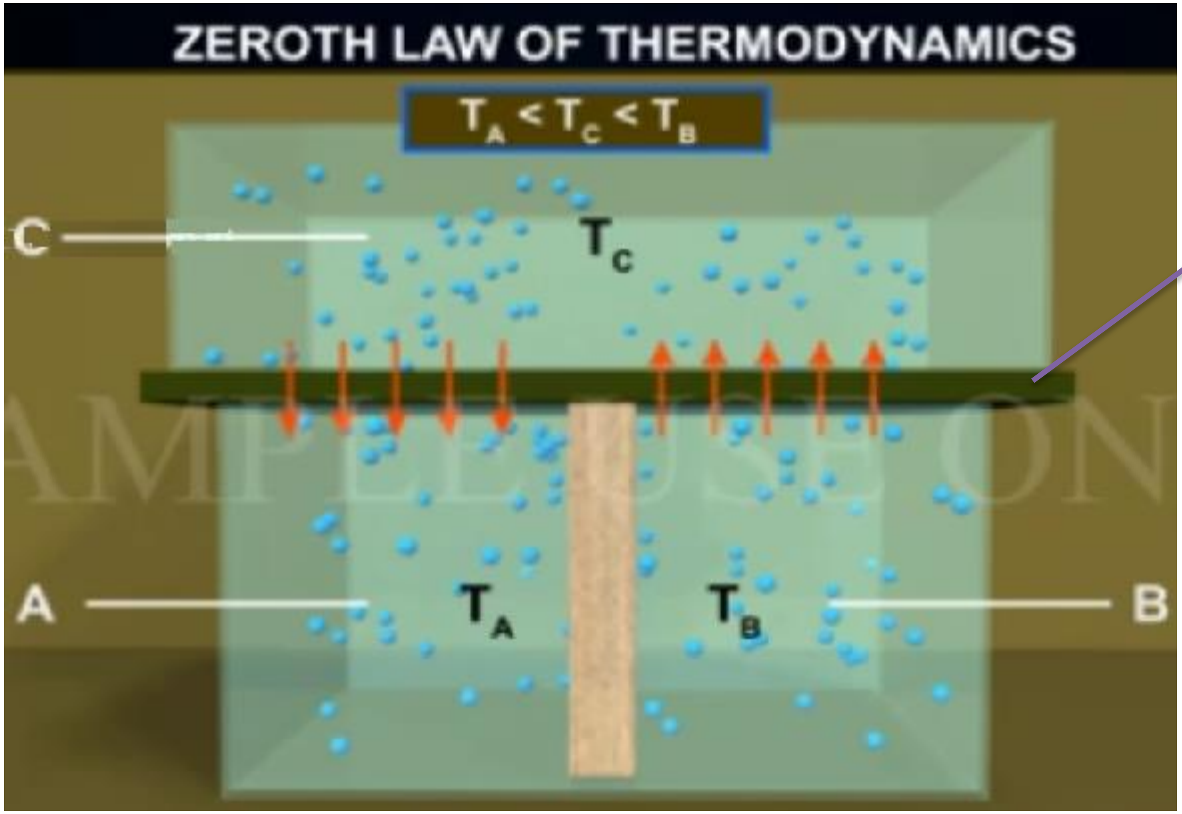
Zeroth Law of Thermodynamics

" *If two bodies are in thermal equilibrium with a third body, there are also in thermal equilibrium with each other.*"



Two bodies reaching thermal equilibrium after being brought into contact in an isolated enclosure.

After Equilibrium $T_A = T_C = T_B$



Diathermic Wall (Allow energy Exchange)

Adiabatic Wall (Not allow energy Exchange)

Temperature of a system or body is a physical quantity, which determines whether the system is in thermal equilibrium with another system in its contact or not

-**Units** :- is an arbitrary amount of quantity be measured with assigned numerical value of unit.

Fundamental units		**(S.I)**
Length	L	m
Mass	M	kg
Time	t	s
Temp.	T	°C

-Secondary units

1-Area	L^2	m^2	
2-Volume	L^3	m^2	
3-Velocity	Lt^{-1}	m/s	
4-Acceleration	Lt^{-2}	m/s^2	
5-Force	MLt^{-2}	$Kg\ ms^{-2}$	(Newton)
6-Density	ML^{-3}	Kg/m^3	
7-Perssure($\frac{F}{A}$)	$ML^{-1}t^{-2}$	N/m^2	($Kgm^{-1}\ S^{-2}$)
8-Work	ML^2t^{-2}	N.m	(Joule)
9-Power	ML^2t^{-3}	J/S	(Watt)