Chapter one

Fundamental concept in Thermodynamic

Thermodynamic = Thermo + Dynamic
(Heat) (Power)

Aspects related to Energy and Energy Transformation
Power Generation
Refrigeration
Relationships among Properties o Matter

What is Thermodynamics?

1-**Thermodynamics**: is a branch of physics which deals with the energy and work of a system

Thermodynamics: is the study of the effect of work, heat, and energy on a system.

Thermodynamics: is only concerned with large scale observations.

2-***Thermodynamics:*** is a science about the effects of changes in temperature, pressure, and volume and how these changes affect a physical system. (e.g. a car engine, an air conditioner).

Thermodynamics

Classical Thermodynamic (C.T)

C.T: Four laws (Zero. First, Second and Third), the First and Second laws are important

Statistical Thermodynamic (S.T)

S.T: Study the relation between macroscopic and microscopic properties of matter

3- ***Thermodynamics*** is a phenomenological theory of matter it derive their concepts from experimental results (thermodynamic system is any macroscopic system)

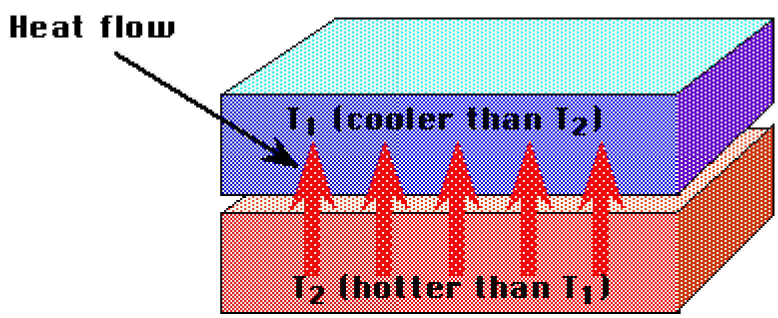
4- ***Thermodynamic*** parameter *is any measurable macroscopic parameters, such as P.V.T.*

What is Heat..?

- Heat energy is a type of kinetic energy.
- Heat Energy related to Thermal energy (or internal energy).
- Thermal Energy is the sum of the kinetic energy $\frac{1}{2}mv^2$, of ALL the individual atoms in a system or object

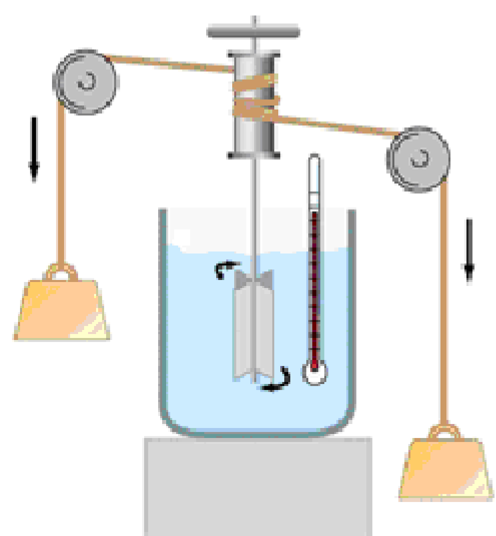
Heat is the energy that flows from one object to another due to a temperature difference

When the energy that can move from the hotter object, to the cold object, is called Heat



James Joule tests the predictions

James Joule's experiment proved that (Heat was a from of energy). In this experiment the kinetic energy of the paddle is transferred to thermal energy in the water, as measured with a sensitive thermometer.



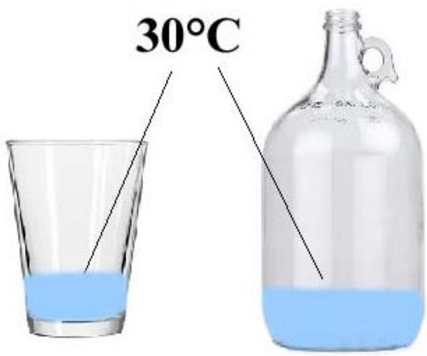
Thermodynamics can be applied to a wide variety of topics in science and engineering, such as engines, phase transitions, chemical reactions, transport phenomena, and even black holes. The results of thermodynamics are essential for other fields of physics and for chemistry, chemical engineering, aerospace engineering, mechanical engineering, cell biology, biomedical engineering, materials science, and are useful for other fields such as economics

What is Temperature?

Is a measure of average kinetic energy of particle in a substance?

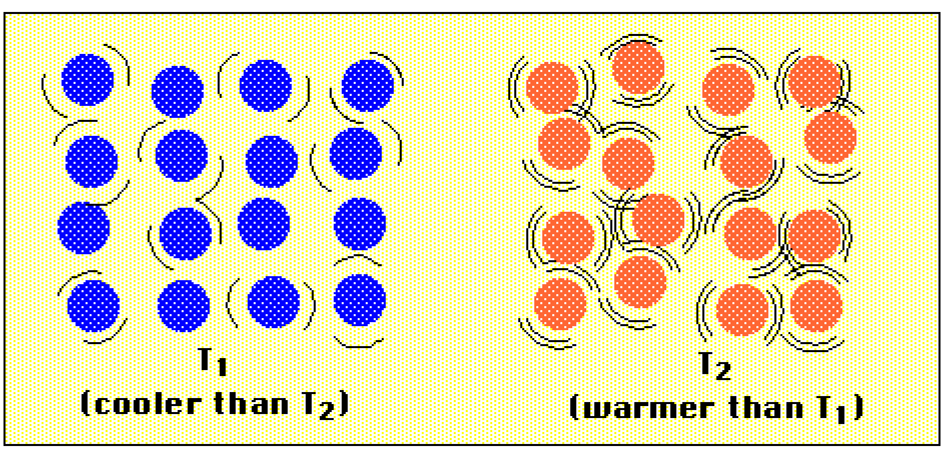
Heat flows due to temperature differences. No heat is transferred between two objects that are at the same temperature (i.e. in thermal equilibrium). 30°C

A cup of boiling water is at the same temperature as a gallon of boiling water, but the gallon of boiling water has more thermal energy than the cup.



Two object in contact on a microscopic level:

Fast moving atoms with a lot of random motion collide with slower moving atoms.
Ask kinetic energy is transferred from the fast moving atoms to the slower moving atoms, we say that the warmer side gave up heat to the colder side and that heat was transferred.



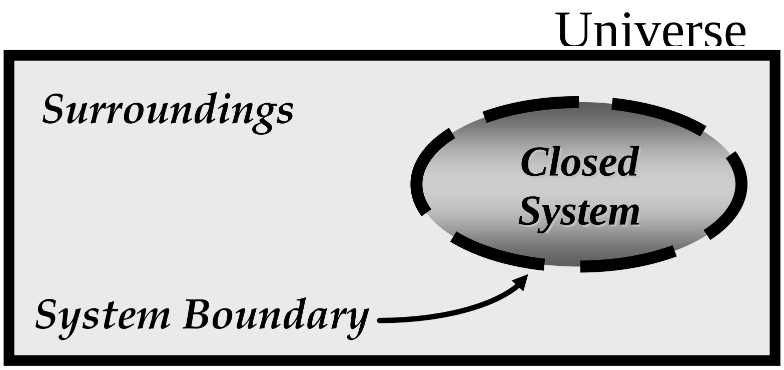
Fundamental concept in thermodynamics

System & Surroundings

System: Quantity o matter or region in space, chosen for study.
Surroundings: Mass or region outside the System.
Boundary: The real or imaginary surface that separates the System from Surroundings.

Boundary: The boundary o a system can be **fixed** or **movable**

Universe= system + surrounding.



Type of Thermodynamic Well

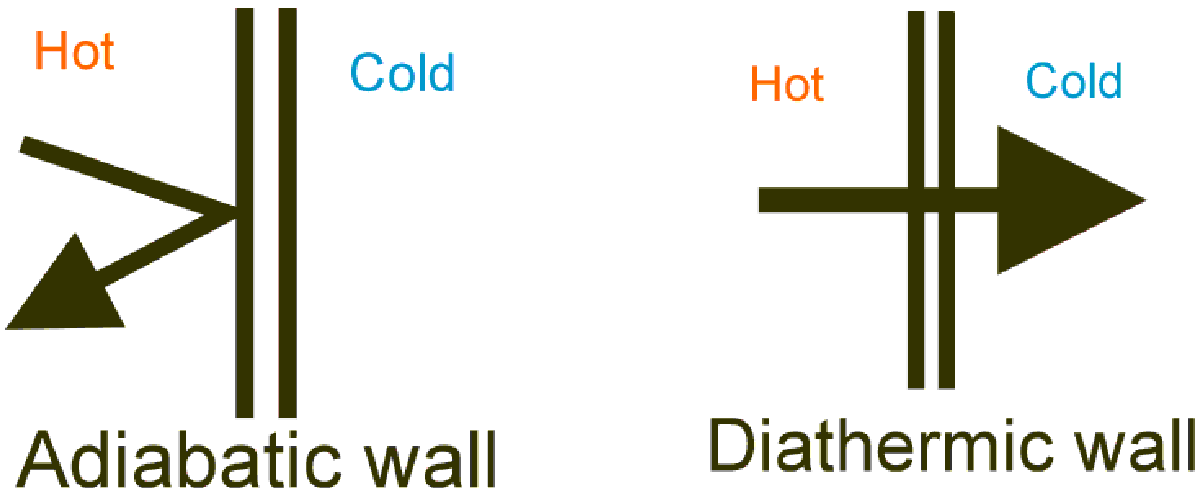
System can be separated from surrounding by the wall:
Adiabatic and diathermal boundary walls:

A - Adiabatic Well:
Perfectly insulating walls that do not allow flow of heat, this wall not permit the heat enter or leave the system

(Adiabatic = No heat exchange = thermally insulating wall)

B - Diathermic wall:- allows heat to flow through it, the temperature is the same at the both sides.

(Diathermal = Heat exchange = thermally conducting wall)



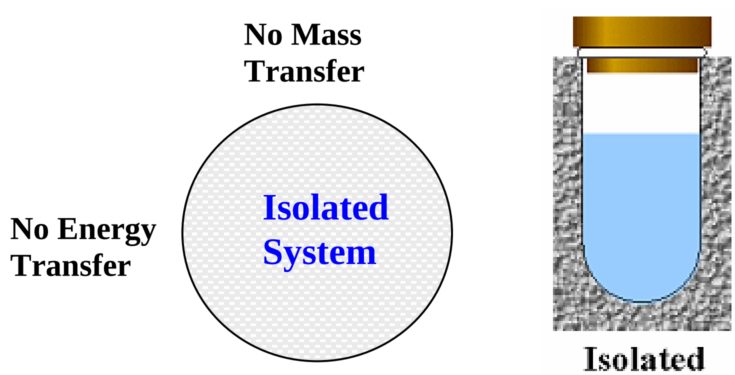
Types of Thermodynamic Systems

Thermodynamic systems can be broadly classified into three types. They are:

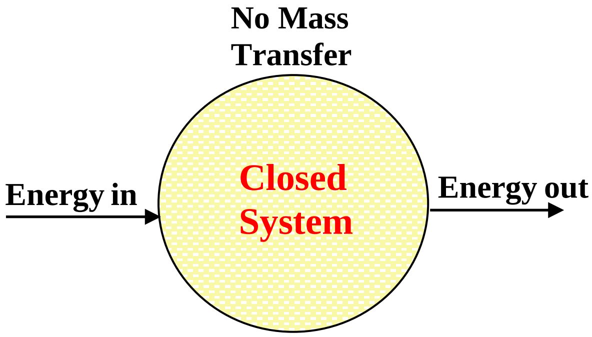
1. Open System
2. Closed System
3. Isolated System

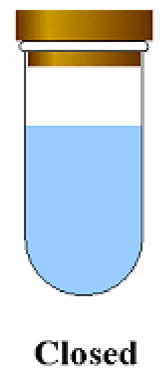
1- **Isolated** –An isolated system does not interact with its surroundings. It does not allow both mass and energy transfer across its boundary. It is more restrictive.

(do not exchange matter or energy with surroundings, and the system have insulated wall (adiabatic wall))

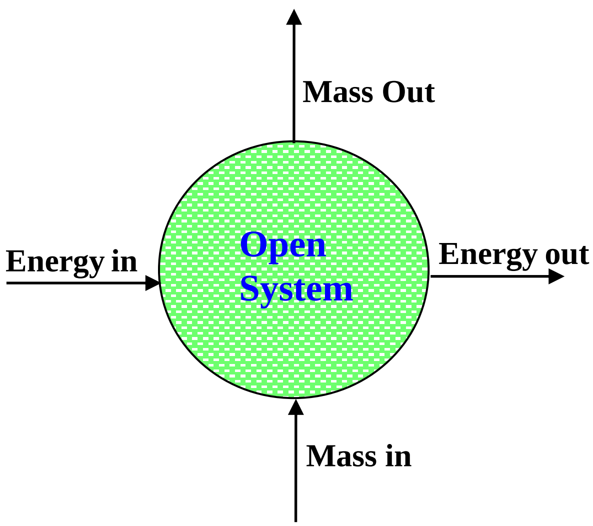


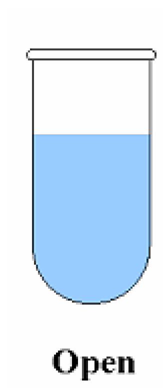
2- **Closed** – A closed system allows only energy (heat and work) to pass in and out of it. It does not allow mass transfer across its boundary. [**Mercury in thermometer]**





3- **Open** – An open system is a thermodynamic system which allows both mass and energy to flow in and out of it, across its boundary. The wall of these systems is permeable wall (**rocket moves, it mass decrease)**





Type of System	**Mass**	**Work**	**Heat**
Open	√	√	√
Closed	×	√	√
Isolated	×	×	×

Properties of a System

- Any characteristic of a system in equilibrium is called a **property**. The property is **independent** of the path used to arrive at the system condition.
- Some thermodynamic properties are pressure ***P***, temperature ***T***, volume ***V***, and mass ***m***.
- Properties may be **intensive** or **extensive**.

Extensive properties: are those that vary directly with size--or extent--of the system.

Some Extensive Properties

a. mass b. volume

c. total energy

Intensive properties: are those that are independent of size.

Some Intensive Properties

a. temperature b. pressure

c. Density

Extensive properties per unit mass are intensive properties. For example,
The specific volume *v*, defined as:

$$\mathrm{v} = \frac{\mathrm{Volume}}{\mathrm{mass}} = \frac{\mathrm{V}}{\mathrm{m}} \qquad \left(\frac{\mathrm{m}^3}{\mathrm{kg}}\right)$$

and density ρ, defined as

$$\rho = \frac{\mathrm{mass}}{\mathrm{volume}} = \frac{\mathrm{m}}{\mathrm{V}} \qquad \left(\frac{\mathrm{kg}}{\mathrm{m}^3}\right)$$

are intensive properties.

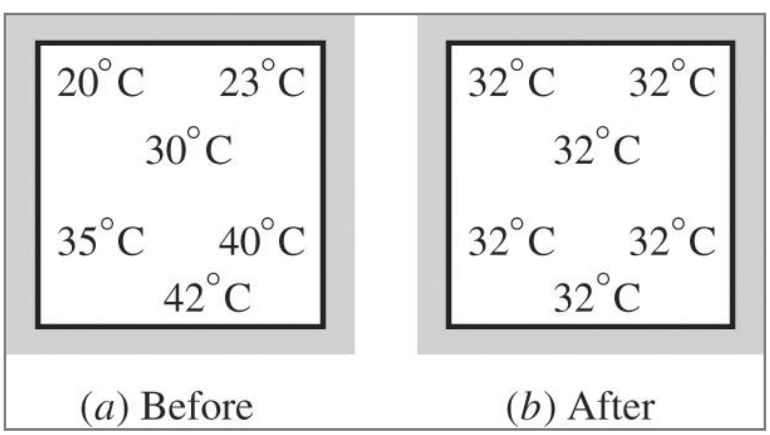
State, Equilibrium and Process

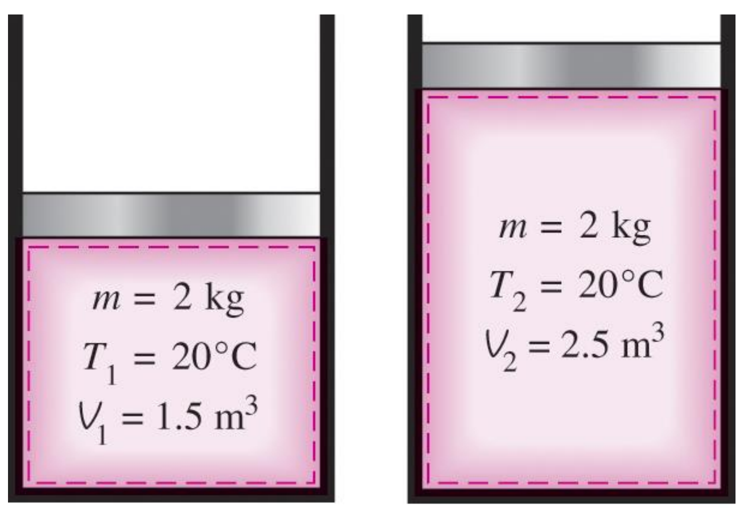
State: a set of properties that describes the conditions of a system. Eg. Mass (m), Temperature (T), and Volume (V)

Thermodynamic equilibrium:

Thermodynamics deals with equilibrium states.

- **Equilibrium**: A state of balance. In an equilibrium state there are no unbalanced potentials (or driving forces) within the system.
- **Thermal equilibrium:** If the temperature is the same throughout the entire system.
- **Mechanical equilibrium:** If there is no change in pressure at any point of the system with time.
- **Phase equilibrium:** If a system involves two phases and when the mass of each phase reaches equilibrium level and stays there.
- **Chemical equilibrium:** If the chemical composition of a system does not change with time, that is, no chemical reactions occur





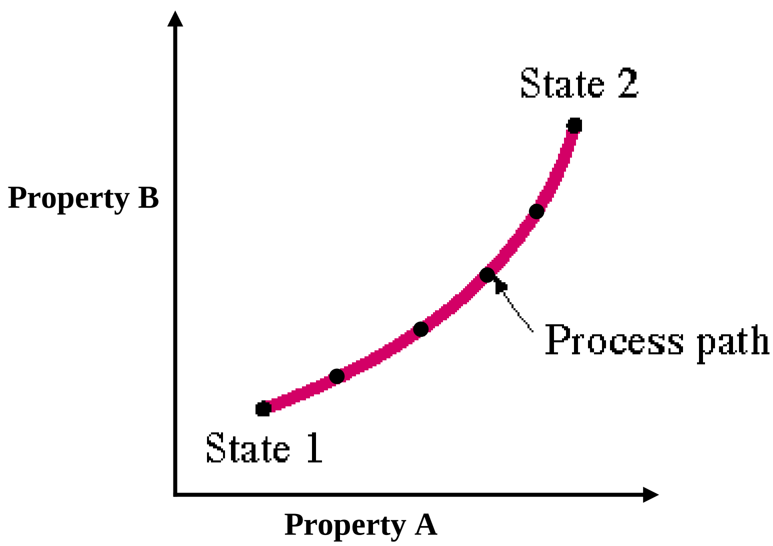
(a) State 1 (b) State 2

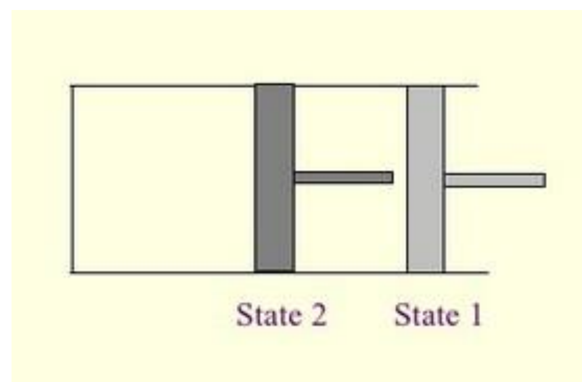
Thermodynamic process

Process

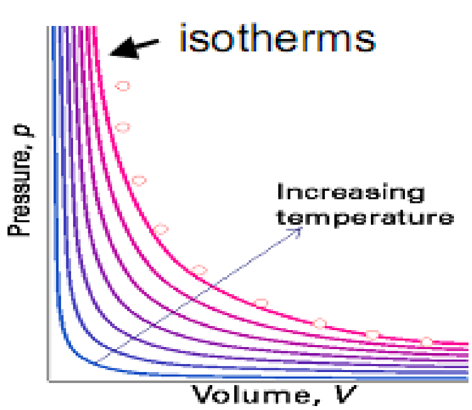
Any change a system undergoes from one equilibrium state to another is known as (Process).

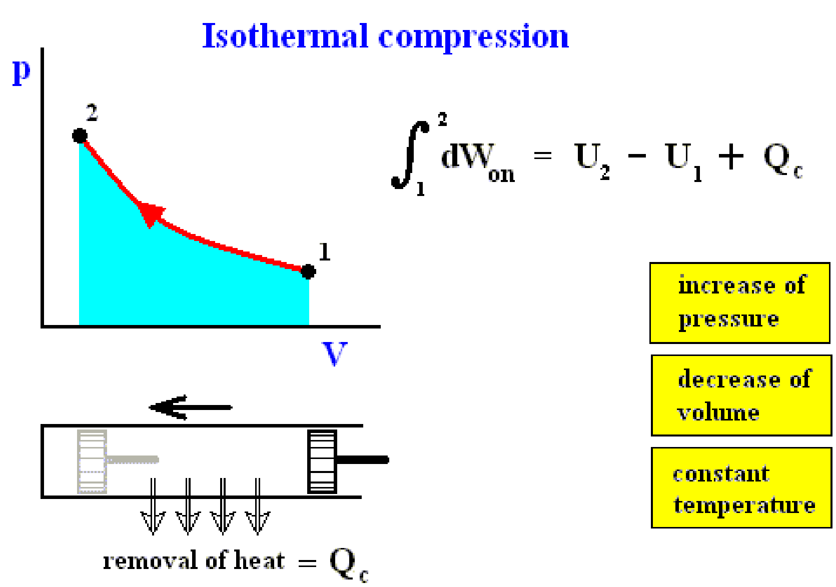
Series of states through which system passes during the process is known as its (Path)





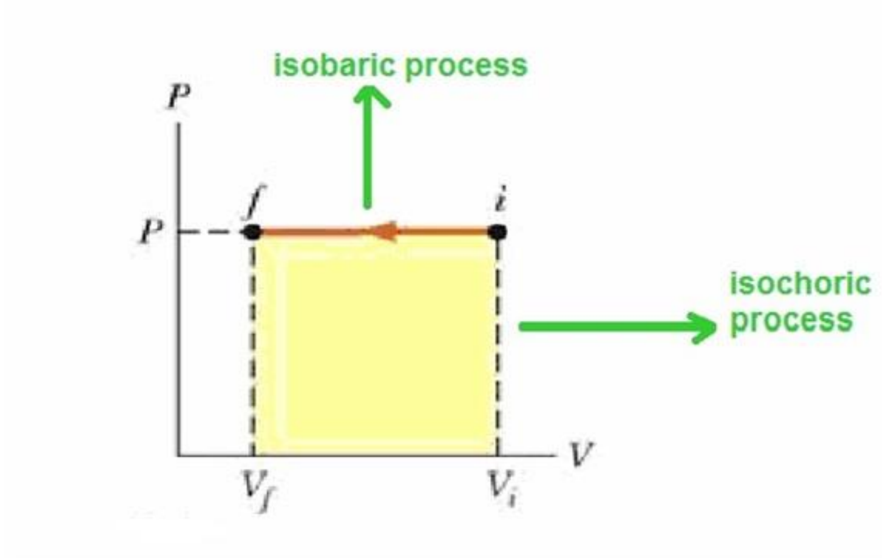
1- *Isothermal process*: - An isothermal process is a change of a system, in which the temperature remains constant: $\Delta T = 0$





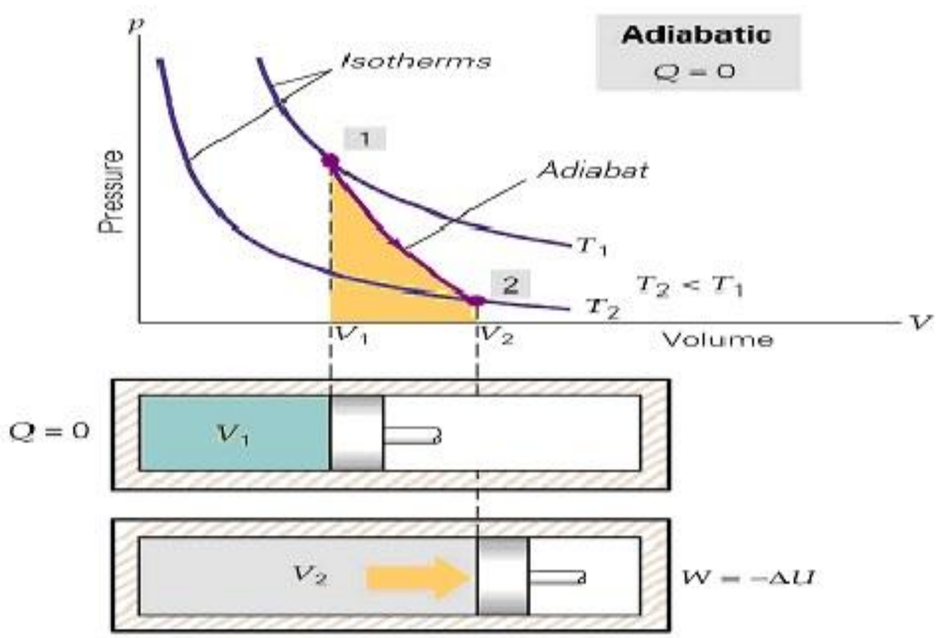
2- Isobaric process:- An isobaric process is a thermodynamic process in which the pressure stays constant

) $Pi - Pf = P$) ($\Delta P = Cons\tan t$ (

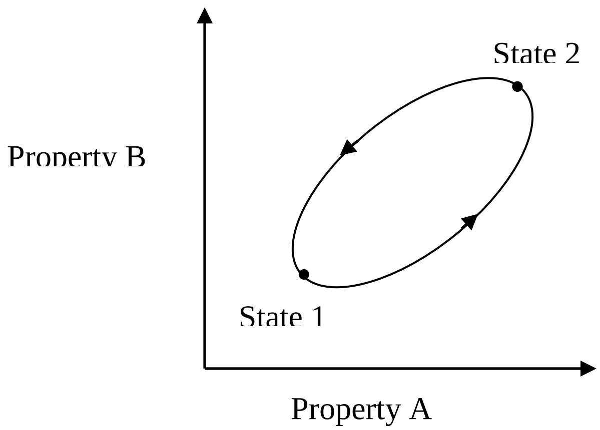


3- Isochoric process:- An isochoric process is a thermodynamic, also called a constant-volume process, an isovolumetric process, or an isometric process.

4- Adiabatic process:- Any process taking place without gain or loss of heat, in the system clearly all three variables change here, (p ,v ,T) but Q=0



5-Cyclic Process:- A system is said to have undergone a cycle if it returns to its ORIGINAL state at the end of the process.
Hence, for a **CYCLE**, the **INITIAL**, and the **FINAL**, States are identical



6- Isentropic Process: - A process where the entropy of the fluid remain constant

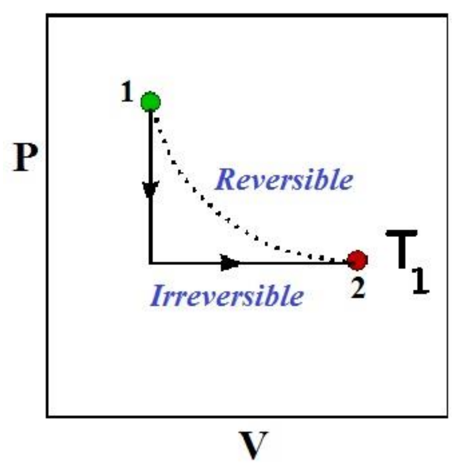
7- Polytropic Process: - When a gas undergoes a reversible process in which there is heat transfer, it is represented with a straight line, $PV^n = constant$

8- Throttling Process: - A process in which there is no change in enthalpy, no work is done and the process is adiabatic.

Some sample processes:

Isothermal Process: temperature is constant T = C
Isobaric Process: pressure is constant P = C
Isentropic Process: entropy is constant s = C
Isochoric / Isometric process: Volume is constant v = C
Adiabatic process: no heat transfer Q = 0

5- Reversible process:- Can be defined as one whose direction can be reversed by an infinitesimal change in some property of the system.



6- Irreversible process:- A process that it is not possible to return the system involved to its original thermodynamic state. All natural process is irreversible process.

Pressure

Pressure: - the pressure P is defined as the magnitude of the force per unit area, and the unit of pressure is (Newton / meter^2. N/m^2).

Pressure unites **:-**

1-bar:- A bar is a unit of pressure that is defined to be equal to 10^5 pascals. bar commonly used in ***Meteorology***.

The bar and the millibar were introduced by the British meteorologist William Napier Shaw in 1909, while he was the director of the Meteorological Office in London.

1 bar = 10^5 Pascal = 1.01325 atmospheres = 14.5038 psi (pounds per square inch) = 29.53 inHg (inches of mercury).

The **bar** is a non-SI **(International System of Units)** unit of pressure, defined by the IUPAC (The International Union of Pure and Applied Chemistry), as exactly equal to 100,000 Pa

$$10^{-1}\ Nm^{-2} = 1\mu\ bar$$

2-atmosphere:- A pressure of 1 standard atmosphere (atm) is defined as the pressure produced by a vertical columns of mercury exactly **76 cm** in high and density ρ= 13.595 gm/cm^3

At point where g=9.8 cm/sec^2, we find from the equation:-

$$P=\rho g\ h$$

$$P= 13.595\times9.8\times76$$

$$=1\times10^6\ dyne/cm^2$$

$$1\ atm= 1\times10^5\ N/m^2 \cong 1\ bar$$

3-mmHg **:-** A unit of pressure equal to that exerted under standard gravity by a high of one millimeter of mercury or 133.322 Pascal.

mm Hg - a unit of pressure equal to 0.001316 atmosphere; named after Torricelli

The *millimeter of mercury* (mmHg) is defined as the pressure exerted at the base of a column of fluid exactly 1 millimeter (mm) high, and the fluid density is exactly 13.5951 gram per cubic centimeter (g/cm^3), at a physical location where the gravity acceleration is exactly 9.80665 m/sec^2.

millimeter of mercury corresponds to the pressure difference:

$\delta P = h\rho g$=0.001m×13,595.1kg/m3×9.80665m/sec2=133.332Pa

4-Pascal: - (PA):- the unit of pressure in the SI (**International System of Units**) unit, it is a pressure of 1N/m^2

a unit of pressure in the meter-kilogram-second system equivalent to one newton per square meter. Blaise *Pascal*

First Known Use: 1956

1bar =10^5 Pascal =0.987 atm

1 atm= 760 millimeter of Hg

= 1013.25 millibar

The unit of mmHg is often called Torr

760 mmHg= 760 Torr

Pascal used by physics (but it is a small unit so KPa is the common direct pressure unit for atmospheric pressure.

5-Torr:- a unit commonly used in experimental work at low pressure is Torr and defined as the pressure produced by a mercury column exactly one millimeter in height

The **torr** (symbol: **Torr**) is a traditional unit of pressure, now defined as exactly 1/760 of a standard atmosphere, which in turn is defined as exactly 101325 pascals. Thus one torr is exactly 101325/760 ≈ 133.3 pascals.

1Torr= 1333N/m^2

Pressure units

V.T.E	**Pascal** (Pa)	**Bar** (bar)	**Technical atmosphere** (at)	**Standard atmosphere** (atm)	**Torr** (Torr)	**Pounds per square inch** (psi)
1 Pa	≡ 1 N/m^2	10^{-5}	1.0197×10^{-5}	9.8692×10^{-6}	7.5006×10^{-3}	1.450377×10^{-4}
1 bar	10^5	≡ 10^6 dyn/cm^2	1.0197	0.98692	750.06	14.50377
1 at	0.980665×10^5	0.980665	≡ 1 kp/cm^2	0.9678411	735.5592	14.22334
1 atm	1.01325×10^5	1.01325	1.0332	≡ p_0	≡ 760	14.69595
1 Torr	133.3224	1.333224×10^{-3}	1.359551×10^{-3}	1.315789×10^{-3}	≈ 1 mm_{Hg}	1.933678×10^{-2}
1 psi	6.8948×10^3	6.8948×10^{-2}	7.03069×10^{-2}	6.8046×10^{-2}	51.71493	≡ 1 lb_F/in^2