ME 209
Basic Thermodynamics (Lecture-1)

Kannan Iyer
Kiyer@me.iitb.ac.in

Department of Mechanical Engineering
Indian Institute of Technology, Bombay

Why Study Thermodynamics?-I

- Thermodynamics is derived from Greek Words "**Therme**" meaning "**Heat**" and "**Dynamis**" meaning "**Force**".
- Subject developed during the age of development of Heat engines ~1750 onwards to explain the heat to work conversion
- Today it represents the study of Energy Interactions
- The kinds of energy we come across can be, Mechanical, Thermal, Photo, Magnetic, Electric, Nuclear, Chemical, etc.

Why Study Thermodynamics?-II

- It cuts across disciplines and hence every engineer studies it in some form or the other
- Our focus shall be Mechanical Work-Heat interaction
- Many components of Power Stations, such as boilers, turbines, pumps, condensers, etc., Refrigeration and Air-conditioning equipment, such as compressors, evaporators, condensers, etc., Automobile engines, such as petrol engine, diesel engine, etc., use the knowledge of thermodynamics.

Different Approaches-I

- **Molecular Approach**
  – Follow the state of each molecule
  – Difficult as even 1 cc of air has ~ 10^{22} molecules at STP
  – With such large numbers, it is ideal to resort to statistical approaches

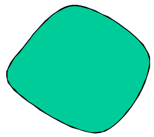
Different Approaches-II

- **Continuum Approach**
  - Assumes that the material and their properties are continuous
  - Measurement methods are synthesized to quantify the properties
  - Suitable laws are generated to relate the various changes in properties like conservation of mass, conservation of energy, etc.
  - Predict system behaviour and verify it with experiments and finally generalize
- We shall follow this approach, which is at times called the Classical Thermodynamics.

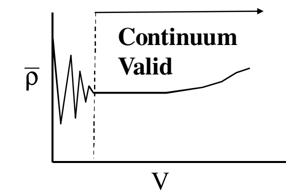
Properties

- In Continuum or macroscopic approach, we define many properties
- Consider the well known property, density

$$\bar{\rho} = \frac{M}{V}$$



- If we keep subdividing this volume into finer ones, till we come to levels of few molecules, the average density variation shall be as shown



Definitions-I

Property

- A characteristic of the state of the matter
  e.g., pressure, density, force, volume, etc.
- A property is said to be **intensive**, if it does not vary with the extent of matter
  e.g., temperature, pressure, density, etc.
- A property is said to be **extensive**, if it depends on the extent of matter
  e.g., mass, volume, force, etc.
- For every extensive property, we can define a corresponding intensive property

mass – Density

Volume-specific volume

Definitions-II

System

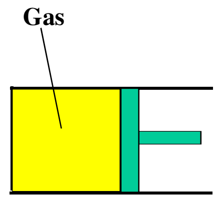
- In thermodynamics, we normally pay attention to a quantity of matter that is of interest to us. This is denoted by system
- A system is **homogeneous**, if its properties are uniform (no spatial variation)
- A system is **isolated**, if it has no energy interactions with its surroundings

Surroundings

- Matter outside the system

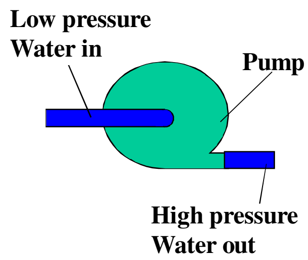
Universe includes both system and surroundings

Definitions-III



- A system is **closed**, if it has no mass exchange, but has energy interactions with its surroundings

- A system is **open**, if it has both mass and energy interactions with its surroundings



Definitions-IV

State

- A set of properties required to specify a system uniquely
- Only a small subset may be defined independently
  - e.g., for gas we can only specify 2 properties independently (p,v) or (v,T), (p,T)
- Relation between the independent property variable and others is called **Equation of State**
  - e.g., pv = RT

Definitions-V

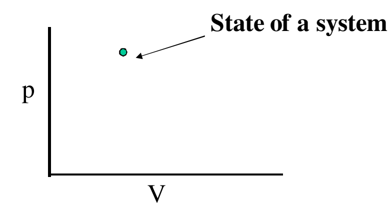
Equilibrium

- In thermodynamics, we normally deal with systems that have no gradients, like homogeneous pressure, temperature, etc.
- These correspond to some internal equilibrium state
  - Mechanical equilibrium implies uniform pressure
  - Chemical equilibrium implies homogeneous composition
  - Thermal equilibrium implies homogeneous temperature

Definitions-V

Representation of the state of a system

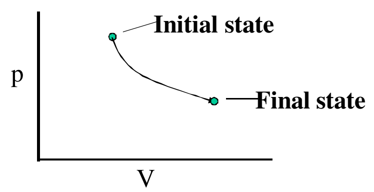
- Isolated systems eventually come to equilibrium
- Only equilibrium states can be represented in state space



Definitions-VI

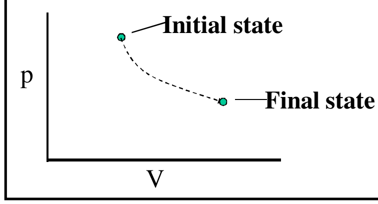
Process

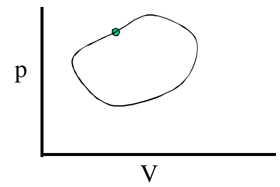
- When energy interactions occur between a system and surroundings, the state of the system changes
- The locus of change of states is called the process
- For a process to be denoted in a state space, it has to be very slow such that every point in the path is an equilibrium state. This is called Quasi-static process



Definitions-VII

- A non-quasi-static process cannot be shown in a state space as a line. However, if the end states are known, it is shown as a dotted line
- If the initial and final states of a process is same, then the process is called a cycle





Definitions-VIII

- Since the end points of a cycle is same, then the initial and final properties shall be same
- As a corollary, if the change of a variable when a cycle is executed is zero, the variable will qualify to be called a property.
- Mathematically, property is a point function and not a path function (independent of path)