MME 231: Lecture 02

The Structure of Thermodynamics

Thermodynamic Systems and Variables

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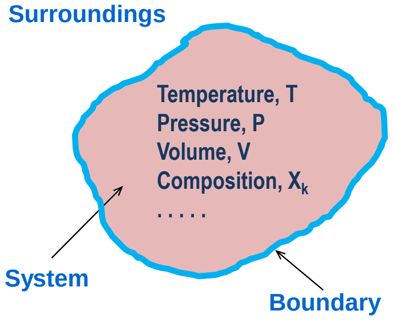
Today's Topics

- **Thermodynamic Systems**
  - Classification of thermodynamic systems
- **Thermodynamic Variables**
  - State functions vs. process variables
  - Extensive vs. intensive variables

The Structure of Thermodynamics

- The science of thermodynamics is rooted with logics and reasons.
- At its foundation there are a very few, very general, and therefore very powerful principles: **The Laws of Thermodynamics**.
- The structure of thermodynamics can be visualised as an **inverted pyramid**.

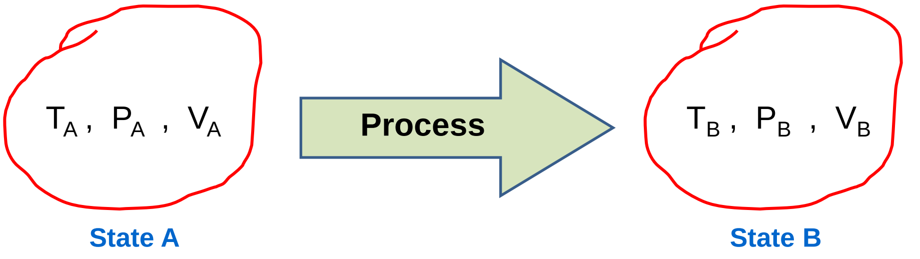
Strategy in Studying Thermodynamic Structure



The subset of the universe in focus for a particular application

- Identify the part of universe that encompasses the problem and define this as **the system**
- Separates the problem using an enclosure (known as **the boundary**) from the rest of the universe (known as **the surroundings**), close enough to the system to have some perceptible effect on the system.
- Specify the conditions of the system at the point of investigation in terms of thermodynamic **properties**.

- If the system undergoes a **process**, its properties change from their initial set of values to a new set of values that define the new state of the system.



A process is a change in the condition or state of the system

- Develop and use appropriate **thermodynamic relations** to compute the changes of these properties.

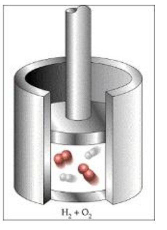
- It is helpful to divide the structure of thermodynamics into the following four categories:
  - Thermodynamic **systems**.
  - Thermodynamic **properties**
  - Thermodynamic **properties**
  - Thermodynamic **relations**

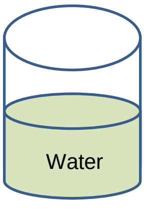
Thermodynamic Systems

- Certain portion of the universe that encompasses the whole problem at hand; the boundary separates the system from its surroundings.
  be explicit about the **nature of the contents** of the system, and the specific **location and character** of its boundary.

- Across the boundary of a system, heat flows, work appears or disappears, and sometimes even matter moves.

- The system and its surroundings are considered to be **isolated**.





Classifications of Thermodynamic Systems

❶ Unary vs. Multicomponent

- **Unary system** (single component)
  - ***Aluminium*** *can,* ***Quartz*** *(SiO_2),* ***Water*** *(H_2O) (when undecomposed)*
- **Multi-component system** (more than one component)
  - ***Steel*** *bar (containing Fe, C, Si, etc.),* ***Water*** *(H, O)*

❷ Homogeneous vs. Heterogeneous

- **Homogeneous system** (single phase)
  - ***Ice*** *(solid phase),* ***Water*** *(liquid phase)*
- **Heterogeneous system** (more than one phase)
  - ***Steel*** *(containing ferrite and cementite),* ***Ice water*** *(solid and liquid phases)*

❸ Closed vs. Open

- **Closed system** (energy but mass transfer across boundary)
  - *A piece of paper*
- **Open system** (mass and energy transfer across boundary)
  - *A cup of tea*
- **Isolated system** (neither mass nor energy transfer across boundary)
  - *Hot milk in thermos flask*

❹ Non-reacting vs. Reacting

- **Non-reacting system** (no chemical reaction within)
  - ***Sugar-water solution** in a glass, Piece of **copper rod***
- **Reacting system** (involving chemical reaction)
  - ***Liquid steel** in a crucible, Piece of **aluminium** in sodium hydroxide solution*

❺ Otherwise simple vs. Complex

- **Otherwise simple system**
  - *No force field other than mechanical force is acting upon the system*
- **Complex system**
  - *Force field other than mechanical such as magnetic, electrical, rotational, etc. is acting upon the system.*

Self Assessment Question #2.1

Classify the following thermodynamic systems:

(a) a solid bar of copper
(b) a glass of ice water
(c) a yttria stabilised zirconia furnace tube
(d) a styrofoam coffee cup
(e) a eutectic alloy turbine blade rotating at 20000 rpm.

Thermodynamic Variables

- Identifiable characteristics of matter whose are **observable** and **can be measured** either directly or indirectly are called variables, functions or, properties.

  Examples: pressure, temperature, volume, mass, velocity, work

- The physical properties of thermodynamics are distinct in two respects:

  ❶ **they can be expressed quantitatively in terms of dimensions and units, and**

  ❷ **the measured value at any particular point of time is unique.**

Thermodynamic State

- It is the **internal condition** of a system as defined by the values of all its properties. It gives a **complete description of the system**.
- Properties describe and specify the state of the system in such a way that **identical states have identical properties**.
- If in any operation, one or more properties of a system change, the system changes its state.

- We must choose the most appropriate set of properties to define the state of the system completely.
  - **Rafiq weighing 72 kg and being 1.75 m tall may be a useful way of identification for police purposes.**
  - **If he has to work in a company you would say Rafiq graduated from BUET in 2002 in MME.**
  - **Rafiq hails from Rajshahi. He has a sister and his father is a poet. He is singer. .... If you are looking at him as a bridegroom!!**
- All of them are properties of Rafiq. But you pick and choose a set of his traits which describe him best for a given situation.
- Similarly, among various properties by which a definition of a thermodynamic system is possible, a situation might warrant giving the smallest number of particular properties which describe the state of the system best.

Classifications of Thermodynamic Variables

❶ Microscopic state and macroscopic state

❷ Independent properties and dependent properties

❸ State functions and process variables

❹ Intensive, extensive, and specific properties

Microscopic state and macroscopic state

- In microscopic sense, any thermodynamic system is **not continuous**.
- If the masses, velocities, positions and all modes of motions of all the particles in any particular instance is known, then this would describe the **microscopic state** or condition of the system and would, in turn, determine all the properties of the system.

- In macroscopic sense, the system is **continuous** and we determine the properties of the system as a whole.
- The state of the system described this way is known as the **macroscopic state** of the system

Independent and Dependent Properties

- It is **not necessary to quantify all of the properties** to define completely the state of system.

- It is found that when a very small number of properties have been measured at any instance of time, all other thermodynamic properties are fixed automatically.

- Thus, only a few numbers of **independent properties are measured experimentally** and the remaining multitude of **dependent properties are calculated using those independent properties**.

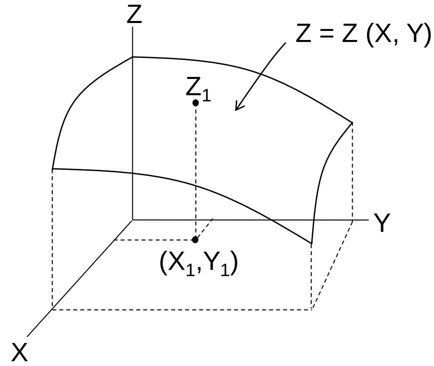
State Functions or Thermodynamic Variables

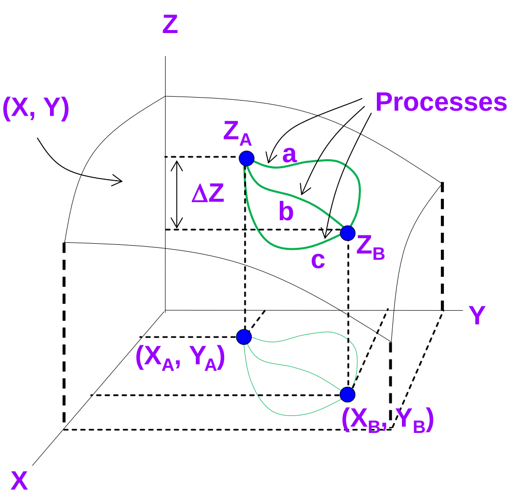
- Depends on the current condition or **state** of the system, not on how the system is arrived at that condition.
  - **Rafiq weighs 72 kg and is 1.75 m tall.**
    We are not concerned how he got to that stage. We are not interested what he ate !!
  - **The temperature today is 500 K.**
    We do not indicate whether the day is heated up to that temperature or cooled down to it.

- Example of state functions: **Pressure**, **Temperature**, **Volume**, **Energy**, etc.

■ If a variable Z depends only on the current values of the variables X and Y, then all three variables are state functions.

- The functional relationship among these variables, **$Z = Z(X, Y)$**, is represented by a surface in (X, Y, Z) space.
- For any given values (X_A, Y_A) in state A, there is a corresponding value of Z_A.





■ Any change in a state function depends only the initial and final state of the system, not on the path followed.

$$\Delta Z = Z_B - Z_A$$

Process Variables

- Only have meaning for **changing** systems
- Examples: **Heat** (Q) and **Work** (W).
- Change is inherent to the very concept of these quantities. **The values of process variables at rest are zero**.
- **Depends explicitly upon the path**, that is, the specific sequence of states the system takes while moving from state A to state B.
- A system can have some energy, but the system contain no work/heat. **Energy is a property of system, work/heat is not**

Intensive, Extensive, and Specific Properties

Intensive properties

- Values are independent of the size/extent of system.
- Vary from place to place within the system at any moment.
- The fundamental or derived properties of system are always intensive.
- Examples: **Temperature**, **Pressure**

Extensive properties

- Values depends on the size/extent of system.
- Only have a value for the system as a whole.
- The total properties the system are always extensive.
- Examples: **Volume**, **Mass**, **Energy**

Specific properties

- Extensive variables per unit mass or volume are termed as specific properties.
- All specific properties are intensive properties
- Examples: Density, specific volume, specific energy.

Next Class

Lecture 03

Thermodynamic Processes and Relations

Rashid/ Ch#2 – Sec. 2.3 & 2.4