21ASC205T

AERO ENGINEERING THERMODYNAMICS

Thermodynamics can be defined as the ***science of energy***.

Microscopic & Macroscopic point of view

- Two view points from which behaviour of matter can be studied –
  - The Macroscopic approach
  - The Microscopic approach

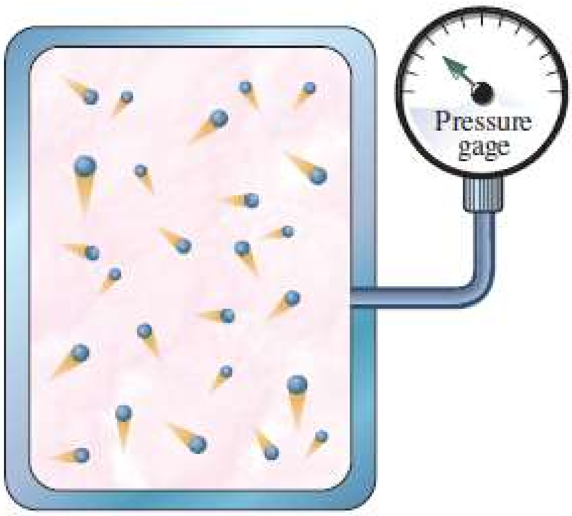
Microscopic approach

- Matter is composed of molecules. They are in constant collision with each other. The position, velocity, and energy for each molecule change very frequently as a result of these collisions.
- The behaviour of the gas is described by summing up the behaviour of each molecule.
- Such a study is made in *microscopic* or *statistical thermodynamics*.

Macroscopic approach

- a certain quantity of matter is considered, *without the events occurring at the molecular level* being taken into account.
- only concerned with the effects of the action of many molecules that can be measured directly.

Microscopic view point	Macroscopic view point
momentum transfer between the molecules and the walls of the container	Pressure of gas in the container

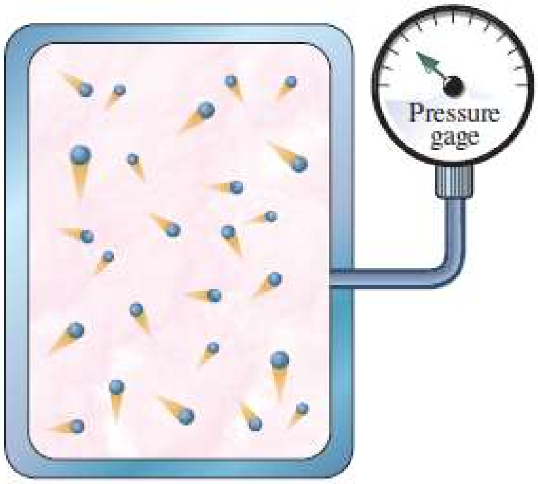


- one does not need to know the behavior of the gas molecules to determine the pressure in the container. It would be sufficient to attach a pressure gage to the container.
- This macroscopic approach to the study of thermodynamics that does not require a knowledge of the behavior of individual molecules is called **classical thermodynamics**.

Concept of ***Continuum***

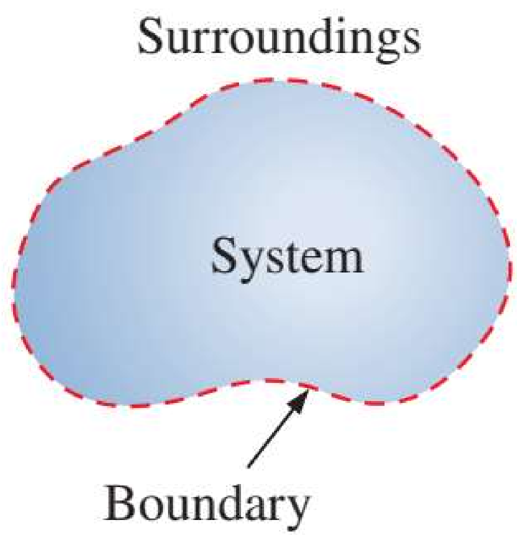
- Though matter is composed of several molecules, the concept of continuum assumes a continuous distribution of mass within the matter or system with no empty space
- disregard the atomic nature of a substance and view it as a continuous, homogeneous matter with no holes, that is, a ***continuum***.
- The properties of the matter are considered as continuous functions of space variables.

1 mm^3 of any gas contains 2.7 x 10^{16} molecules – so can be considered as a continuous distribution of mass



System

- A **system** is defined as a *quantity of matter or a region in space chosen for study.*
- The *mass or region outside the system* is called the **surroundings**.
- The *real or imaginary surface that separates the system from its surroundings* is called the **boundary** which can be either fixed or movable



Types of system

- Classified based on the mass and energy interactions between system and surroundings
  - ➢Closed system
  - ➢Open system
  - ➢Isolated system

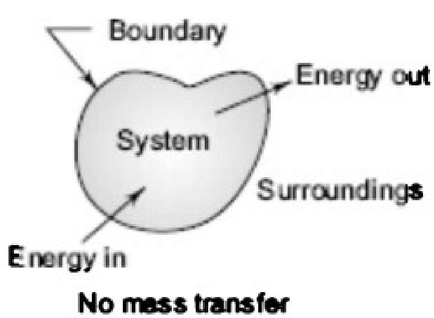


Fig. 1.8 *A closed system*

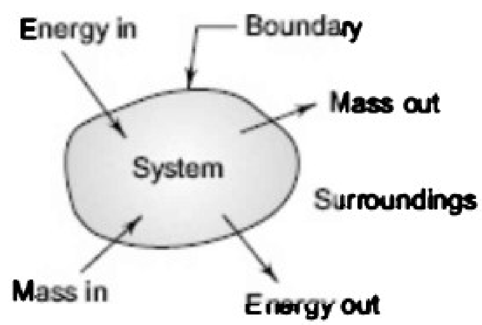


Fig. 1.9 *An open system*

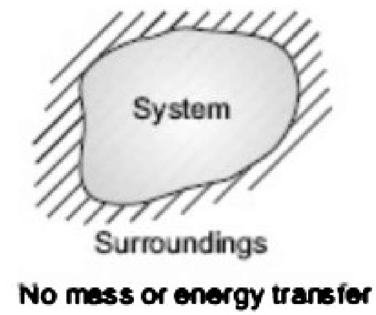
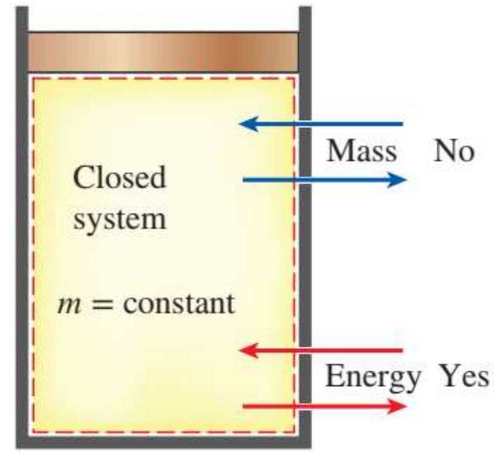


Fig. 1.10 *An isolated system*

Closed system (or control mass)

- No mass can cross the boundary – Fixed mass
- Energy, in the form of heat or work, can cross the boundary



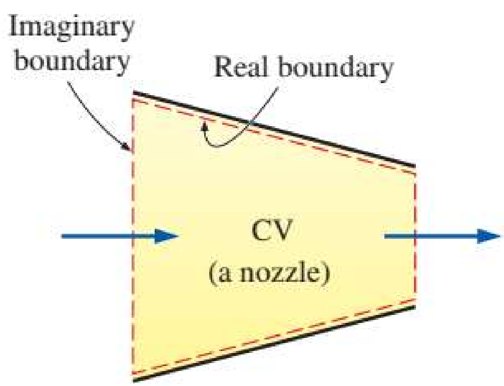
Isolated system

- Both Mass and Energy cannot cross the boundary

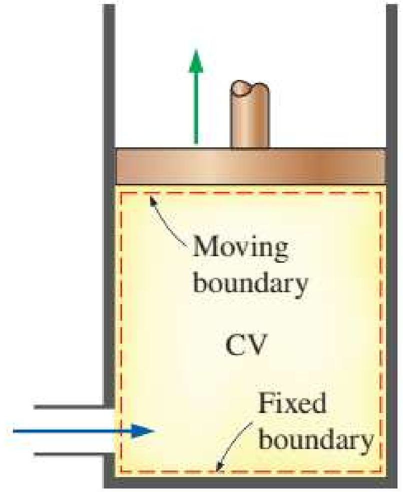
Open system (or control volume)

Both mass and energy can cross the boundary

A water heater, a car radiator, a turbine, and a compressor all involve mass flow and should be analyzed as control volumes (open systems) instead of as control masses (closed systems)



(*a*) A control volume (CV) with real and imaginary boundaries



(*b*) A control volume (CV) with fixed and moving boundaries as well as real and imaginary boundaries

Properties of a system

- Any characteristic of a system is called a **property**
  pressure *P*, temperature *T*, volume *V*, and mass *m*, *density ρ*, viscosity μ etc

Properties are considered to be either *intensive* or *extensive*.

Intensive properties are those that are independent of the mass of a system
Example: temperature, pressure, and density.

Extensive properties are those whose values depend on the size—or extent—of the system.
Example: Total mass, total volume, and total momentum.

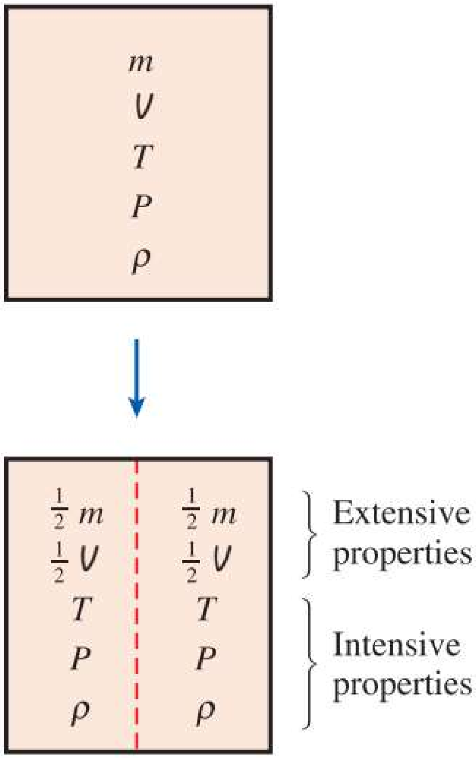


FIGURE 1–23
Criterion to differentiate intensive and extensive properties.

Extensive properties per unit mass are called **specific properties**.

Examples of specific properties are:
specific volume ($v = V/m$)
specific total energy ($e = E/m$).

State and Equilibrium

- At a given **state**, all the properties of a system have fixed values. If the value of even one property changes, the state will change to a different one.

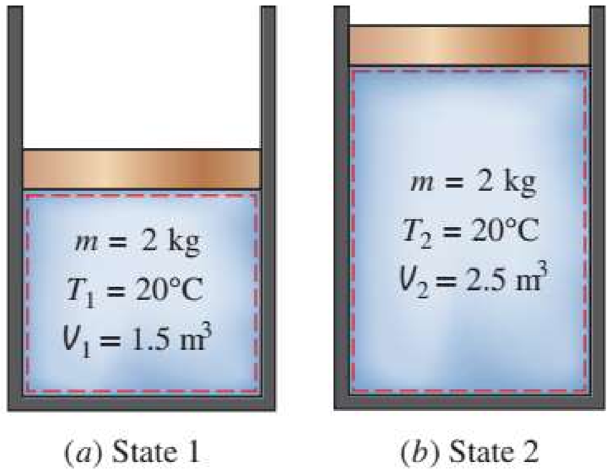


FIGURE 1–26
A system at two different states.

Thermodynamics deals with *equilibrium* states. The word **equilibrium** implies a state of balance. In an equilibrium state there are no unbalanced potentials (or driving forces) within the system.

A system is in ***thermodynamic equilibrium*** only when the conditions of all the relevant types of equilibrium are satisfied

- **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** when the mass of each phase reaches an equilibrium level and stays there
- **chemical equilibrium** if its chemical composition does not change with time, that is, no chemical reactions occur.
- **Etc…**

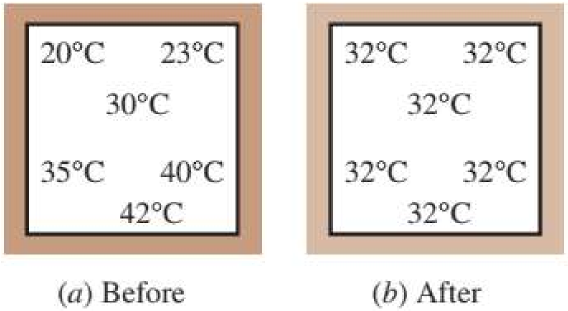


FIGURE 1–27
A closed system reaching thermal equilibrium.

Processes and Cycle

- Any change that a system undergoes from one equilibrium state to another is called a **process**.
- The series of states through which a system passes during a process is called the **path** of the process

Process diagrams plotted by employing thermodynamic properties as coordinates are very useful in visualizing the processes.

Some common properties that are used as coordinates are temperature *T*, pressure *P*, and volume *V* (or specific volume *v*).

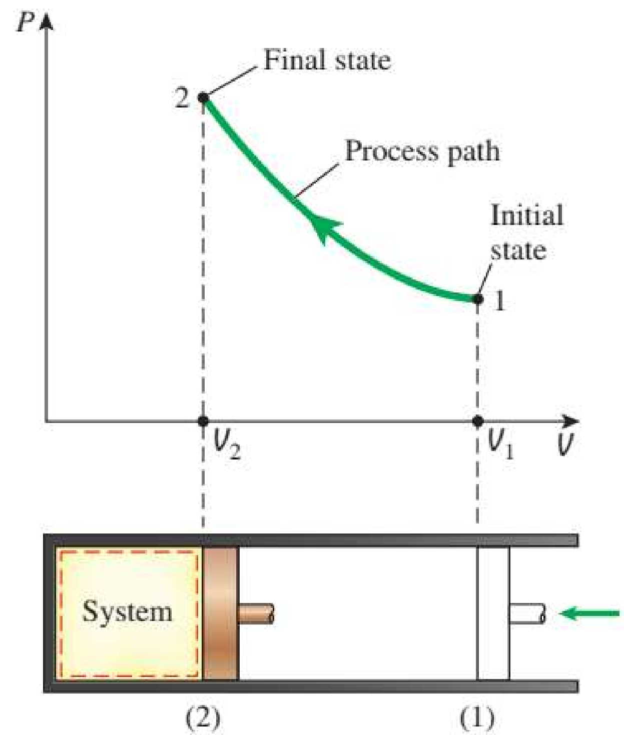
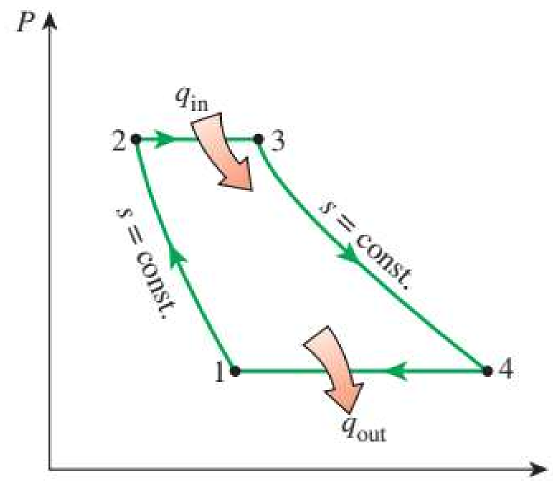


FIGURE 1–31
The *P*-*V* diagram of a compression process.

Examples of few processes:

- An **isothermal process**, for example, is a process during which the temperature T remains constant;
- an **isobaric process** is a process during which the pressure P remains constant;
- an **isochoric** (or **isometric**) **process** is a process during which the specific volume v remains constant

A system is said to have undergone a **cycle** if it returns to its initial state at the end of the process. That is, for a cycle the initial and final states are identical.



(b) P-υ diagram

Path and Point functions

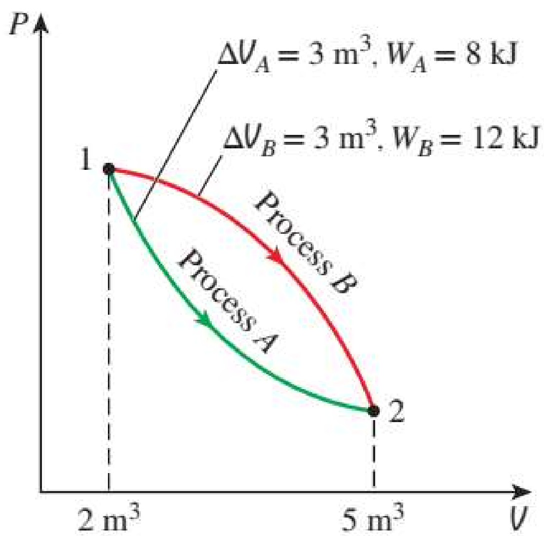


FIGURE 2–22
Properties are point functions; but heat and work are path functions (their magnitudes depend on the path followed).

Consider two states 1 and 2.

A system undergoes two Processes, Process A and Process B to reach from State 1 to State 2

Properties are **point functions** (i.e., they depend on the state only, and not on how a system reaches that state), and they have **exact differentials** designated by the symbol *d*

Change in volume $$\int_1^2 dV = V_2 - V_1 = \Delta V$$

That is, the volume change during process 1–2 is always the volume at state 2 minus the volume at state 1, regardless of the path followed

Thermal equilibrium

when a body is brought into contact with another body that is at a different temperature, heat is transferred from the body at higher temperature to the one at lower temperature until both bodies attain the same temperature. At that point, the heat transfer stops, and the two bodies are said to have reached **thermal equilibrium**.

Zeroth law of thermodynamics

When a body A is in thermal equilibrium with a body B, and also separately with a body C, then B and C will be in thermal equilibrium with each other.

This is known as the *zeroth law of thermodynamics* It is the basis of temperature measurement.

By replacing the third body with a thermometer, the zeroth law can be restated as *two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact*