

Lecture 1 Basic concepts and classification of thermodynamic systems, parameters and properties

Goal of the lecture: To study the fundamental principles of thermodynamics, including the classification of systems, their properties, and parameters used to describe their state.

Brief lecture notes: This lecture introduces the basic ideas and terminology of thermodynamics that form the foundation for understanding physical and chemical processes. We will discuss what constitutes a thermodynamic system and its surroundings, how systems are classified (open, closed, and isolated), and the significance of boundaries and control volumes. The lecture will also explain thermodynamic properties such as pressure, temperature, volume, internal energy, enthalpy, and entropy, distinguishing between intensive and extensive parameters. Furthermore, we will analyze the concept of equilibrium, the state of a system, and the types of thermodynamic processes. These principles serve as the basis for the later study of the laws of thermodynamics and energy transformations.

Main part

Thermodynamics is a branch of physics that studies energy transformations and the quantitative relationships between different forms of energy and matter. The word thermodynamics originates from the Greek words *therme* (heat) and *dynamis* (power). Historically, the development of thermodynamics began in the 19th century with the invention of the steam engine.

- Sadi Carnot (1824) first formulated the concept of a *heat engine* and introduced the idea of the Carnot cycle.
- Rudolf Clausius (1850) introduced the term entropy (S) and formulated the Second Law of Thermodynamics.
- William Thomson (Lord Kelvin) defined the absolute temperature scale (Kelvin).

The main purpose of thermodynamics is to describe how systems exchange heat (Q) and work (W) with their surroundings and to predict the resulting changes in energy and state. According to the First Law of Thermodynamics, the change in the internal energy U of a system is given by:

$$\Delta U = Q - W$$

where

ΔU – change in internal energy,

Q – heat added to the system,

W – work done by the system.

Thermodynamics deals with macroscopic quantities such as temperature (T), pressure (P), and volume (V), which represent the average behavior of an enormous number of particles.

2. Thermodynamic System and Surroundings

A thermodynamic system is a specific quantity of matter or a region in space selected for analysis. Everything outside the system is referred to as the surroundings, and the boundary separates them.

Classification of Systems

Thermodynamic systems are classified as open, closed, or isolated. An open system exchanges both matter and energy with its surroundings (e.g., boiling water in an open pot, where mass and energy transfer $\neq 0$). A closed system exchanges energy but not matter (e.g., a piston–cylinder with gas, where mass transfer = 0, energy transfer $\neq 0$). An isolated system exchanges neither matter nor energy (e.g., an ideal thermos flask, where mass transfer = 0 and energy transfer = 0) (Figure 1)

Types of Thermodynamic Systems

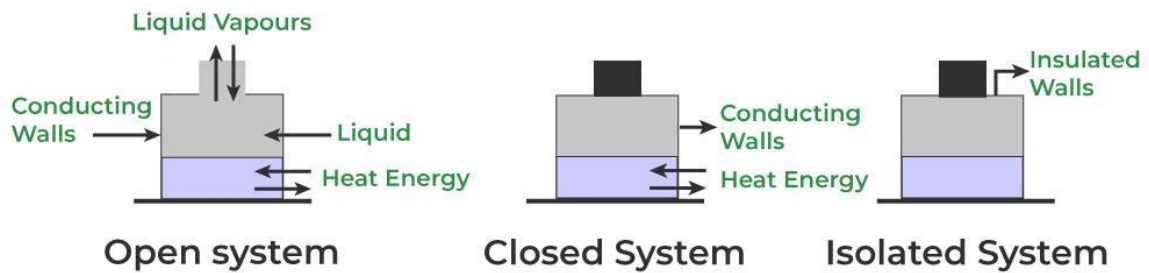


Figure 1. Types of Thermodynamic Systems

3. Types of Thermodynamic Processes

Process	Condition	Key Equation	Characteristics / Notes	Example
Isothermal	$\Delta T = 0$ (temperature constant)	$PV = \text{constant}$ or $P_1 V_1 = P_2 V_2$	Temperature remains constant; internal energy does not change.	Slow expansion of a gas in thermal contact with a heat bath.
Isobaric	$\Delta P = 0$ (pressure constant)	$W = P(V_2 - V_1)$	Work depends on volume change; heat added changes both internal energy and does work.	Heating of a gas in a movable piston at constant pressure.
Isochoric (Isometric)	$\Delta V = 0$ (volume constant)	$W = 0, Q = \Delta U$	No work is done; all heat changes internal energy.	Heating a gas in a rigid, sealed container.
Adiabatic	$Q = 0$ (no heat exchange)	$PV^\gamma = \text{constant}, \gamma = \frac{c_p}{c_v}$	Energy change occurs only as work; rapid compression or expansion.	Expansion of gas in an insulated cylinder.

4. Thermodynamic Properties and Parameters

A property is any measurable characteristic used to define the system's state. Examples: pressure (P), temperature (T), volume (V), mass (m), density (ρ), internal energy (U), enthalpy (H), and entropy (S).

Equation of State

For gases, the ideal gas law relates state variables:

$$PV = nRT$$

Where n – number of moles, $R = 8.314 \text{ J}\cdot\text{mol}^{-1}\text{K}^{-1}$ – universal gas constant. A system's state is defined by a specific set of independent properties. When these properties change, the system passes from one state to another.

5. Equilibrium and State

A system is in thermodynamic equilibrium when all macroscopic parameters remain constant over time and there are no internal driving forces.

It requires:

1. Mechanical equilibrium: no unbalanced pressure differences.

$$P_{\text{inside}} = P_{\text{outside}}$$

2. Thermal equilibrium: uniform temperature throughout the system.

$$T_1 = T_2$$

3. Chemical equilibrium: no net chemical reactions or diffusion.

A system not in equilibrium will spontaneously evolve toward it until all gradients (T, P, concentration) disappear. The concept of equilibrium is central to all thermodynamic analyses because only equilibrium states can be described by state functions (U, H, S).

Questions for self-control:

1. What is meant by a thermodynamic system, and how is it different from its surroundings?
2. What is a thermodynamic process, and how do isothermal, isobaric, isochoric, and adiabatic processes differ from one another?
3. What conditions define thermodynamic equilibrium in a system?
4. What role do thermodynamic parameters (P, V, T) play in describing the state of a system?
5. How are heat (Q), work (W), and internal energy (U) related according to the First Law of Thermodynamics?

Literature

1. Moran, M. J., Shapiro, H. N., Boettner, D. D., Bailey, M. B. *Fundamentals of Engineering Thermodynamics*, 9th ed. — Wiley, 2021.
2. Çengel, Y. A., Boles, M. A. *Thermodynamics: An Engineering Approach*, 9th ed. — McGraw-Hill Education, 2019.
3. Atkins, P., de Paula, J. *Physical Chemistry*, 12th ed. — Oxford University Press, 2022.
4. Sonntag, R. E., Borgnakke, C. *Introduction to Engineering Thermodynamics*, 4th ed. — Wiley, 2019.
5. Zemansky, M. W., Dittman, R. H. *Heat and Thermodynamics: An Intermediate Textbook*, 8th ed. — McGraw-Hill, 2017.

