UNIT-I: BASIC CONCEPTS & FIRST LAW OF THERMODYNAMICS

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OBJECTIVES

System & Control Volume: A System is a defined quantity of matter or region in space chosen for thermodynamic study. A Control Volume is an open system where mass and energy cross the boundary. The region outside the system is called the Surroundings, and together they form the Universe.

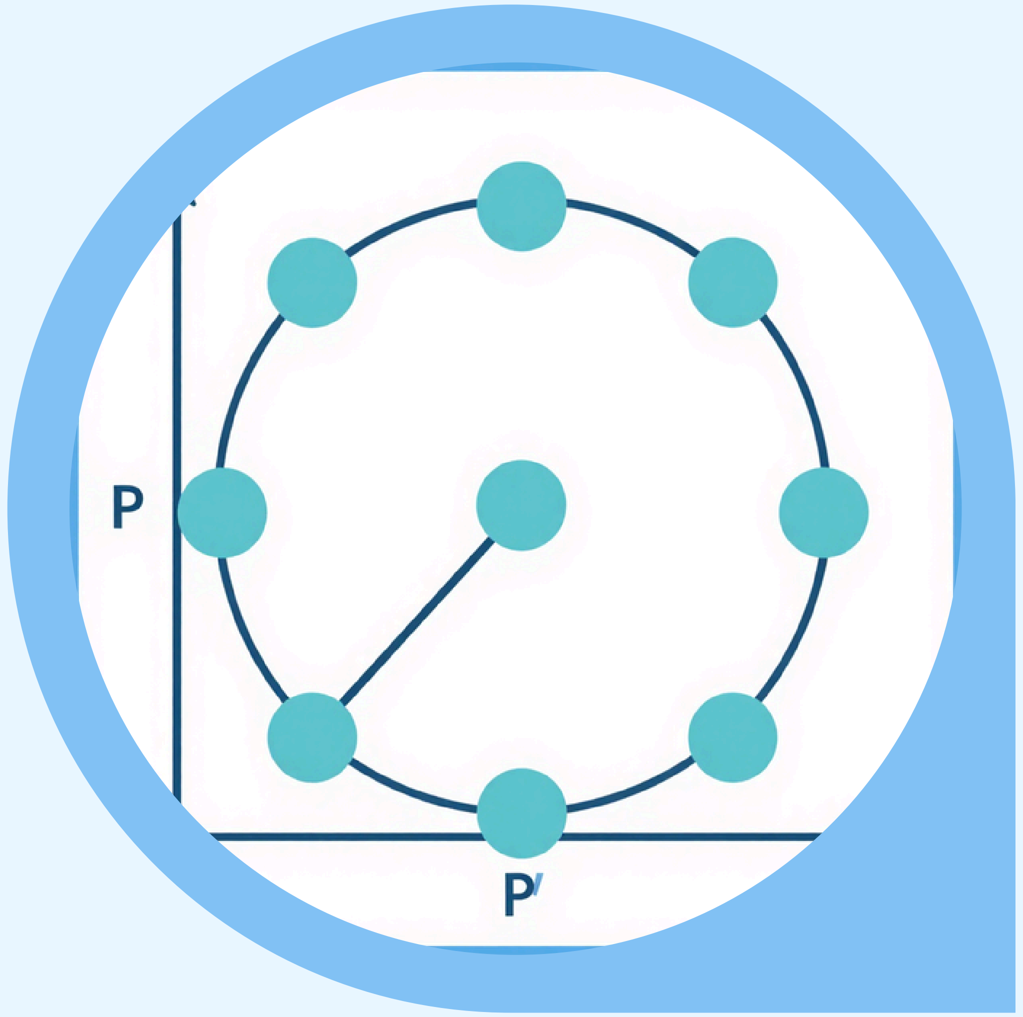
Types of Systems: (1) Closed System – fixed mass, energy exchange allowed, no mass transfer. (2) Open System – both mass and energy cross the boundary. (3) Isolated System – neither mass nor energy crosses the boundary. Boundaries separate the system from its surroundings.

OVERVIEW

- Macroscopic Viewpoint: Studies the overall behavior of a system using bulk properties (pressure, temperature, volume) without considering individual molecules. Properties are measurable and averaged over large number of particles.

- Microscopic Viewpoint & Continuum: Analyzes molecular-level behavior using statistical mechanics. The Concept of Continuum assumes matter is continuously distributed, enabling thermodynamic properties to be defined at every point. Thermodynamic Equilibrium requires mechanical, thermal & chemical equilibrium simultaneously.

STATE, PROPERTY & PROCESS



Thermodynamic State & Properties: A thermodynamic state is the condition of a system described by its properties (pressure, temperature, volume, etc.). Properties are macroscopic characteristics — intensive (independent of mass) or extensive (dependent on mass). Exact differentials represent state functions whose change depends only on initial and final states.

Process, Cycle & Inexact Differentials: A process is the path of change from one state to another (isothermal, adiabatic, isobaric, isochoric). A cycle returns the system to its initial state. Inexact differentials (like heat and work) are path functions — their values depend on the path taken, not just the endpoints.

METHOD

A quasi-static process is an idealized process that occurs infinitely slowly, ensuring the system remains in thermodynamic equilibrium at every instant. It is a reversible process where no energy is dissipated, and the system can return to its original state without any net change in the surroundings.

An irreversible process is one that cannot be reversed to restore both the system and surroundings to their original states. Real-world processes are inherently irreversible due to friction, heat transfer across finite temperature differences, and unrestrained expansion.

Causes of irreversibility include: friction between moving parts, heat transfer across finite temperature gradients, free or unrestrained expansion of gases, mixing of dissimilar substances, inelastic deformation, and chemical reactions occurring spontaneously.

ENERGY FORMS

Energy in State & Transition: Stored energy (internal, potential, kinetic) exists in a system's state. Energy in transition (Work & Heat) crosses boundaries. Displacement Work: $W = \int P \, dV$ — boundary work done by expansion or compression of a system.

Other Forms of Work: Electrical, shaft, spring, and stirring work. Heat (Q): Energy transferred across boundary due to temperature difference — a path function, not a property. Both Work & Heat are inexact differentials, dependent on the process path.

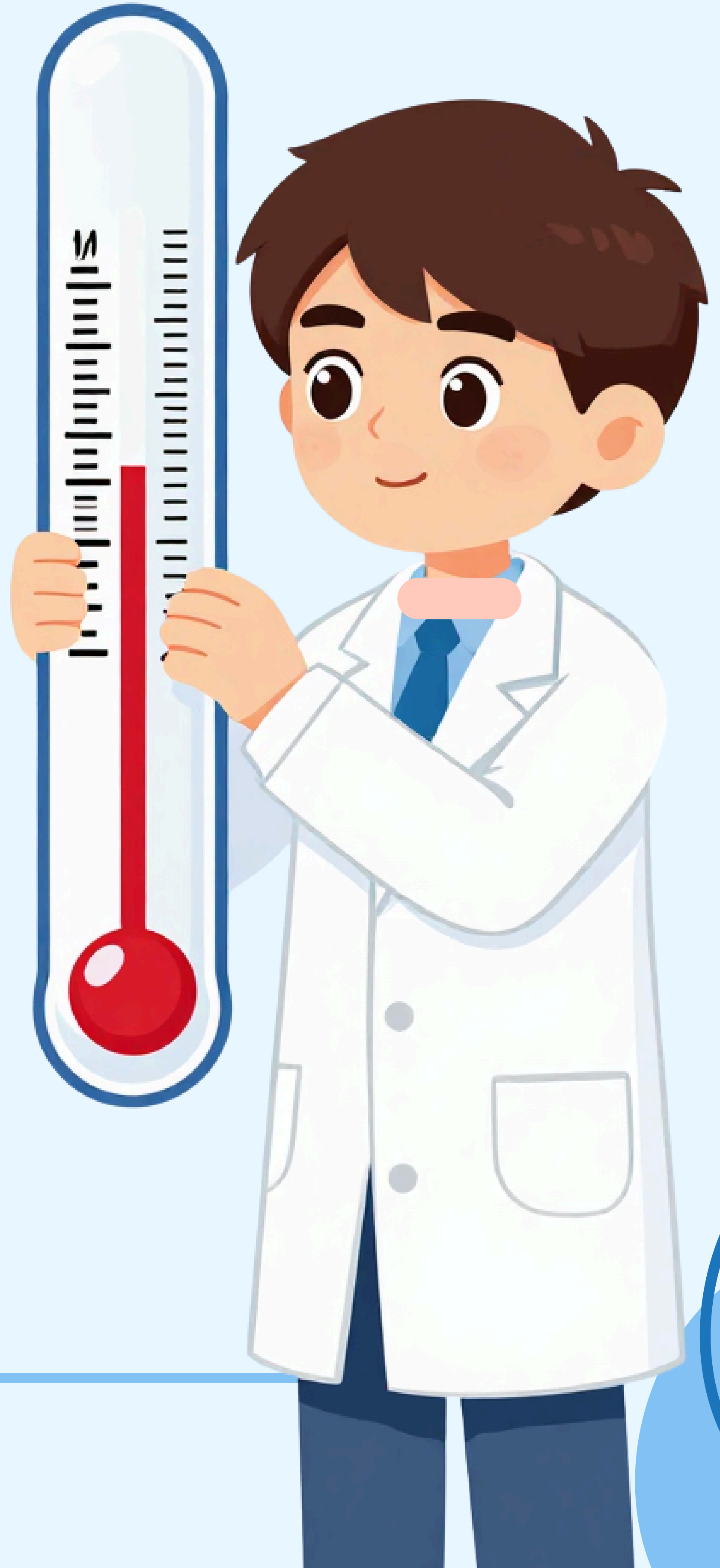
POINT & PATH FUNCTIONS

Point Functions (State Functions): Properties that depend only on the state of the system, not on the path followed. Examples include Temperature (T), Pressure (P), Volume (V), Internal Energy (U), and Enthalpy (H). Their differentials are exact differentials (dU, dV, dT) and the change depends only on initial and final states.

Path Functions: Properties that depend on the path followed during a process, not just the end states. Heat (Q) and Work (W) are path functions. Their differentials are inexact differentials (δQ, δW). Zeroth Law of Thermodynamics: If two systems are each in thermal equilibrium with a third system, they are in thermal equilibrium with each other — forming the basis of temperature measurement.

CONCEPT OF TEMPERATURE

Principles of Thermometry: Temperature is measured using thermometers based on thermometric properties. Reference Points: Fixed points like ice point (0°C) and steam point (100°C) define temperature scales. Constant Volume Gas Thermometer: Pressure of a fixed volume of gas varies linearly with temperature, serving as a primary standard. Scales of Temperature: Celsius, Fahrenheit, and Kelvin scales are commonly used. Zeroth Law forms the basis for temperature measurement and thermal equilibrium.

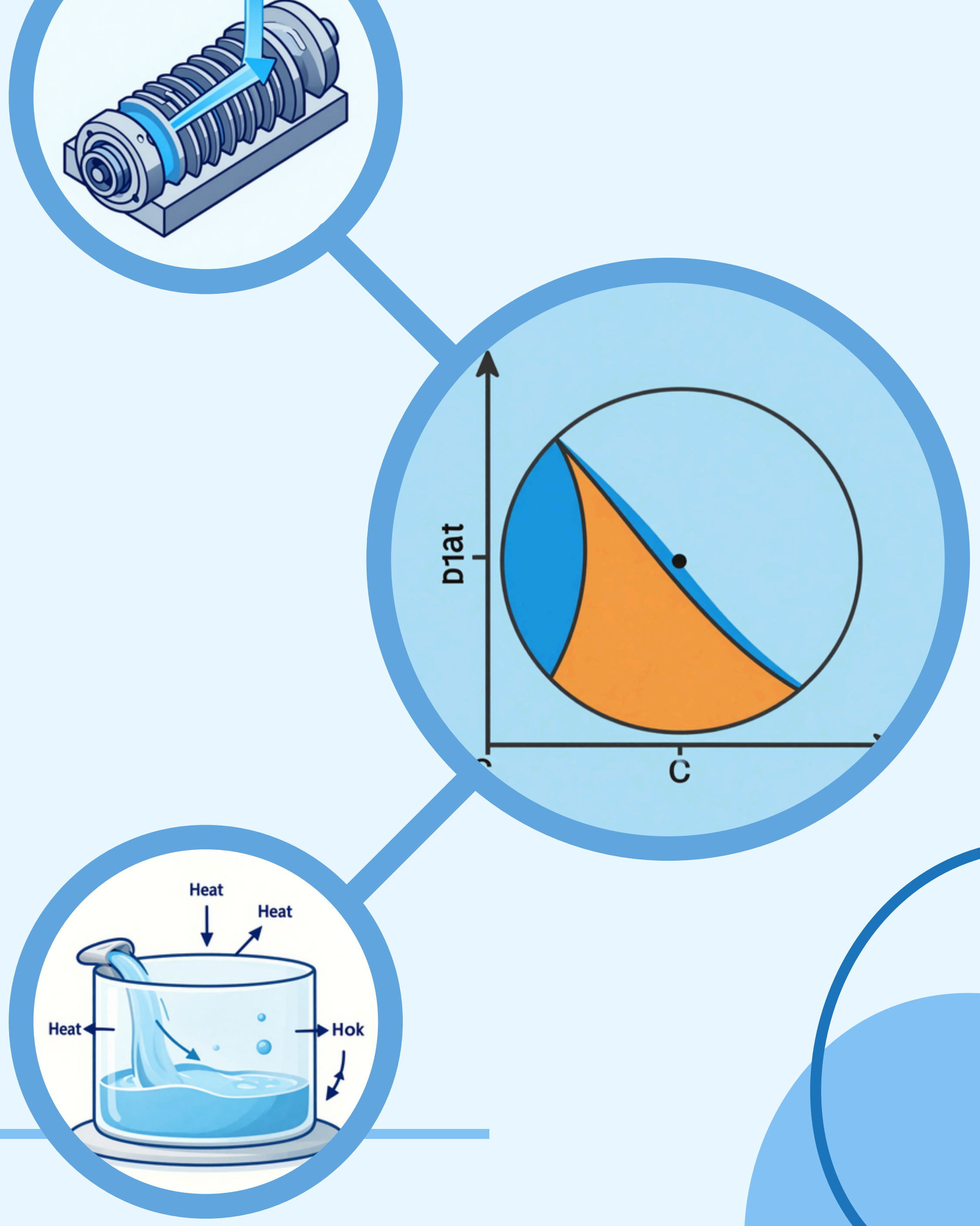


SCALES OF TEMPERATURE

Temperature Scales & Ideal Gas Scale: Various temperature scales include Celsius, Fahrenheit, Kelvin, and Rankine. The Ideal Gas Scale is based on the behavior of an ideal gas in a constant-volume thermometer, defining absolute zero and establishing a universal thermodynamic temperature scale independent of the working substance.

PMM-I & Joule's Experiments: Perpetual Motion Machine of the First Kind (PMM-I) violates the First Law by producing work without energy input. Joule's experiments demonstrated the equivalence of heat and work, establishing the mechanical equivalent of heat (1 cal = 4.186 J), forming the foundation of the First Law of Thermodynamics.

FIRST LAW OF THERMODYNAMICS



First Law & Corollaries: Energy is conserved — it can neither be created nor destroyed, only transformed. Corollary I: A perpetual motion machine of the first kind (PMM-I) is impossible. Corollary II: The internal energy of an isolated system remains constant.

Applied to Process & Flow Systems: For a closed process: $Q - W = \Delta U$. For open/flow systems, the Steady Flow Energy Equation (SFEE) accounts for enthalpy, kinetic energy, potential energy, heat, and work: $Q - W = \Delta h + \Delta KE + \Delta PE$. Applications include turbines, compressors, nozzles, and boilers.

THANK YOU

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