

Introduction to Thermodynamics

Introduction to Thermodynamics

Fundamental concepts, laws, and key terminology

1. What Is Thermodynamics?

- **Definition:** The branch of physics that studies the relationships between heat, work, energy, and the properties of matter.
 - **Scope:** Applies to all systems—from microscopic particles to engines, stars, and the atmosphere.
 - **Goal:** Predict how energy is transferred and transformed, and determine the direction of natural processes.
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2. Basic Terminology

Term	Symbol	Description
System	—	Portion of the universe under study (e.g., a gas in a cylinder).
Surroundings	—	Everything external to the system.
Boundary	—	Interface separating system and surroundings (real or imaginary).
Closed System	—	No mass exchange, but energy (heat/work) can cross the boundary.
Open System	—	Both mass and energy can cross the boundary.
Isolated System	—	Neither mass nor energy cross the boundary.
State Variable	—	Property that defines the system's condition (e.g., pressure P , volume V , temperature T).
Process	—	Transformation from one state to another (e.g., isothermal, adiabatic).
Cycle	—	Sequence of processes that returns a system to its initial state.
Equilibrium	—	No net macroscopic changes; all state variables are uniform and constant.
Heat (Q)	—	Energy transfer due to temperature difference.

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Term	Symbol	Description
Work (W)	–	Energy transfer due to forces acting through a distance (e.g., expansion work).
Internal Energy (U)	–	Total microscopic kinetic + potential energy of a system.
Enthalpy (H)	$H = U + PV$	Useful for processes at constant pressure.
Entropy (S)	–	Measure of disorder or the number of microscopic configurations.

3. The Four Laws of Thermodynamics

0th Law – Thermal Equilibrium

- **Statement:** If system A is in thermal equilibrium with system B, and B with system C, then A is in thermal equilibrium with C.
- **Consequence:** Defines temperature as an empirical property; allows the use of thermometers.

1st Law – Conservation of Energy

- **Statement:** The change in internal energy of a closed system equals the net heat added to the system minus the net work done by the system.
- **Mathematical Form:**
$$\Delta U = Q - W$$
- **Implications:** Energy cannot be created or destroyed, only transferred or converted.

2nd Law – Directionality & Entropy

- **Multiple formulations** (choose the most convenient):
 - **Clausius:** Heat cannot spontaneously flow from a colder body to a hotter one.
 - **Kelvin/Planck:** No cyclic device can convert all absorbed heat into work; some heat must be rejected to a colder reservoir.
 - **Entropy Form:** For any isolated system, the total entropy never decreases; it increases for irreversible processes and remains constant for reversible ones.

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- Mathematical expression for a reversible process:

$$[dS = \frac{\delta Q_{\text{rev}}}{T}]$$

3rd Law – Absolute Zero

- **Statement:** As the temperature of