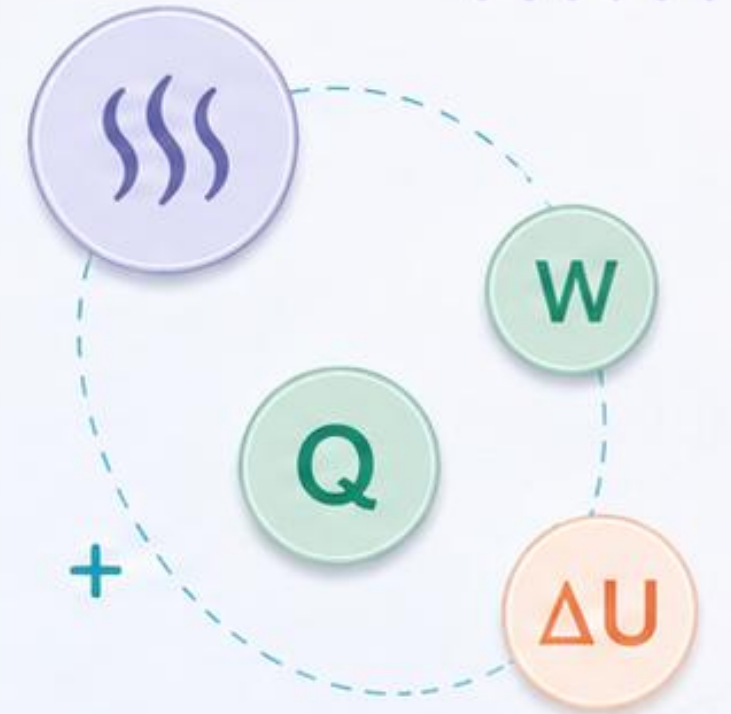


Chapter 11

Thermodynamics

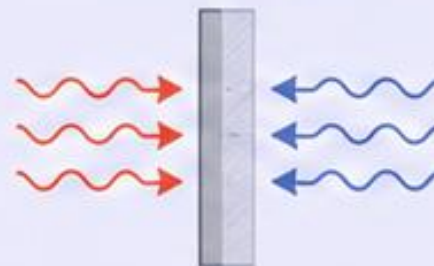
Heat • Laws • Processes



Ideal Gas Law

$$PV = nRT$$

Heat Transfer



Thermodynamic Process



THERMODYNAMICS: THE BIG PICTURE

① WHAT IT STUDIES

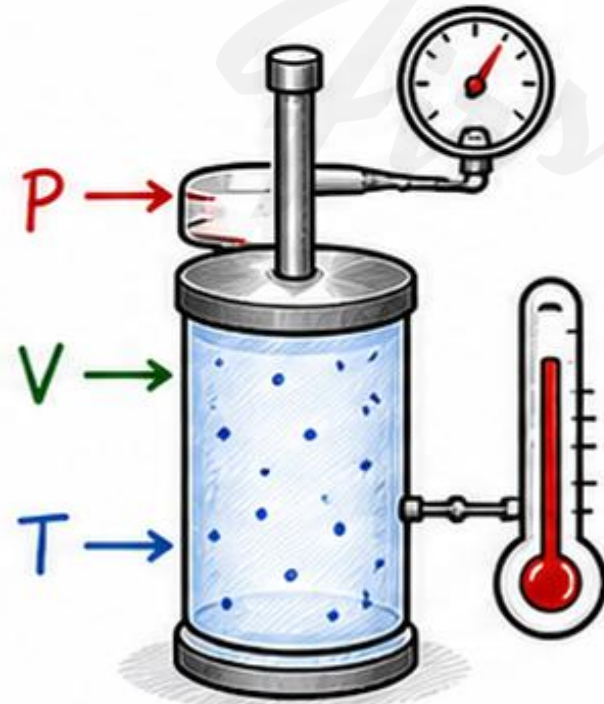
- Thermodynamics studies heat, temperature and the interconversion of heat and other forms of energy.
- It is a **macroscopic** science: it describes a bulk system using measurable variables.
- Main variables: pressure P , volume V , temperature T , mass m and composition.

P , V , T , m , composition

② MACROSCOPIC vs MICROSCOPIC

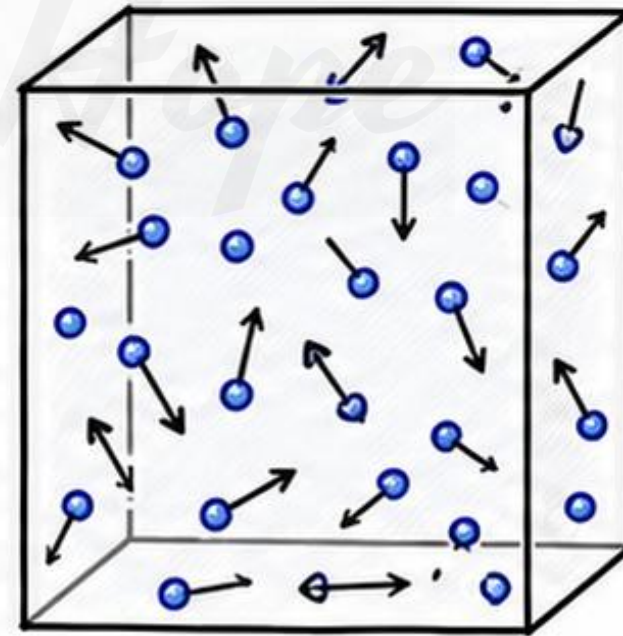
MACROSCOPIC

- Few bulk variables
- Directly measurable
- Does not track each molecule



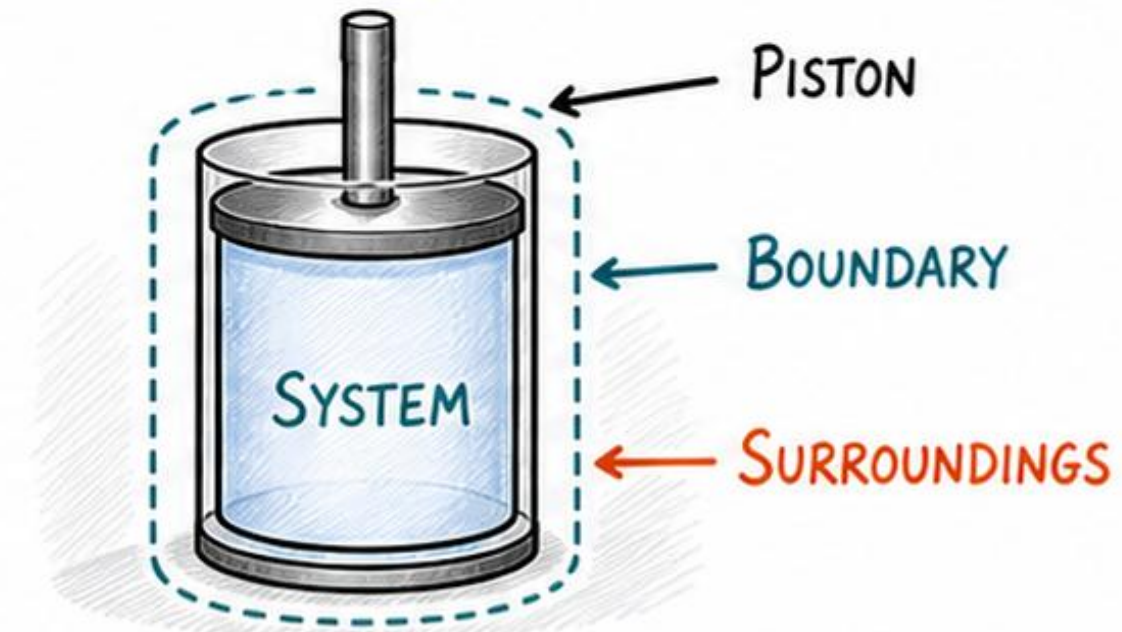
MICROSCOPIC

- Positions and velocities of an enormous number of molecules.



③ SYSTEM, SURROUNDINGS & BOUNDARY

- **System** = part chosen for study.
- **Surroundings** = everything outside the system.
- **Boundary** separates system and surroundings and may **allow** or **block** energy transfer.

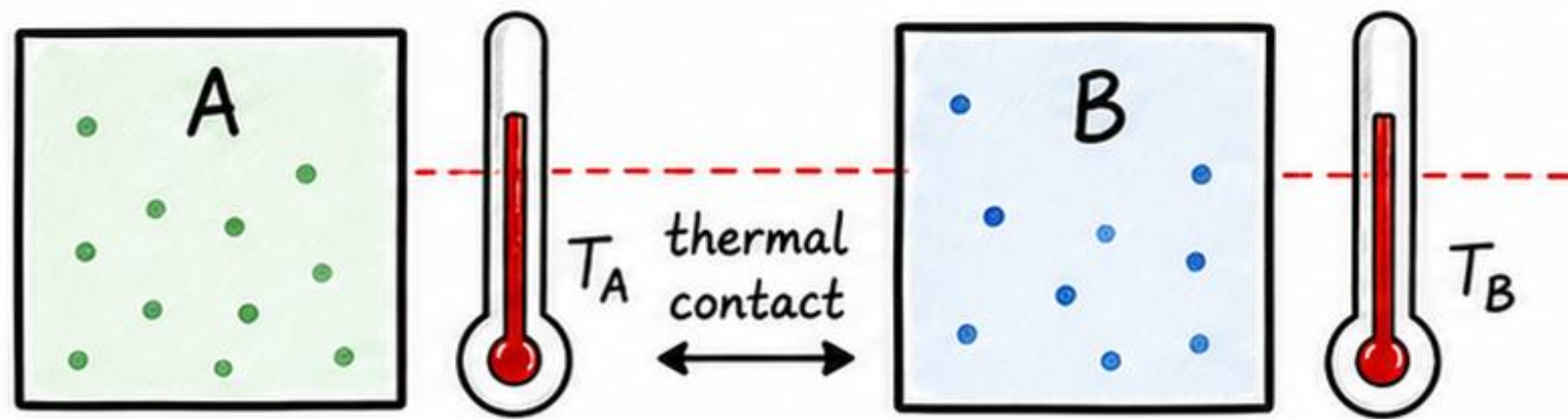


Thermodynamics describes the **internal macroscopic state** — not the motion of the whole body.

THERMAL EQUILIBRIUM & TYPES OF WALLS

EQUILIBRIUM STATE:

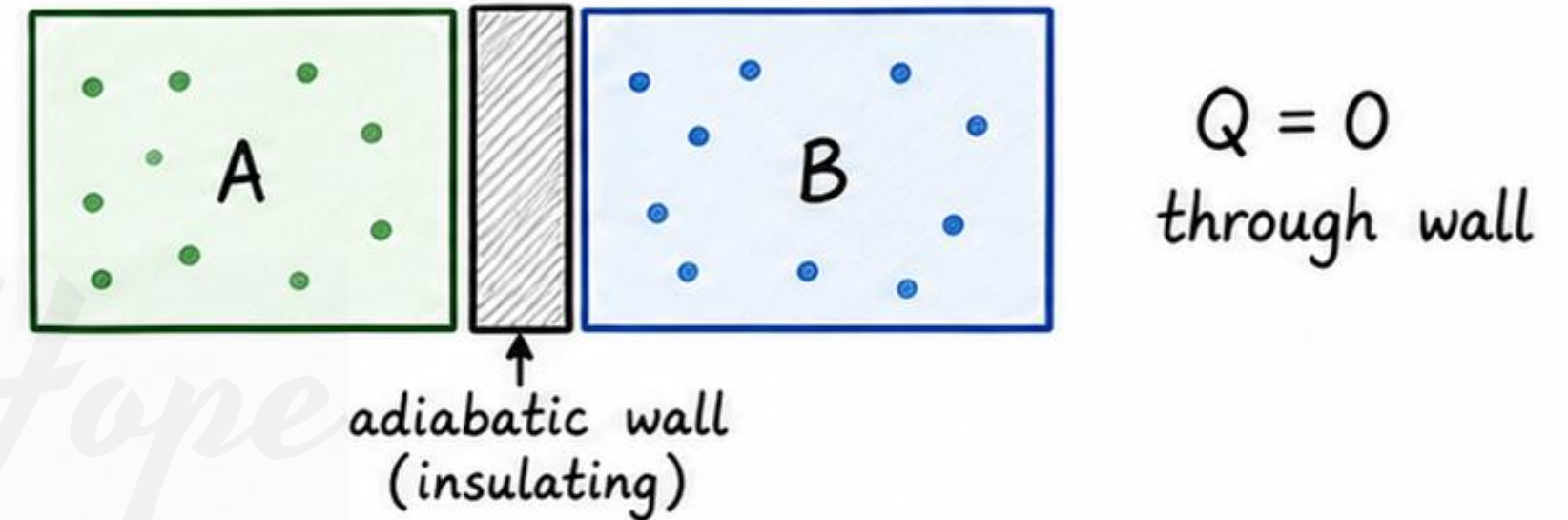
- A thermodynamic system is in equilibrium when its macroscopic variables do not change with time.
- For a gas: pressure P , volume V , temperature T , mass and composition stay fixed.
- Thermal equilibrium means two systems in thermal contact have equal temperature and no net heat flow.



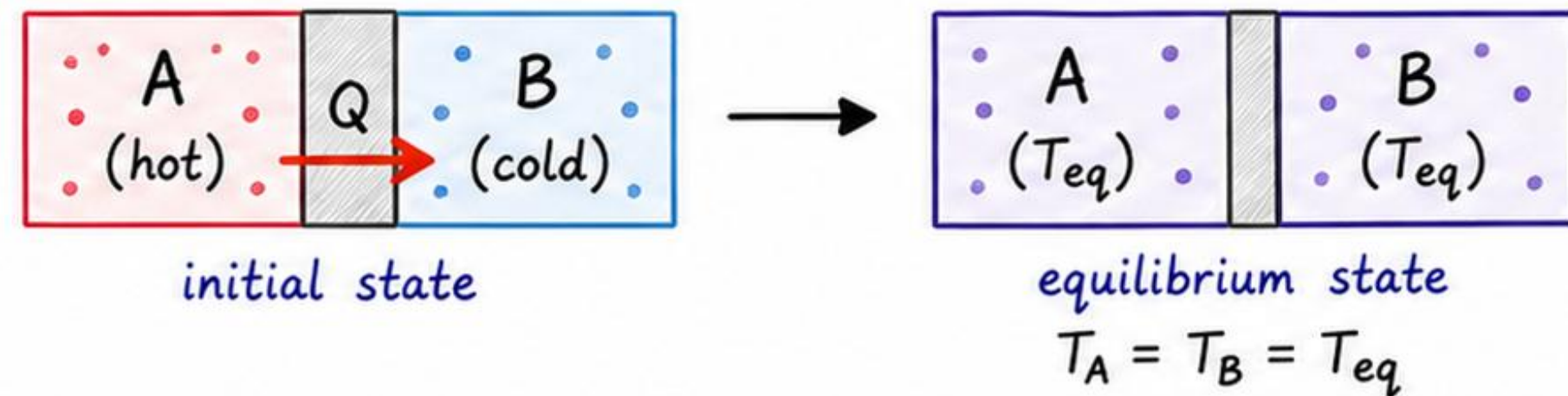
At equilibrium: $T_A = T_B$ and no net heat flow.

BOUNDARIES:

- 1) **ADIABATIC WALL** — insulating; does not allow heat transfer.



- 2) **DIATHERMIC WALL** — conducting; allows heat transfer.



The final equilibrium depends on the surroundings and the nature of the boundary.

ZEROTH LAW OF THERMODYNAMICS

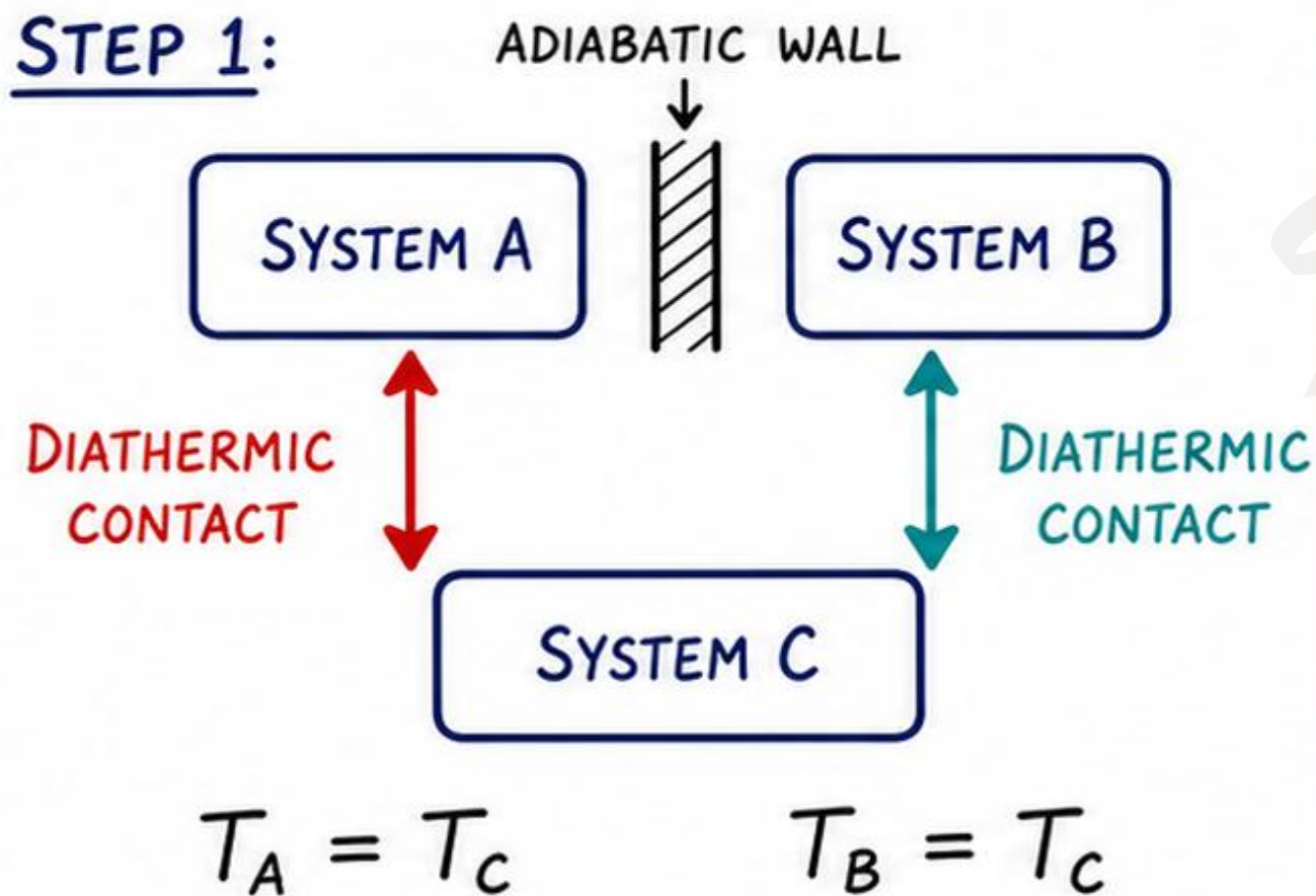
STATEMENT:

If two systems are separately in thermal equilibrium with a third system, they are in thermal equilibrium with each other.

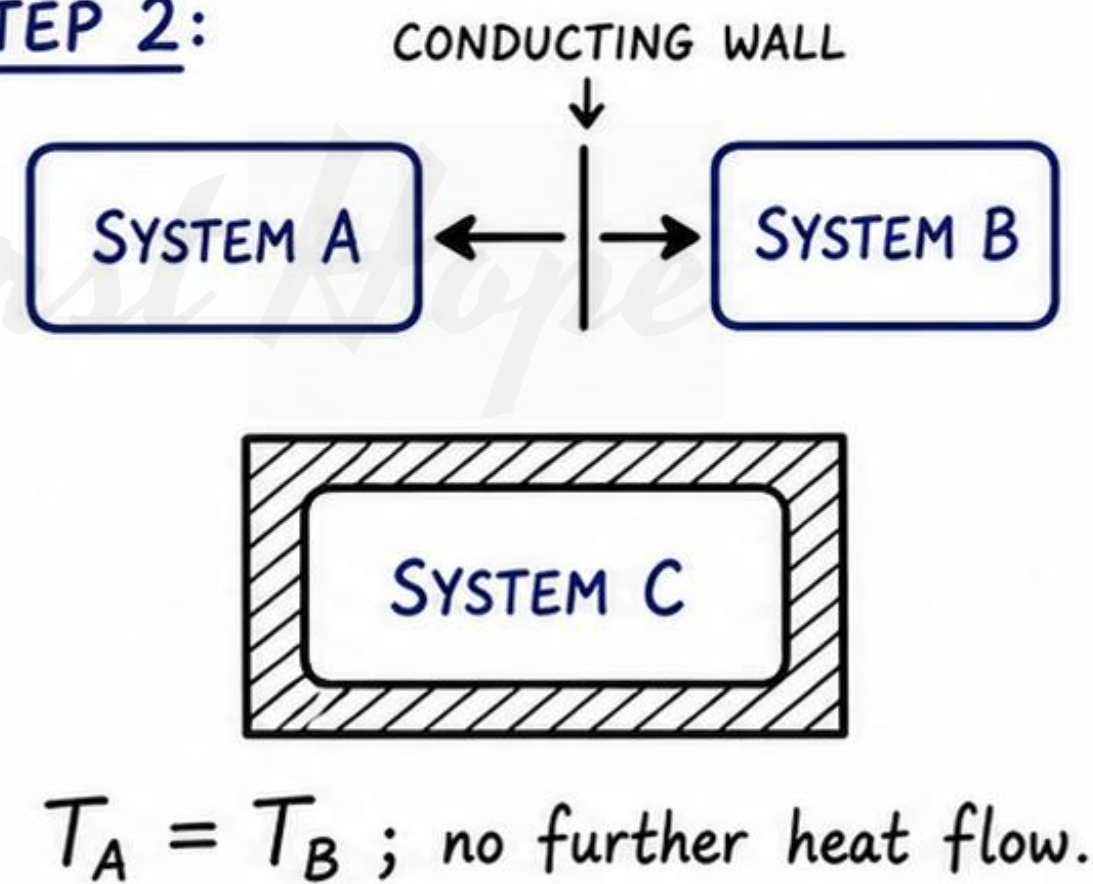
WHY IT MATTERS:

- Formal basis of temperature.
- Equal temperature means thermal equilibrium.
- A thermometer acts as the third system.

STEP 1:



STEP 2:

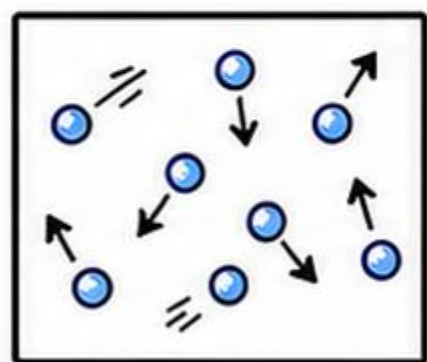


Temperature is the thermodynamic variable that has the same value in systems at thermal equilibrium.

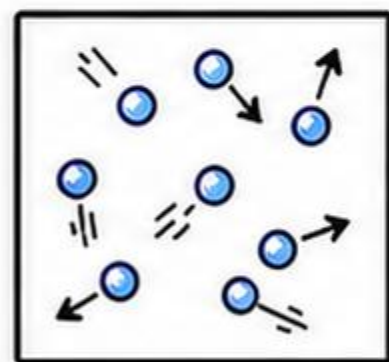
HEAT, INTERNAL ENERGY & WORK

INTERNAL ENERGY (U):

- Sum of microscopic kinetic and potential energies of all molecules.
- Includes random translational, rotational and vibrational motion.
- Does not include kinetic energy of the whole body.
- U is a state variable: it depends only on the state, not the path.



Molecules move randomly inside the system.



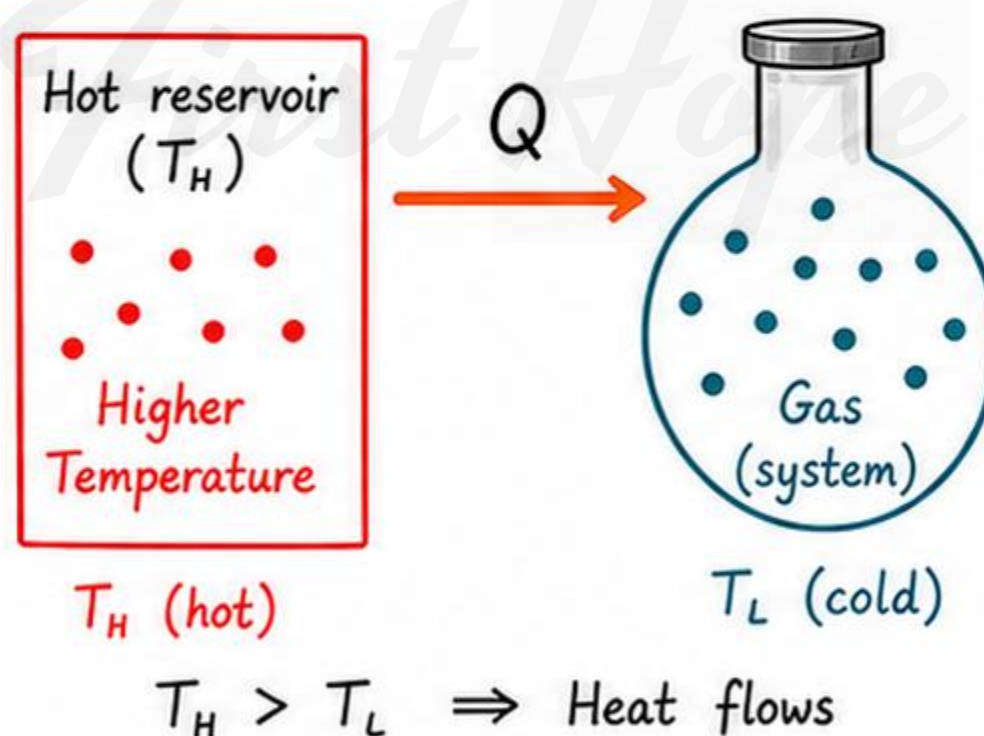
Box (system) moving with velocity V.

$$KE_{\text{bulk}} = \frac{1}{2} M V^2$$

Bulk kinetic energy NOT part of U.

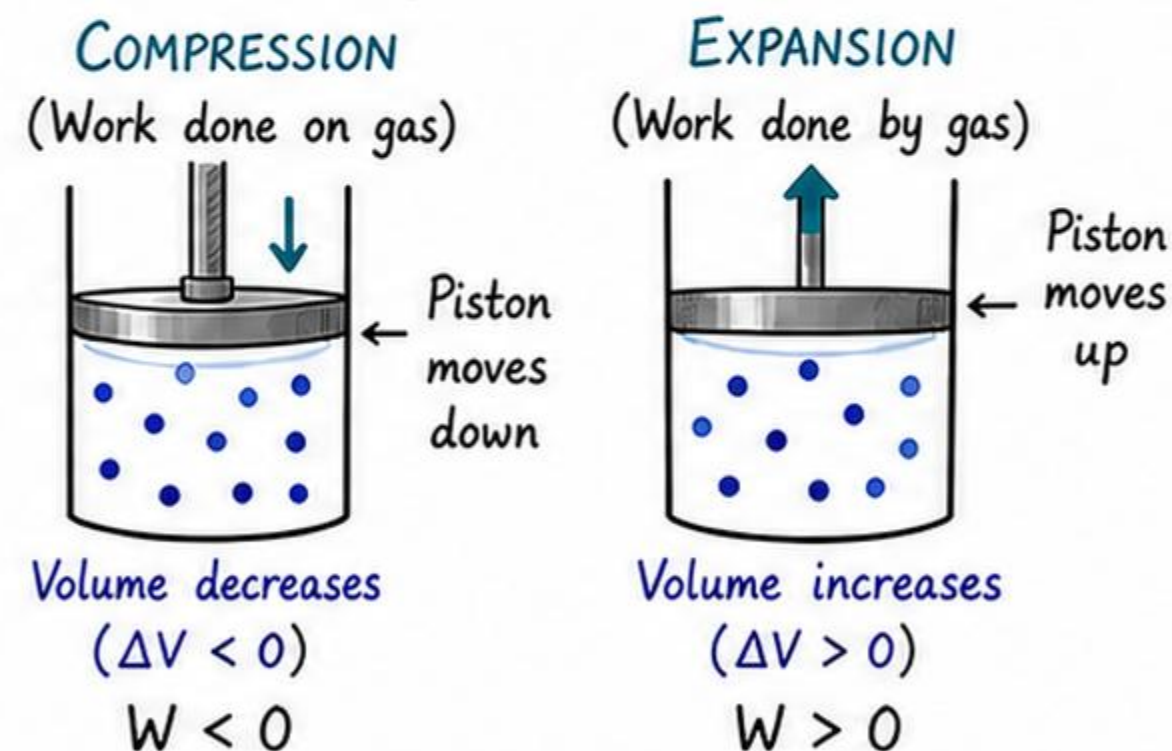
HEAT (Q):

- Energy transferred only because of a temperature difference.
- Flows spontaneously from higher T to lower T.
- Heat is energy in transit; a system does not "contain heat".



WORK (W):

- Energy transfer by mechanical means, not by temperature difference.
- Compression: surroundings do work on gas.
- Expansion: gas does work on surroundings.



U = state variable
Depends only on the state,
not on the path.

Q and **W** = path-dependent modes of energy transfer
Their values depend on how the process is carried out.

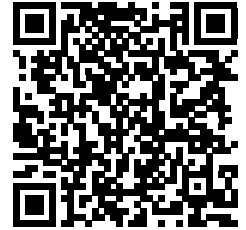


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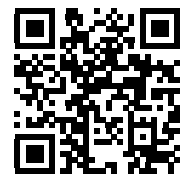


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