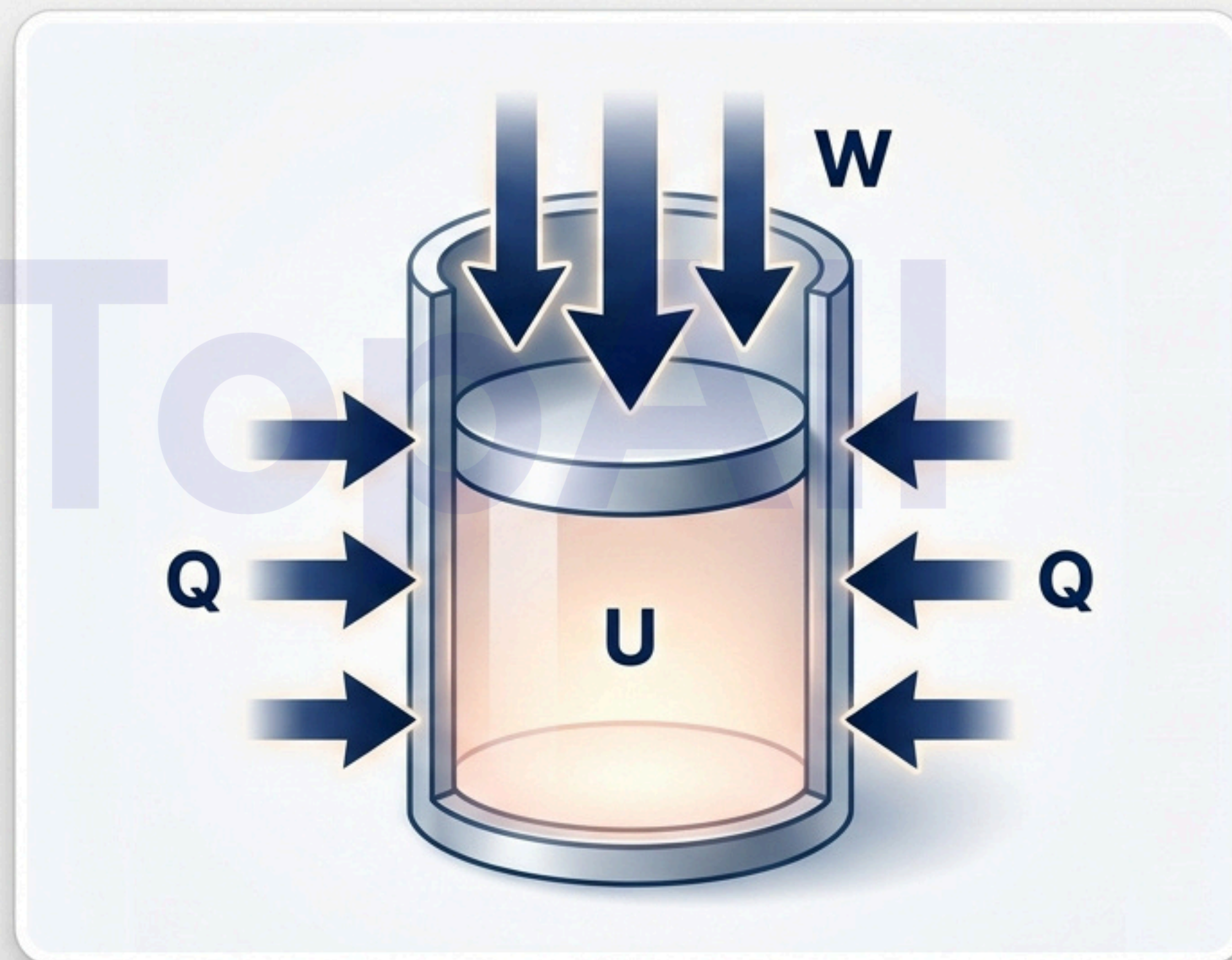
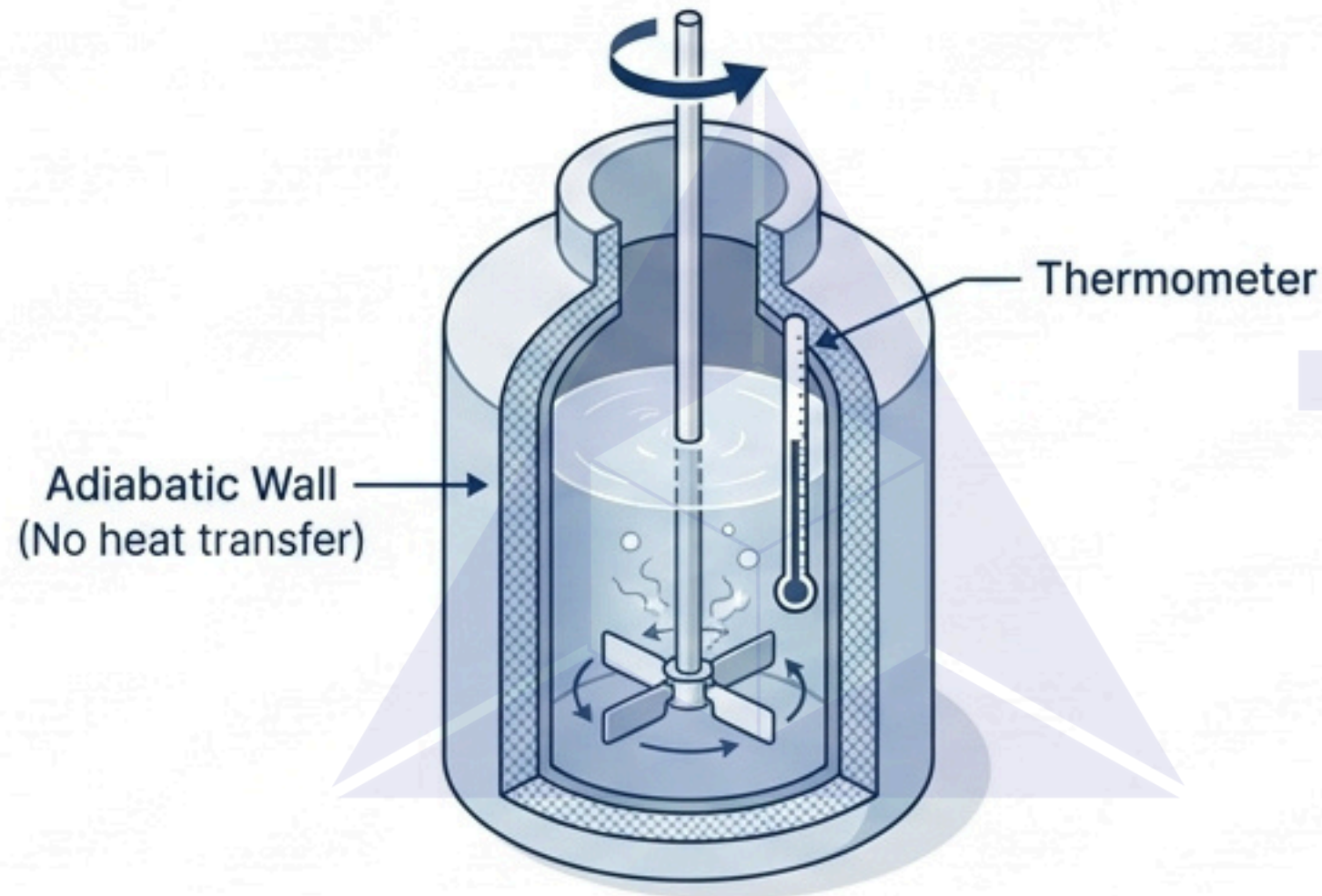


Work, Heat, and the First Law

Understanding internal energy transfers and the conservation of energy in macroscopic systems.



Work as Energy Transfer



The Joule Experiment

J.P. Joule (1840–50) demonstrated that whether rotating paddles (mechanical work) or an immersion rod (electrical work) are used, applying 1 kJ of work produces the exact same temperature rise ($T_A \rightarrow T_B$).

The State Function

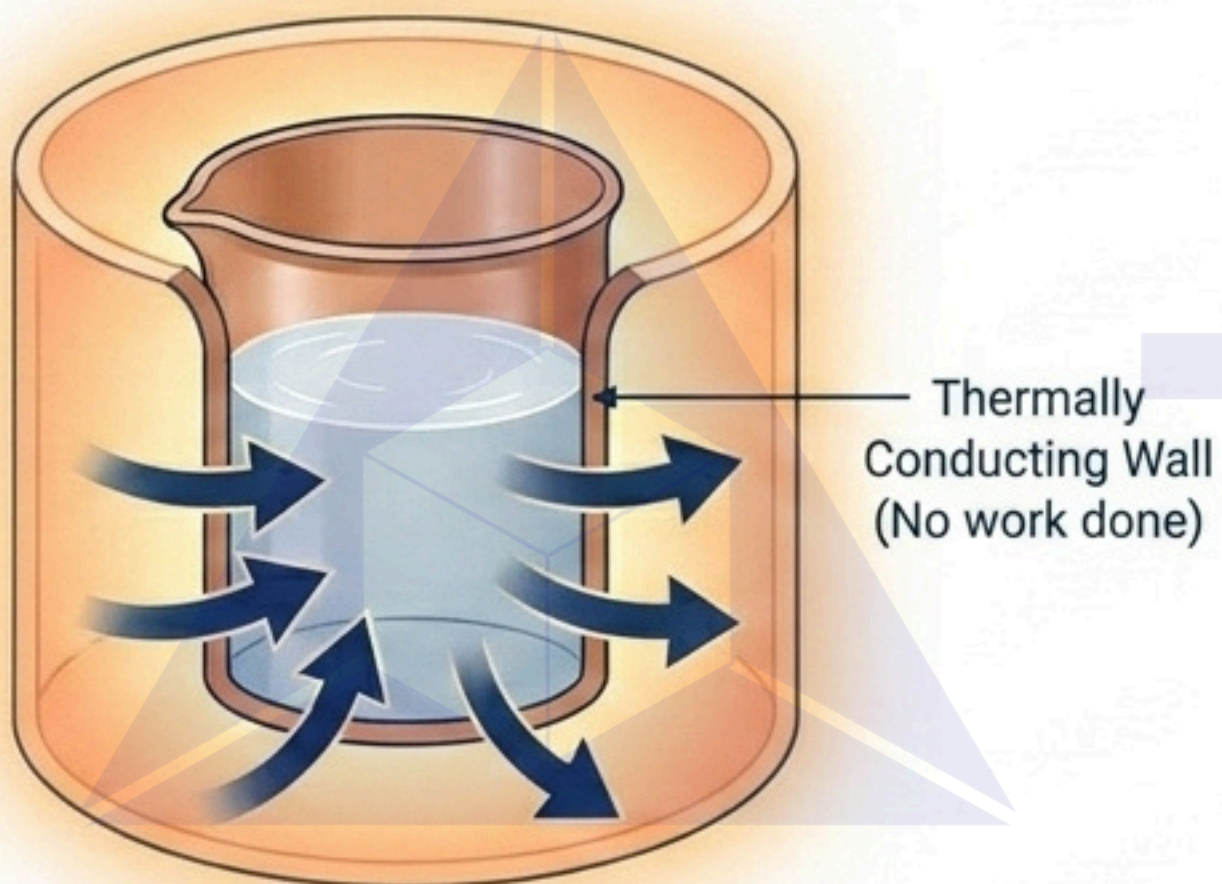
Because the temperature change is identical regardless of how the work is done, Internal Energy (U) is a state function. It depends only on the current state, not the path taken to reach it.

Takeaway: Work done on an adiabatic system directly increases its internal energy.

$$\Delta U = U_2 - U_1 = w_{\text{ad}}$$

(where w_{ad} = adiabatic work)

Heat as Energy Transfer



Temperature Difference

Energy exchange driven purely by a difference in temperature is defined as heat (q).

Constant Volume

When the container's volume is rigid ($\Delta V = 0$), no expansion work is possible. Therefore, all heat transferred directly alters the system's internal energy.

Takeaway: Heat transferred into a rigid system directly increases its internal energy.

$$\Delta U = q$$

(at constant volume, $w = 0$)



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General Case: $\Delta U = q + w$

$$\begin{array}{|c|} \hline [q] \\ \hline \text{(Heat Transfer)} \\ \hline \end{array} + \begin{array}{|c|} \hline [w] \\ \hline \text{(Work Done)} \\ \hline \end{array} = \begin{array}{|c|} \hline [\Delta U] \\ \hline \text{(Change in Internal Energy)} \\ \hline \end{array}$$

Path-Dependent Variables

q and w can vary drastically depending on exactly how a change is carried out.



State Function

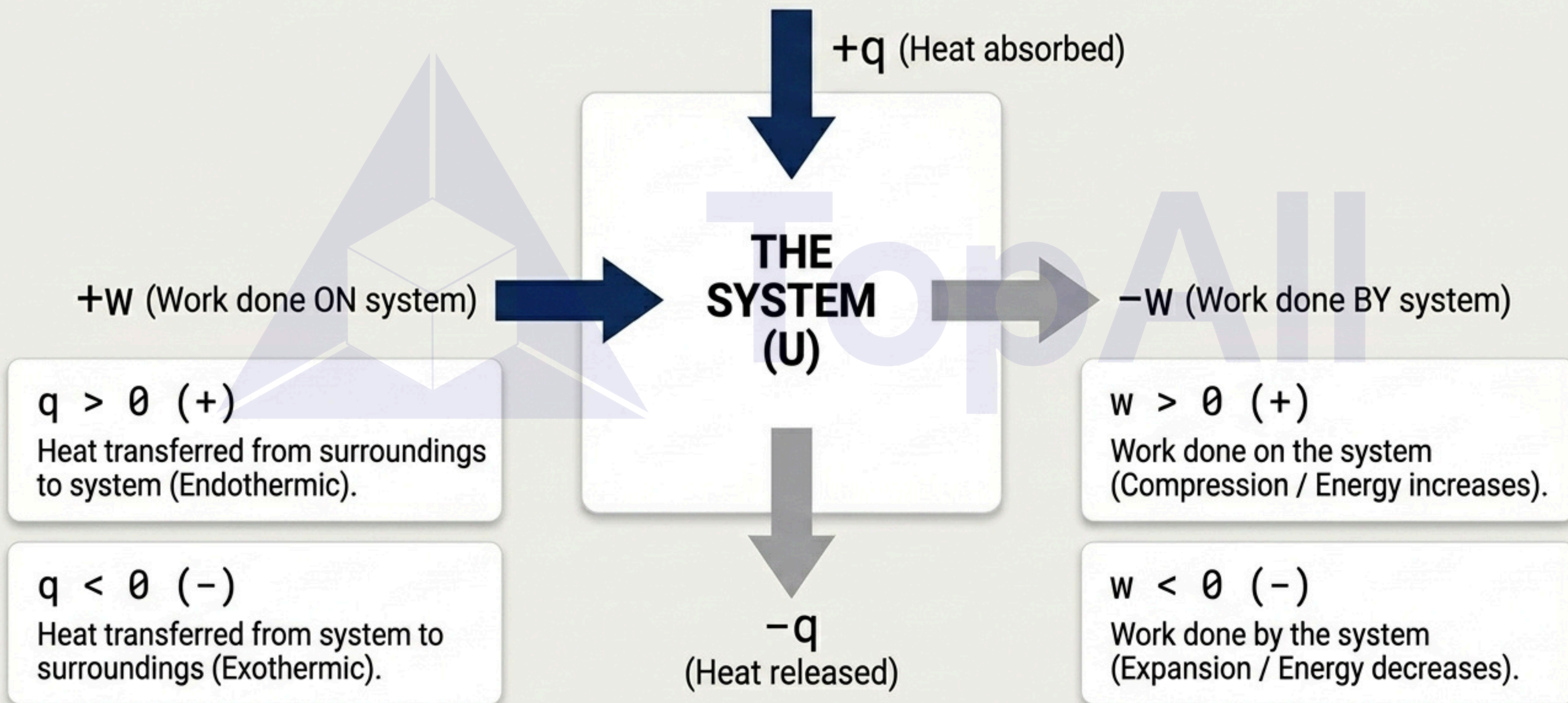
ΔU depends ONLY on the initial and final states. Regardless of the specific mix of q and w , their sum is always identical for the same change in state.



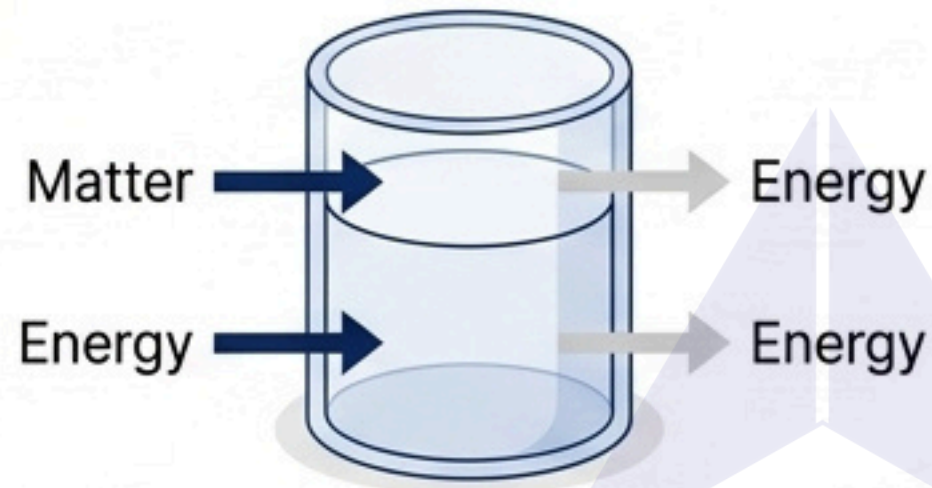
Note: There is a critical difference between mechanical properties (like absolute volume) and thermodynamic properties. We cannot measure a system's absolute internal energy. We can only ever measure the change (ΔU).

Thermodynamic Sign Convention

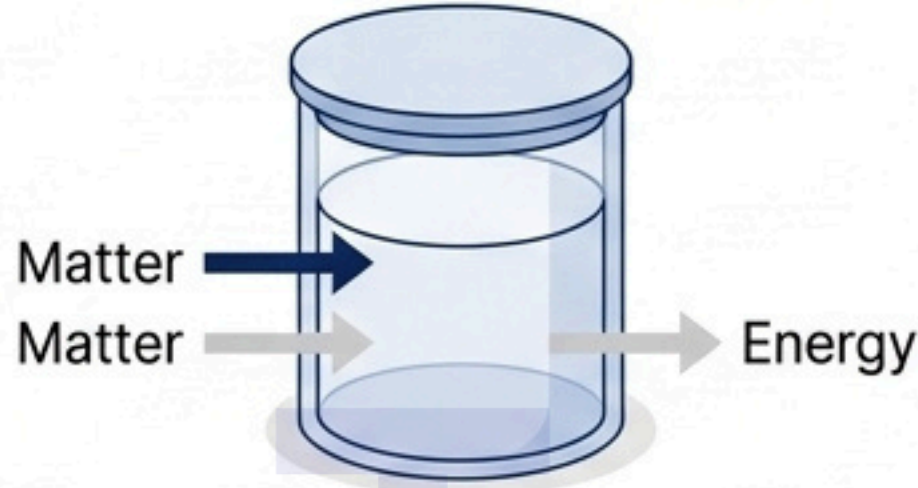
Reminder: Always define boundaries before assigning signs.



The First Law of Thermodynamics



1. Open System



2. Closed System



3. Isolated System

The Mathematical Statement

If there is no transfer of heat ($q = 0$) and no work is done ($w = 0$), then $\Delta U = 0$.

The Physical Statement

The energy of an isolated system is constant.

Law of Conservation of Energy: Energy can neither be created nor destroyed; it can only be transformed from one form to another. Because nothing exists outside the universe, the universe itself is an isolated system.

$$\text{Universe} = \text{System} + \text{Surroundings} \quad | \quad \Delta U_{\text{isolated}} = 0$$



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