AP Physics 2 Thermodynamics: Formulas, Signs and Examples

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Imagine warming a sealed cylinder with a movable piston. Heat enters the gas, its particles transfer energy through collisions, and the expanding gas can push the piston. Thermodynamics keeps track of that energy.

Define the system and signs

The system is the gas you choose to study; everything else is its surroundings. A closed system exchanges energy but not matter. An isolated system exchanges neither; an insulated bottle is only an approximation because real insulation is imperfect.

Here Q is heat added to the system, Wby is work done by the system, and Delta U is the change in its internal energy. All three are measured in joules (J). With this convention, Delta U = Q - Wby . An equivalent convention uses work done on the gas: Delta U = Q + Won. Never mix the two conventions in one calculation.

Worked example: where did the energy go?

A gas absorbs 500 J of heat and does 200 J of work on a piston.

1. Heat enters, so Q = +500 J.

2. The gas does work, so Wby = +200 J.

3. Delta U = 500 - 200 = +300 J.

4. The internal energy rises by 300 J; the other 200 J transfers to the surroundings as work.

Useful formulas, with conditions

Relationship	Meaning and limits
Q = mcDelta T	Temperature change without a phase change, with approximately constant specific heat c. Mass m is in kg; c in J/(kg·K). A Celsius temperature difference equals the same numerical kelvin difference.
PV = nRT	Ideal gas model: absolute pressure P in Pa, volume V in m^3, amount n in moles, temperature T in kelvins and R ≈ 8.31 J/(mol·K).
Wby = PDelta V	Expansion or compression at constant opposing pressure. For varying pressure, work is the signed area under the pressure-volume path for a quasistatic process.
P = F(normal)/A	Uniform pressure is normal force divided by area, in Pa = N/m^2.
eta = Wnet/Qhot	Heat-engine efficiency: useful net work divided by energy received from the hot reservoir in one cycle.
etaCarnot = 1 - Tcold/Thot	Maximum efficiency for a reversible engine between two thermal reservoirs; temperatures must be in kelvins. This is not the efficiency of every engine.

Compare four processes

Process	What stays fixed	What follows
Isothermal ideal gas	Temperature	Delta U = 0, so Q = Wby. Work depends on the path and volume change.
Adiabatic	No heat crosses the boundary: Q = 0	Delta U = -Wby. Temperature can change.
Isobaric	Pressure	Wby = PDelta V. The work is zero if there is no volume change.
Isochoric	Volume	Pressure-volume work is zero; if there are no other work modes, Delta U = Q.

Heat transfer and equilibrium

Conduction transfers energy through microscopic interactions; convection transports energy with moving fluid; radiation transfers energy through electromagnetic waves. Thermal equilibrium means no net heat transfer between bodies at the same temperature.

What the second law actually says

The total entropy of an isolated system does not decrease. It increases for irreversible processes and stays constant for an ideal reversible process. Heat flows spontaneously from hotter to colder bodies; a refrigerator can move heat the other way by receiving work. “Entropy always increases everywhere” is not correct.

Entropy is related to how many microscopic arrangements are compatible with a system’s macroscopic state. Calling it only “disorder” can hide the physics. For reversible heat transfer at a constant temperature, Delta S = Qrev/T; a changing temperature requires a more general calculation.

Two quick checks

Practice: A gas is compressed adiabatically. What happens to its internal energy?

Q = 0 and work done by the gas is negative. Therefore Delta U = -Wby is positive: its internal energy rises.

Practice: What is the Carnot efficiency between 600 K and 300 K?

1 - 300/600 = 0.50, or 50%. This is the reversible upper limit for those reservoirs, not a promise for a real engine.

Sources and next practice

Check OpenStax’s heat-engine explanation , Carnot efficiency and entropy . Continue with Refresh Kid AP Physics 2 .

References

https://openstax.org/books/college-physics/pages/15-3-introduction-to-the-second-law-of-thermodynamics-heat-engines-and-their-efficiency

https://openstax.org/books/college-physics/pages/15-4-carnots-perfect-heat-engine-the-second-law-of-thermodynamics-restated

https://openstax.org/books/university-physics-volume-2/pages/4-6-entropy

Read the companion article: https://refreshkid.com/blog/your-go-to-ap-physics-2-thermodynamics-cheat-sheet/