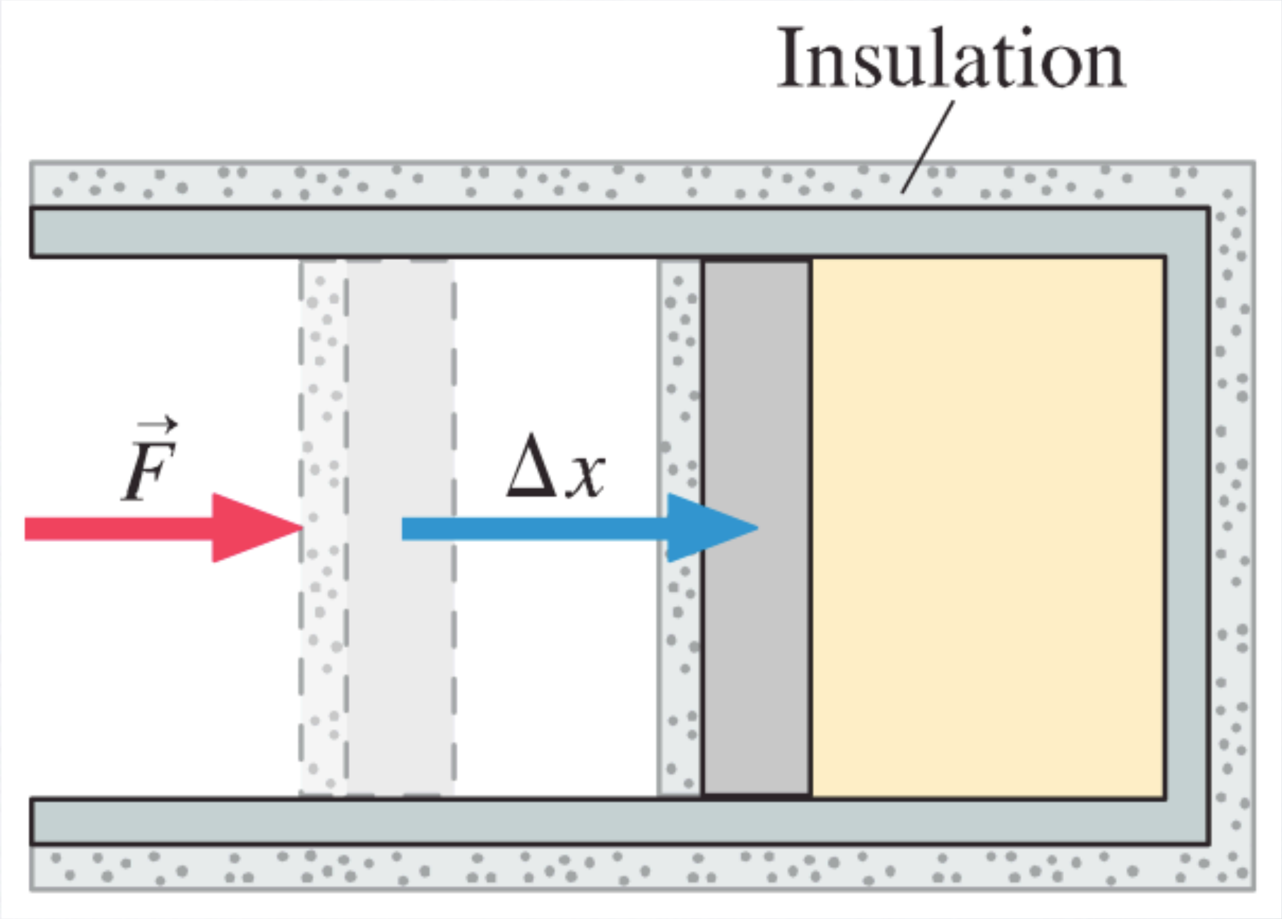
THE FIRST LAW OF THERMODYNAMICS

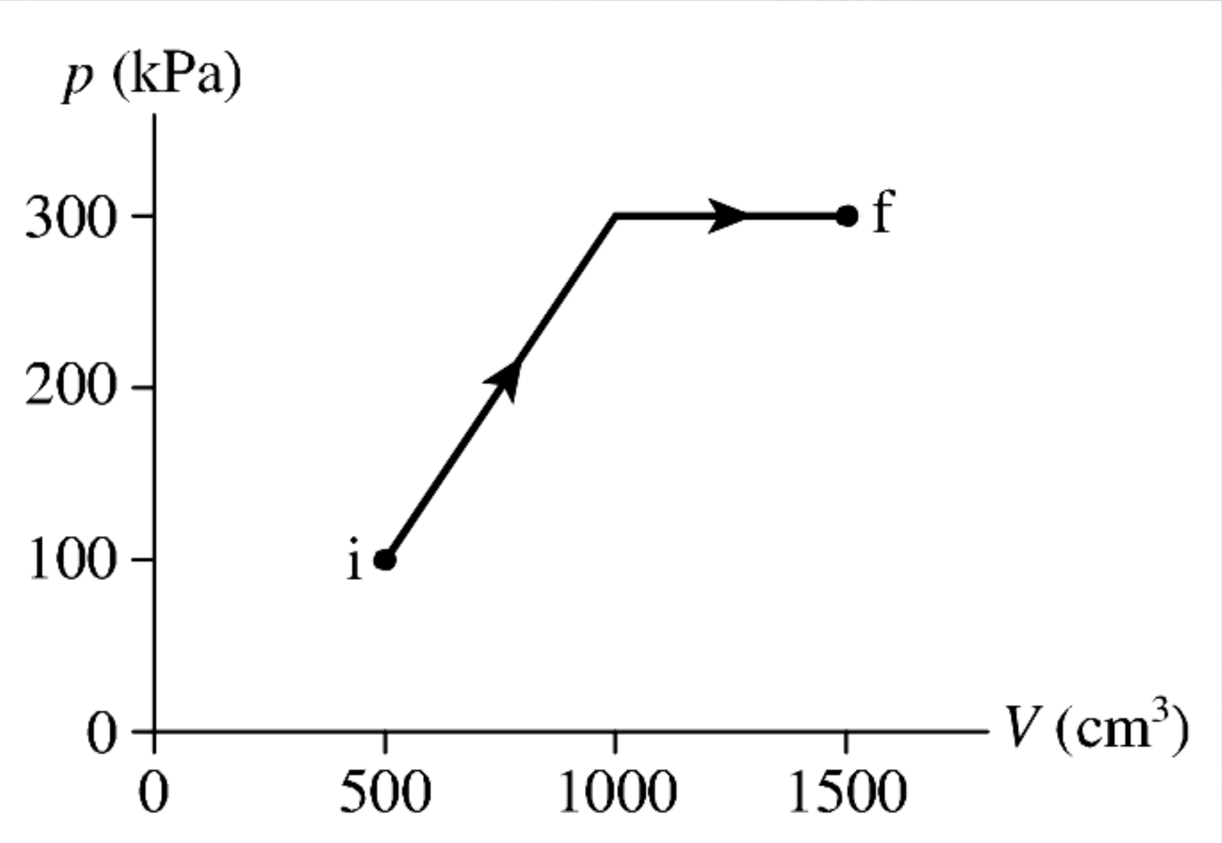
1. A gas cylinder and piston are covered with heavy insulation. The piston is pushed into the cylinder, compressing the gas. In this process the gas temperature

a. increases.
b. decreases.
c. doesn't change.
d. There's not sufficient information to tell.

Explain.



2. How much work (in joules) is done on the gas in the ideal-gas process shown in the figure?



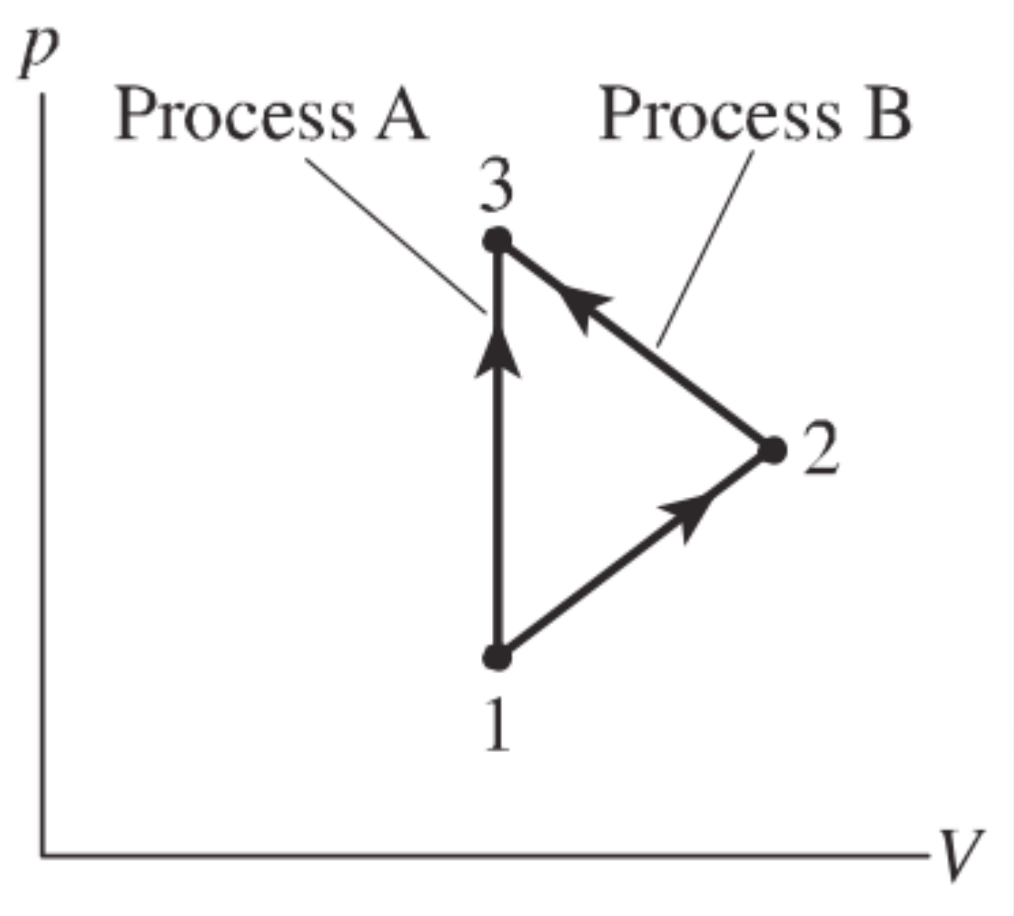
3. Two processes take an ideal gas from state 1 to state 3. Compare the work done by process A to the work done by process B.

a. $W_A = W_B = 0$

b. $W_A = W_B$ but neither is zero

c. $W_A > W_B$

d. $W_A < W_B$



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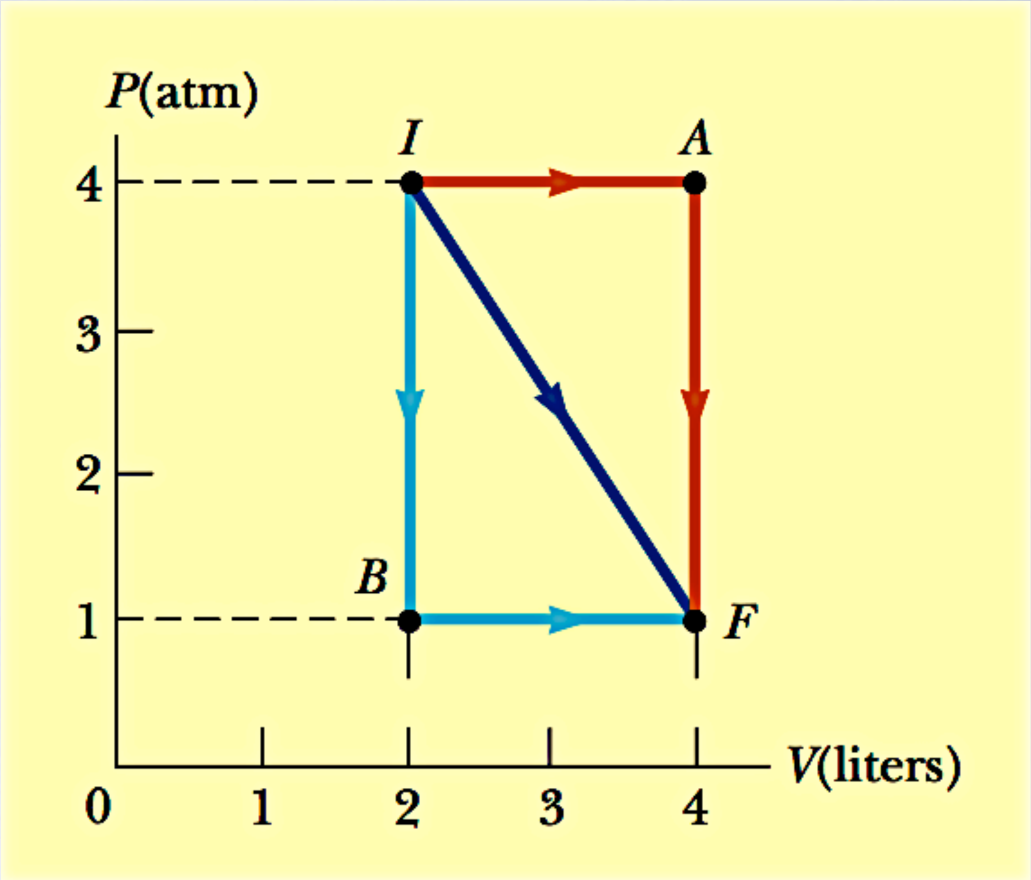
A gas expands from *I* to *F* along three possible paths, as indicated in the figure. Calculate the work in joules done by the gas along the paths *IAF*, *IF*, and *IBF*.



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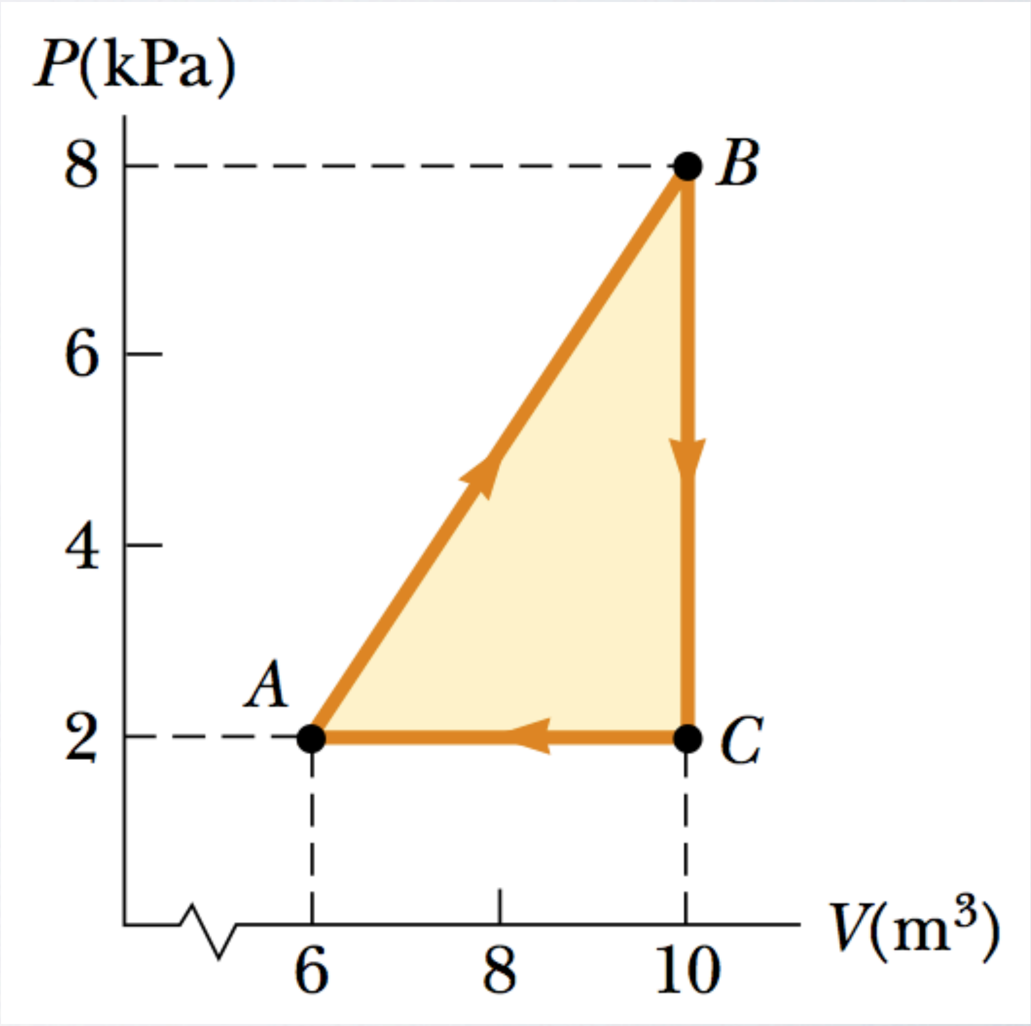
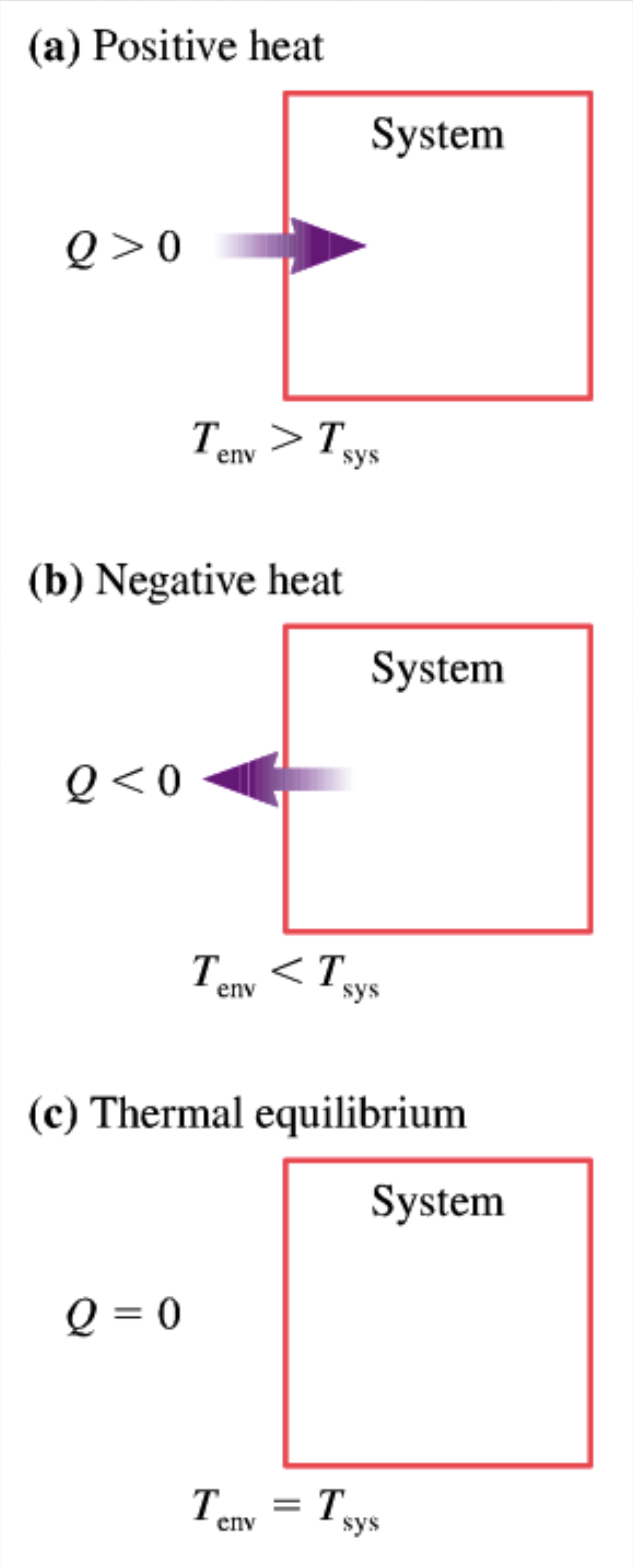
A gas is taken through the cyclic process described in the figure. (a) Find the net energy transferred to the system by heat during one complete cycle. (b) If the cycle is reversed — that is, if the process follows the path *ACBA* — what is the net energy input per cycle by heat?





The sign of heat

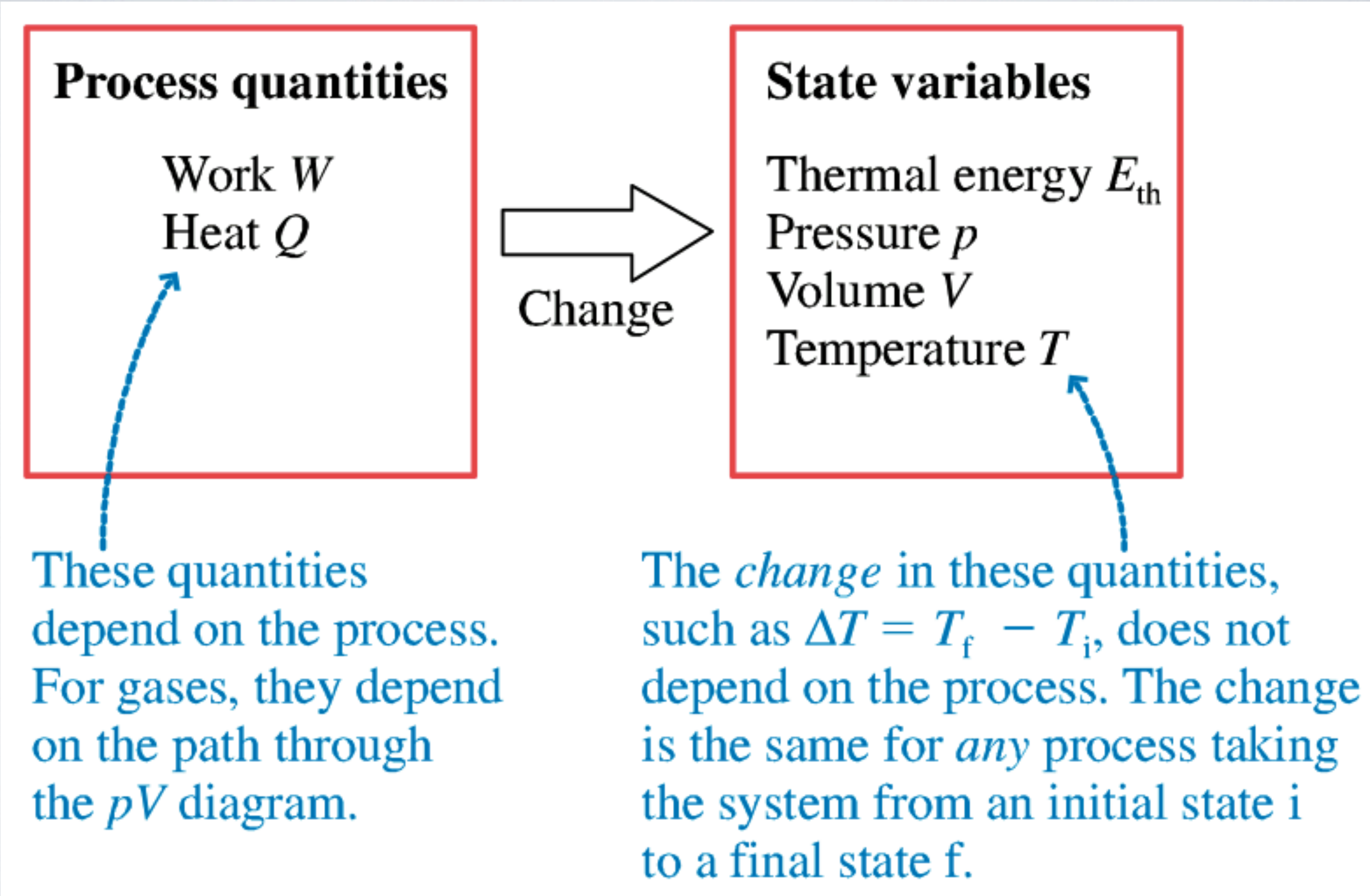
Understanding work and heat

	Work	**Heat**
Interaction:	Mechanical	Thermal
Requires:	Force and displacement	Temperature difference
Process:	Macroscopic pushes and pulls	Microscopic collisions
Positive value:	$W > 0$ when a gas expands. Energy is transferred out.	$Q > 0$ when the environment is at a higher temperature than the system. Energy is transferred in.
Negative value:	$W < 0$ when a gas is compressed Energy is transferred in.	$Q < 0$ when the system is at a higher temperature than the environment. Energy is transferred out.
Equilibrium:	A system is in mechanical equilibrium when there is no net force or torque on it.	A system is in thermal equilibrium when it is at the same temperature as the environment.

The trouble with heat

- Thermal energy is an energy *of the system* due to the motion of its atoms and molecules. It is a *form* of energy. Thermal energy is a state variable, and it makes sense to talk about how E_{th} changes during a process. The system's thermal energy continues to exist even if the system is isolated and not interacting thermally with its environment.
- Heat is energy transferred *between the system* and the environment as they interact. Heat is *not* a particular form of energy, nor is it a state variable. It makes no sense to talk about how heat changes. $Q = 0$ if a system does not interact thermally with its environment. Heat may cause the system's thermal energy to change, but that doesn't make heat and thermal energy the same.
- Temperature is a state variable that quantifies the "hotness" or "coldness" of a system. We haven't given a precise definition of temperature, but it is related to the thermal energy *per molecule*. A temperature difference is a requirement for a thermal interaction in which heat energy is transferred between the system and the environment.

Process quantities and State variables



Which one or more of the following processes involves heat?

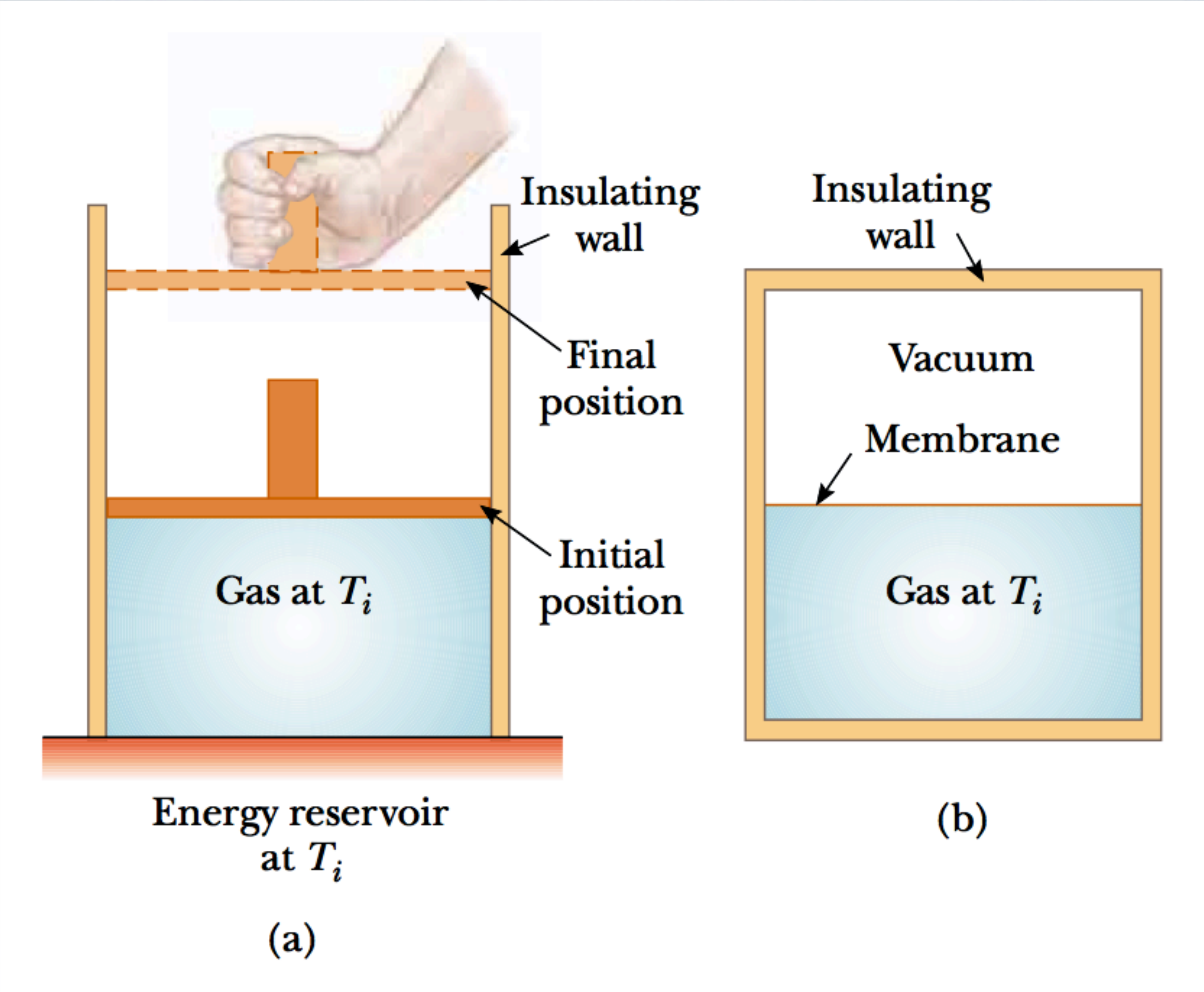
a. The brakes in your car get hot when you stop.
b. A steel block is held over a candle.
c. You push a rigid cylinder of gas across a frictionless surface.
d. You push a piston into a cylinder of gas, increasing the temperature of the gas.
e. You place a cylinder of gas in hot water. The gas expands, causing a piston to rise and lift a weight. The temperature of the gas does not change.

The First Law of Thermodynamics

$Q = \Delta U + W$ or $Q = \Delta E_{th} + W$

or $\Delta E_{th} = W + Q$ (note difference in sign notation)

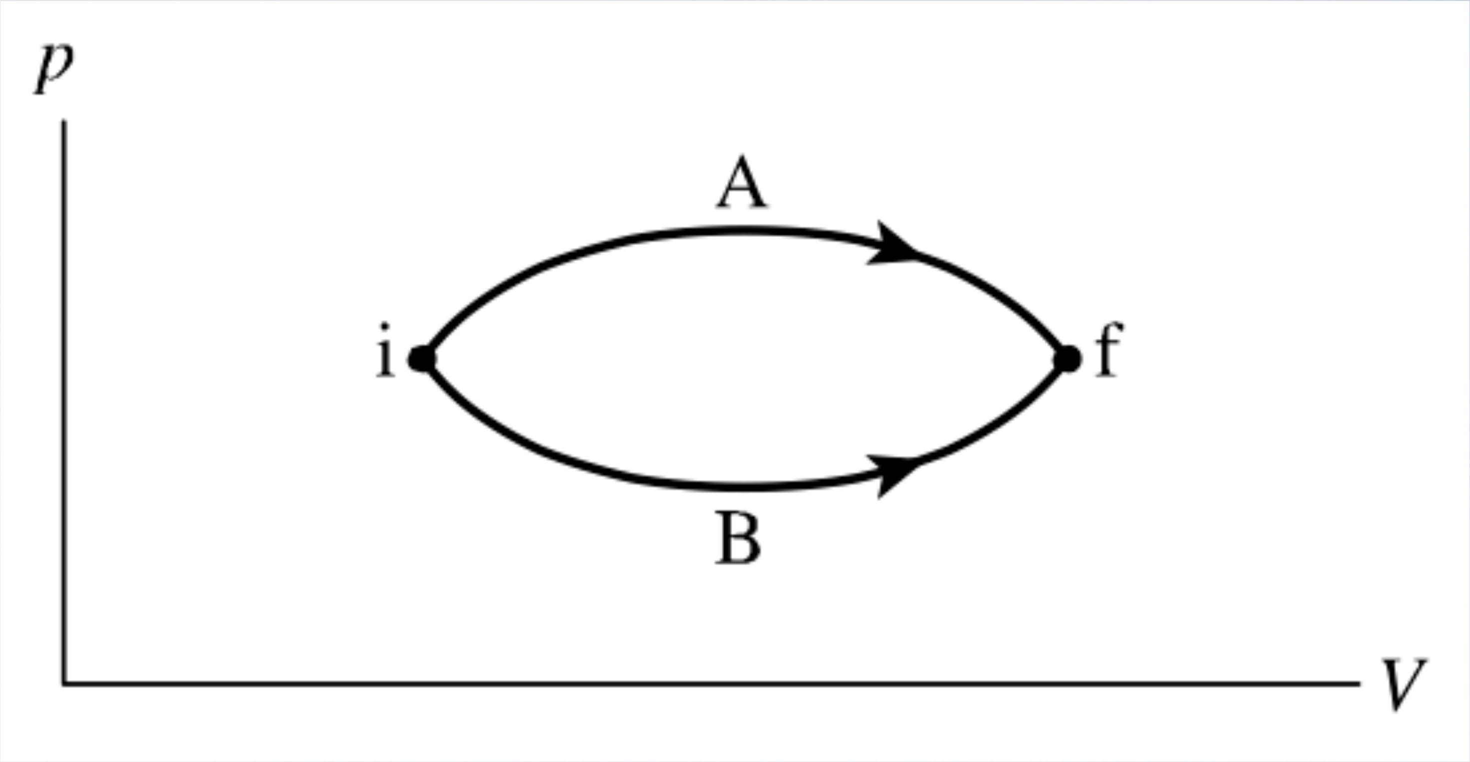
1. The first law of thermodynamics doesn't tell us anything about the value of E_{th}, only how E_{th} changes. Doing 1 J of work changes the thermal energy by $\Delta E_{th} = 1$ J regardless of whether $E_{th} = 10$ J or 10,000 J.
2. The system's thermal energy isn't the only thing that changes. Work or heat that changes the thermal energy also changes the pressure, volume, temperature, and other state variables. The first law tells us only about ΔE_{th}. Other laws and relationships must be used to learn how the other state variables change.



(a) A gas at temperature T_i expands slowly while absorbing energy from a reservoir in order to maintain a constant temperature. (b) A gas expands rapidly into an evacuated region after a membrane is broken.

For the two processes shown, which of the following is true?

a. $Q_A > Q_B$
b. $Q_A = Q_B$
c. $Q_A < Q_B$



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In the figure, the change in internal energy of a gas that is taken from *A* to *C* is +800 J. The work done along the path *ABC* is +500 J. (a) How much energy must be added to the system by heat as it goes from *A* through *B* and on to *C*? (b) If the pressure at point *A* is five times that at point *C*, what is the work done by the system in going from *C* to *D*? (c) What is the energy exchanged with the surroundings by heat as the gas is taken from *C* to *A* along the green path? (d) If the change in internal energy in going from point *D* to point *A* is +500 J, how much energy must be added to the system by heat as it goes from point *C* to point *D*?