Reversible and irreversible processes
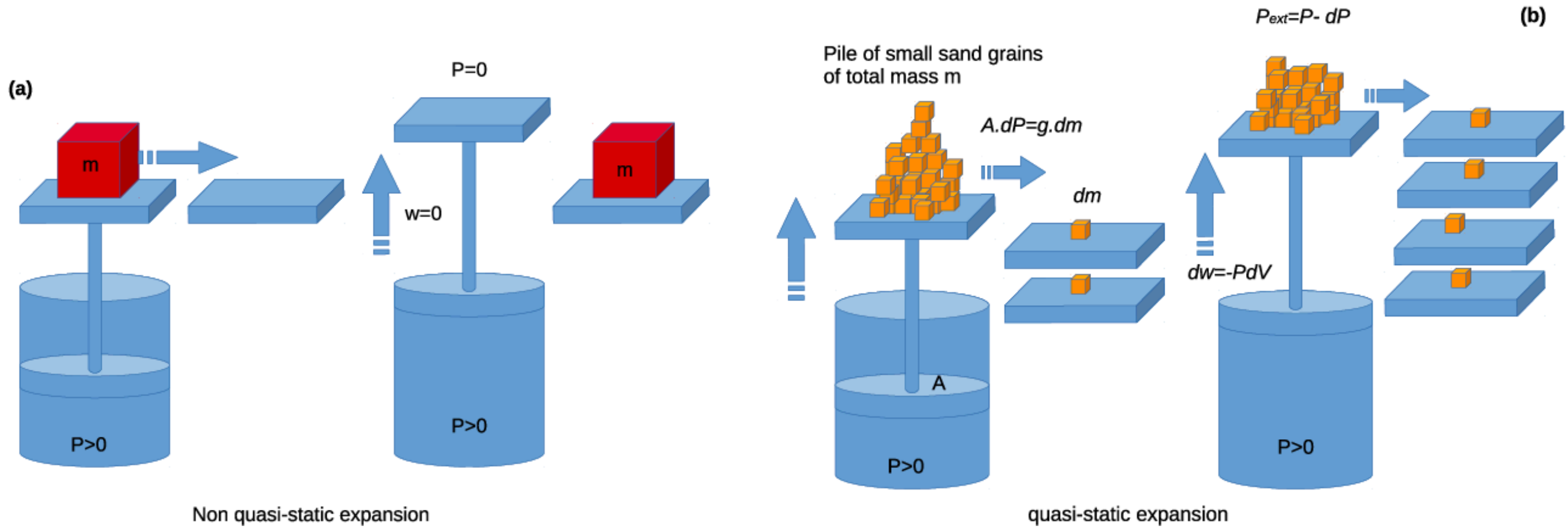

(a)

P=0

w=0

P>0

P>0

m

Non quasi-static expansion

(b)

$P_{ext} = P - dP$

Pile of small sand grains of total mass m

$A \cdot dP = g \cdot dm$

dm

$dw = -PdV$

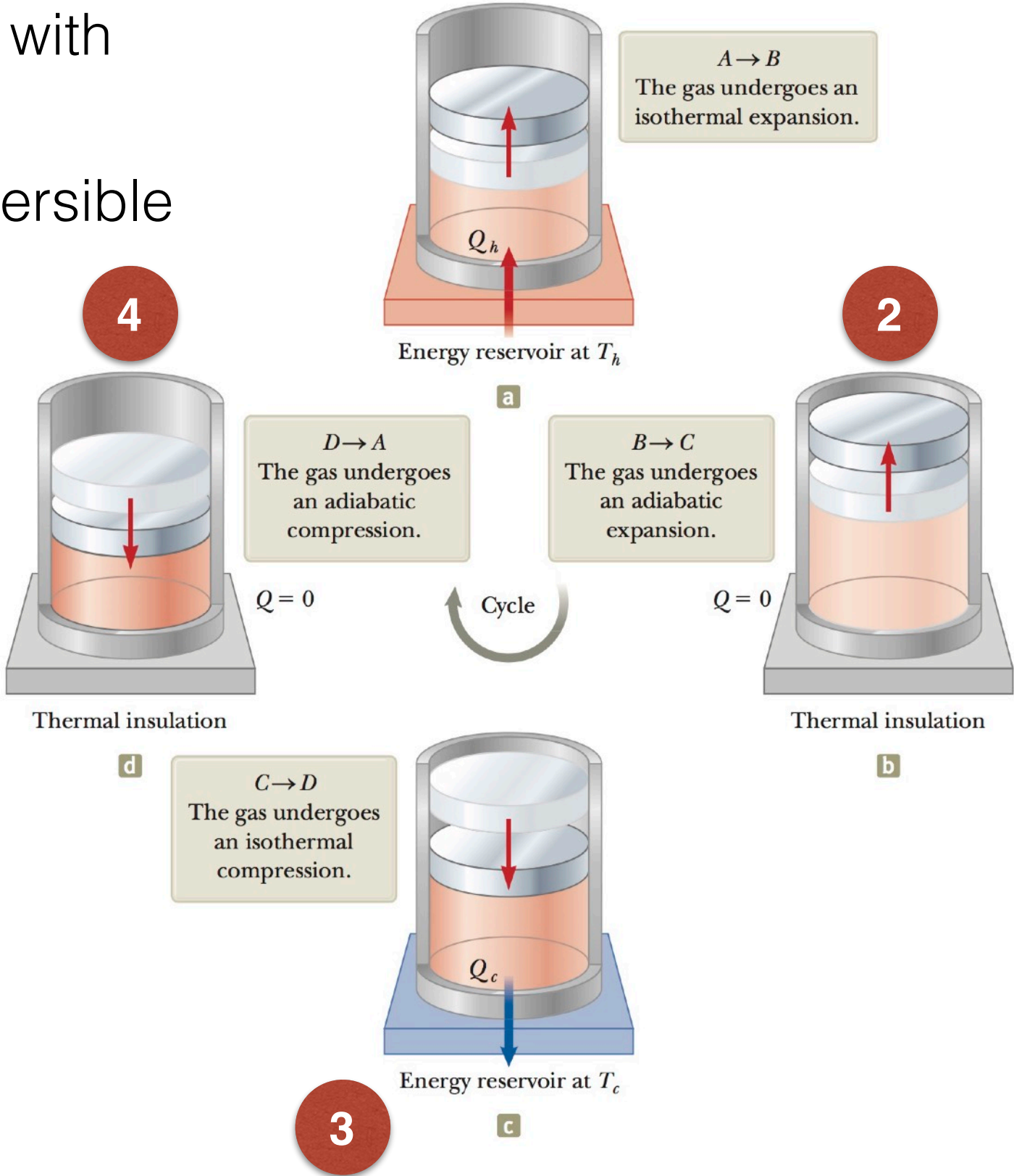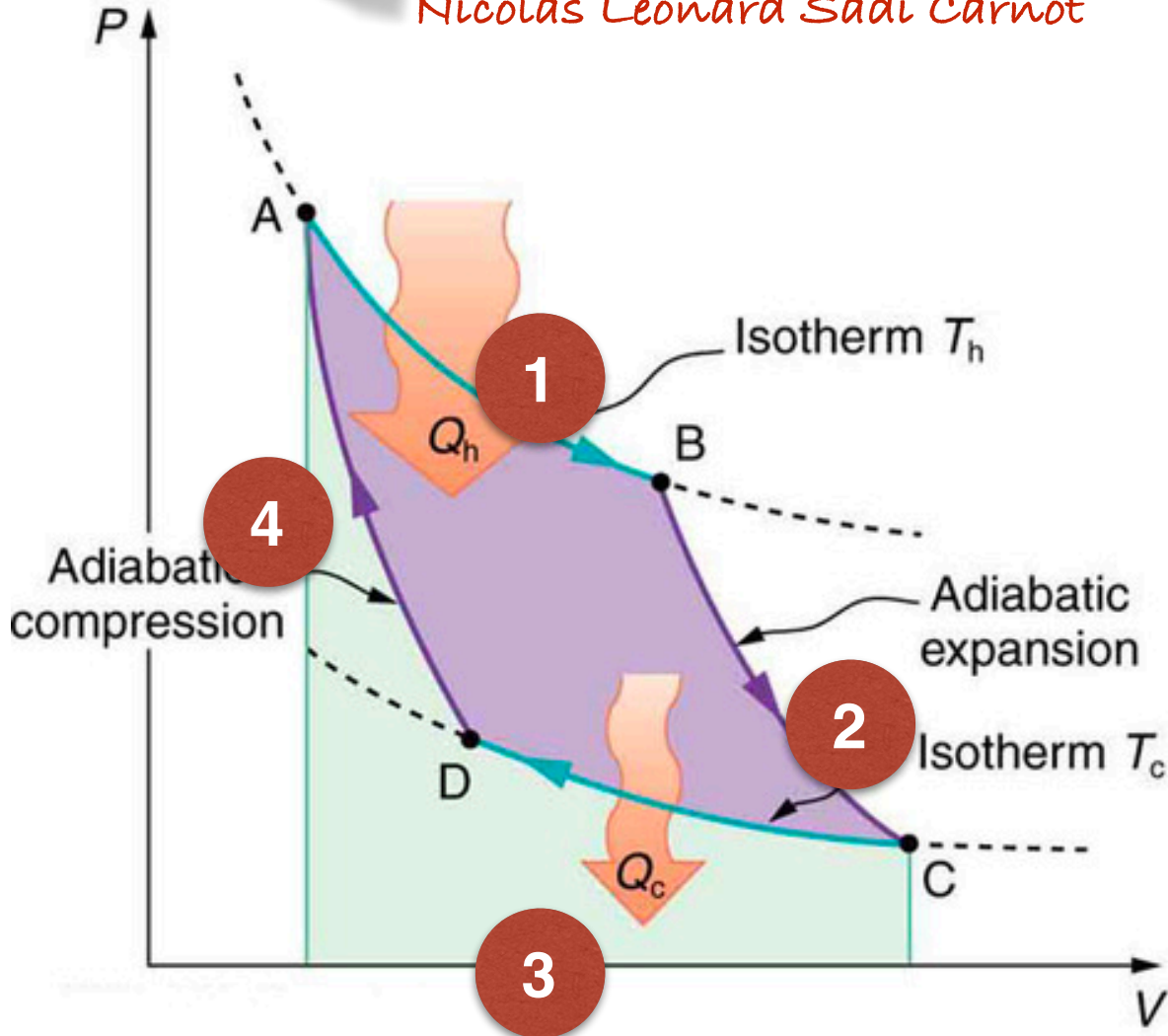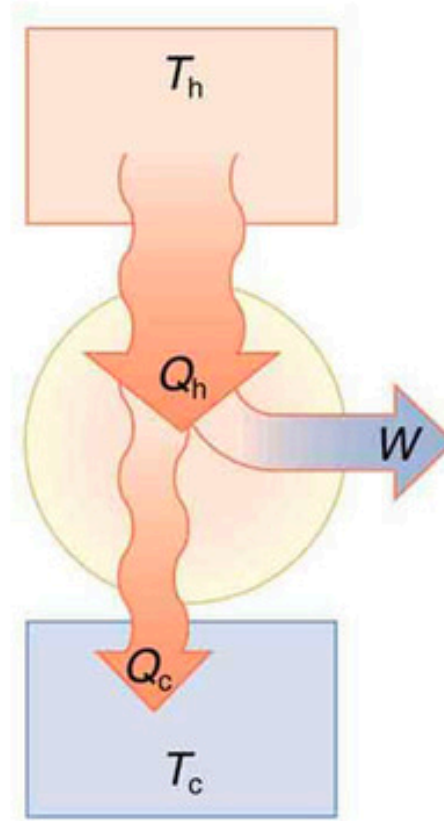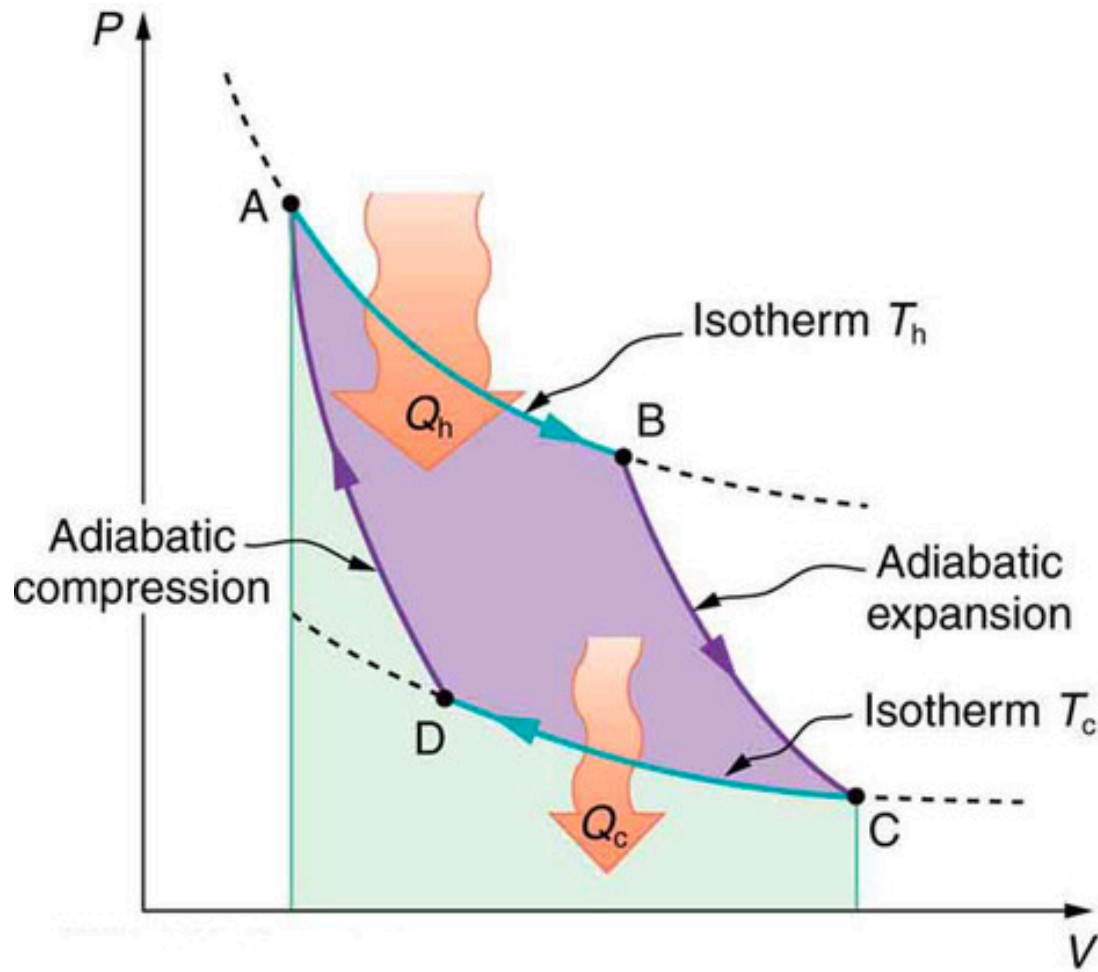A

P>0

P>0

quasi-static expansion

Carnot engine

Consider the engine with the following cycle:

Note: Carnot is a reversible process

Nicolas Léonard Sadi Carnot

$A \rightarrow B$
The gas undergoes an isothermal expansion.

Energy reservoir at T_h

a

$D \rightarrow A$
The gas undergoes an adiabatic compression.

$Q = 0$

Cycle

$B \rightarrow C$
The gas undergoes an adiabatic expansion.

$Q = 0$

Thermal insulation

d

Thermal insulation

b

$C \rightarrow D$
The gas undergoes an isothermal compression.

Q_c

Energy reservoir at T_c

c

Isotherm T_h

Q_h

Adiabatic compression

Adiabatic expansion

Isotherm T_c

Q_c

Carnot engine

Thermal efficiency of the engine:

$$e = 1 - \frac{|Q_C|}{|Q_H|}$$

Exercise - 4

An ideal gas is taken through a Carnot cycle. The isothermal expansion occurs at 250°C, and the isothermal compression takes place at 50.0°C. The gas takes in 1.20×10^3 J of energy from the hot reservoir during the isothermal expansion. Find (a) the energy expelled to the cold reservoir in each cycle and (b) the net work done by the gas in each cycle.
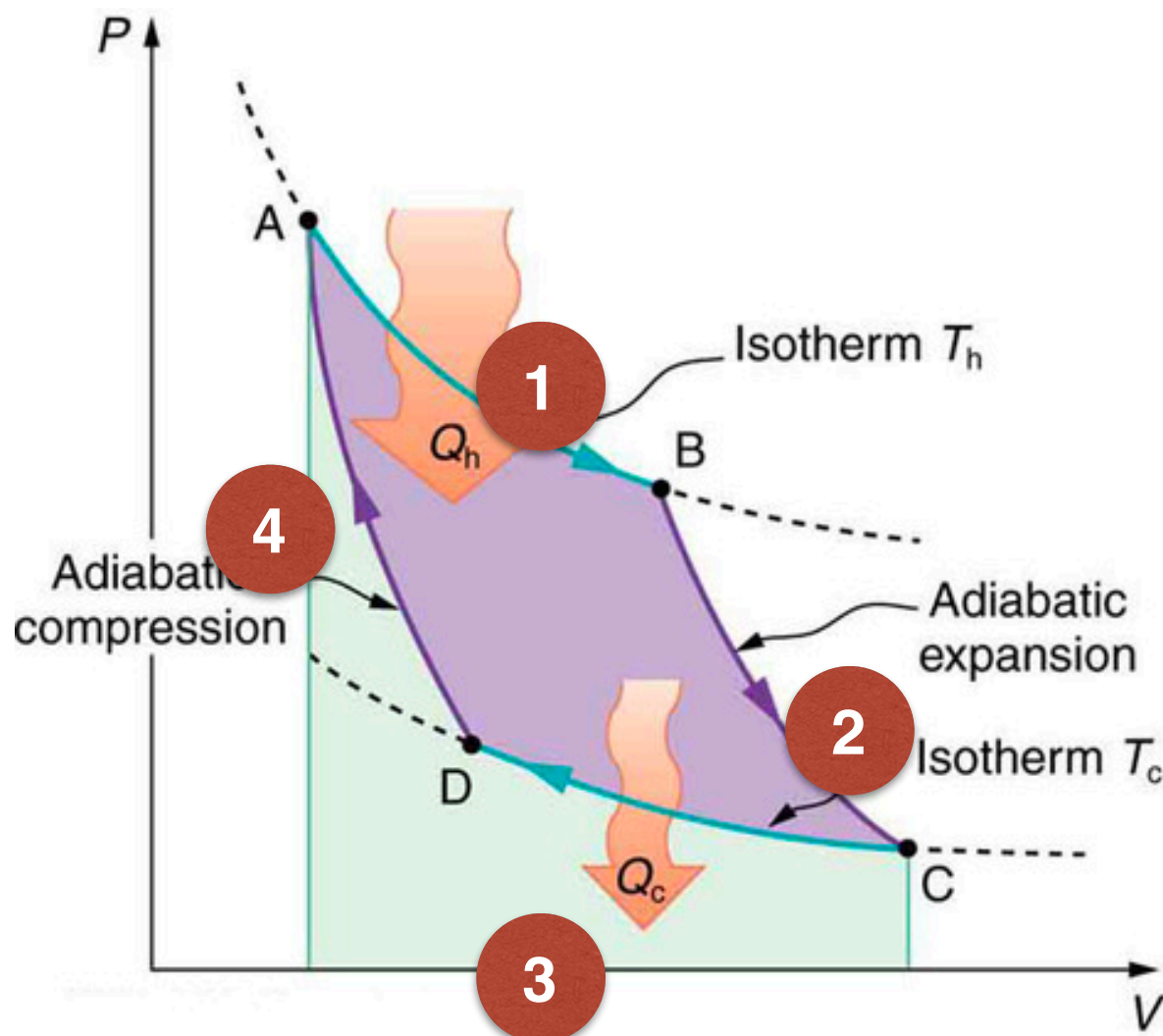
Exercise - 5

In which case will the efficiency of a Carnot cycle be higher:
When the hot body temperature is increased by ΔT, or when the cold body temperature is decreased by the same magnitude?

Carnot's principle

Carnot's principle
"The efficiency of a quasi-static or reversible Carnot cycle depends only on the temperatures of the two heat reservoirs, and is the same, whatever the working substance. A Carnot engine operated in this way is the most efficient possible heat engine using those two temperatures."

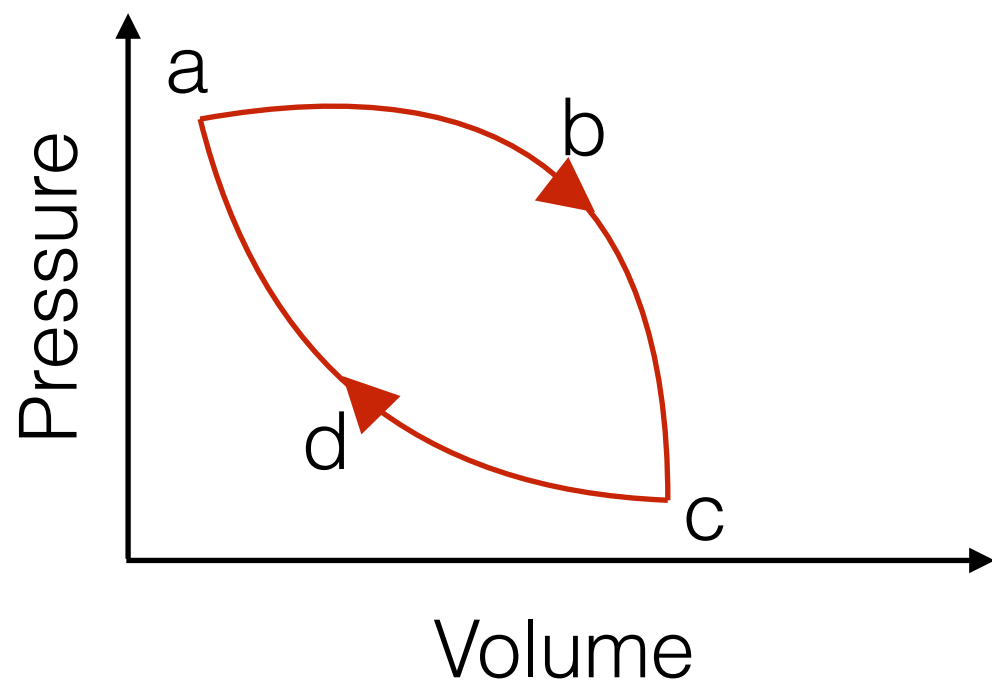## Carnot Engine and the Concept of Entropy

State variables

Do you understand the following statement?
- Internal energy is a state variable
- Heat is not a state variable
- Entropy is a state variable

You can start by considering the cyclic process

Exercise - 6

Imagine a Carnot engine that operates between the temperatures T_H = 850 K and T_L = 300 K. The engine performs 1200 J of work each cycle, which takes 0.25 s.

(a) What is the efficiency of this engine?

(b) What is the average power of this engine?

(c) How much energy $|Q_H|$ is extracted as heat from the high-temperature reservoir every cycle

(d) How much energy $|Q_L|$ is delivered as heat to the low- temperature reservoir every cycle?

(e) By how much does the entropy of the working substance change as a result of the energy transferred to it from the high-temperature reservoir? From it to the low-temperature reservoir?

Exercise - 6

2nd Law of the Thermodynamics

The second law of thermodynamics states that a closed system has entropy that may
  increase: irreversible process
or otherwise
  remain constant: reversible process

If

$$\Delta S = \Delta S_{\text{gas}} + \Delta S_{\text{res}}$$

And processes can happen if

$$\Delta S \geq 0$$

Exercise - 7

When a metal bar is connected between a hot reservoir at T_h and a cold reservoir at T_c, the energy transferred by heat from the hot reservoir to the cold reservoir is Q. In this irreversible process, find expressions for the change in entropy of (a) the hot reservoir, (b) the cold reservoir, and (c) the Universe, neglecting any change in entropy of the metal rod.