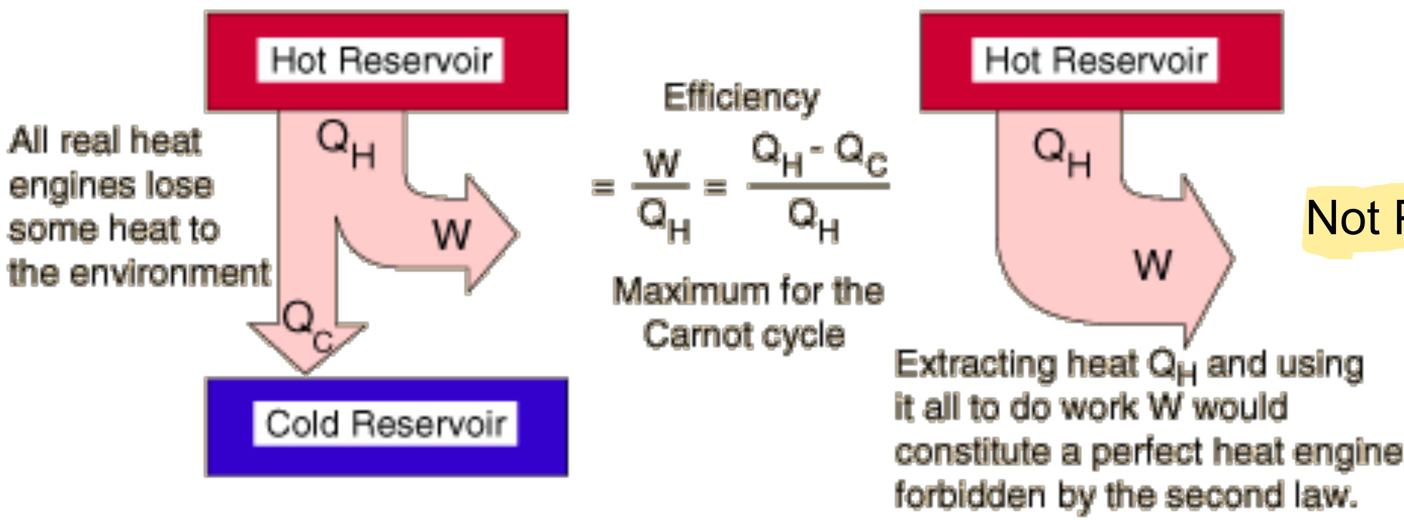
Second Law of Thermodynamics – Heat Engine

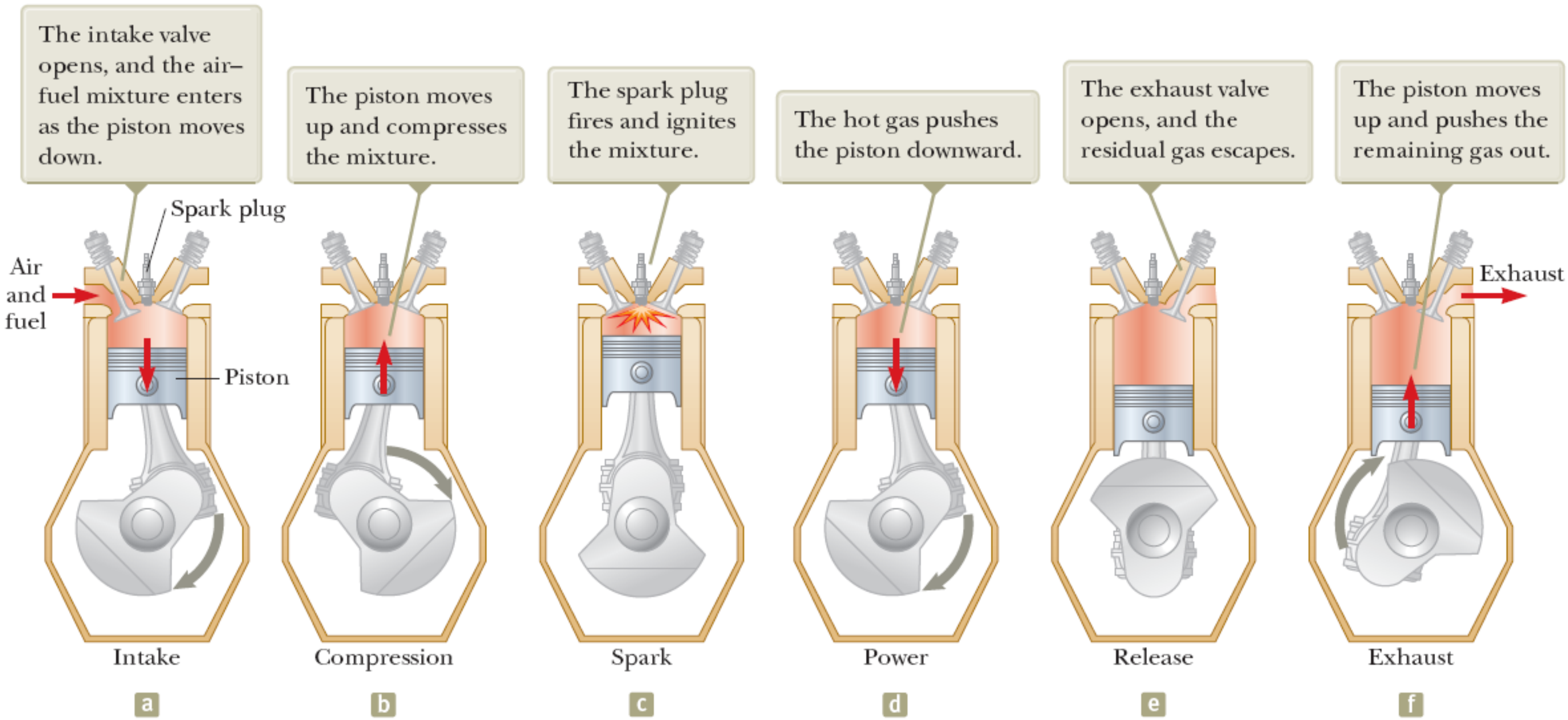
It is impossible to construct a heat engine that, operating in a cycle, produces no effect other than the input of energy by heat from a reservoir and the performance of an equal amount of work.

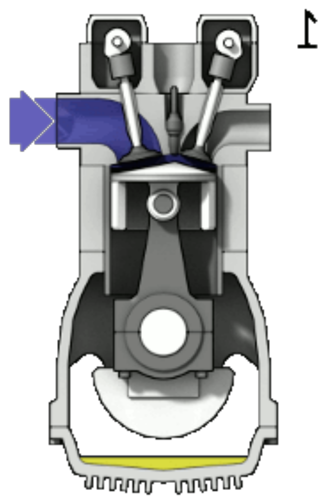
$$e = \frac{W_{out}}{Q_H} = \frac{|Q_H| - |Q_C|}{|Q_H|} = 1 - \frac{|Q_C|}{|Q_H|} < 1$$



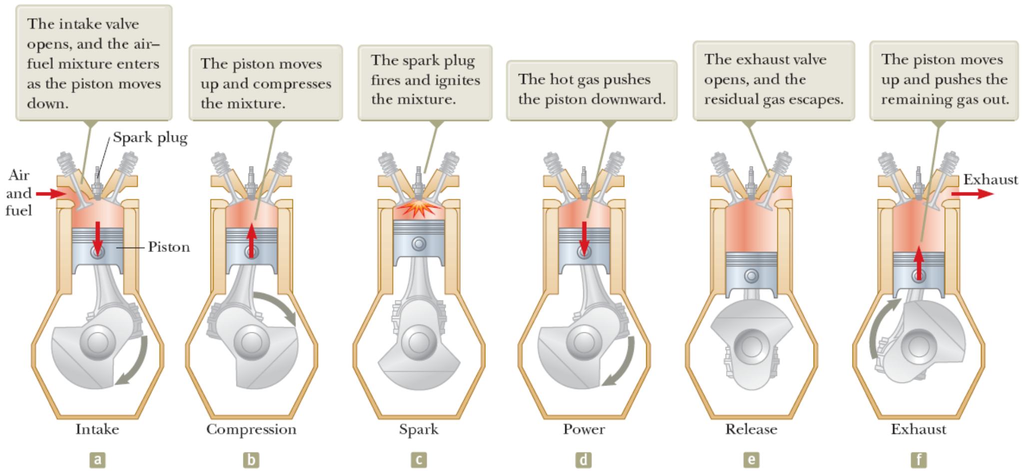
Not Possible

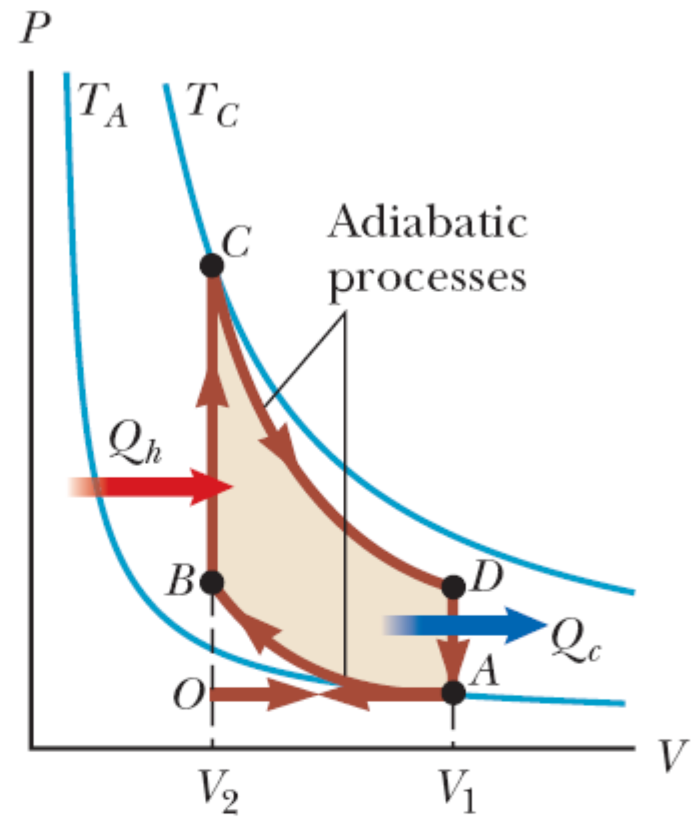
Practical Heat Engine: Otto Cycle (ICE)





Practical Heat Engine: Otto Cycle (ICE)





Processes:
O→A: Intake – constant P, increasing V
A→B: adiabatic compression
B→C: isochoric heating
C→D: adiabatic expansion
D→A: isochoric cooling
A→O: Exhaust – constant P, decreasing V

$$e = 1 - \frac{1}{(V_1/V_2)^{\gamma-1}} \quad (Otto\ Cycle)$$

$$\gamma \approx \tfrac{7}{5} = 1.4$$

gamma

Ideal Heat Engine: Carnot Cycle

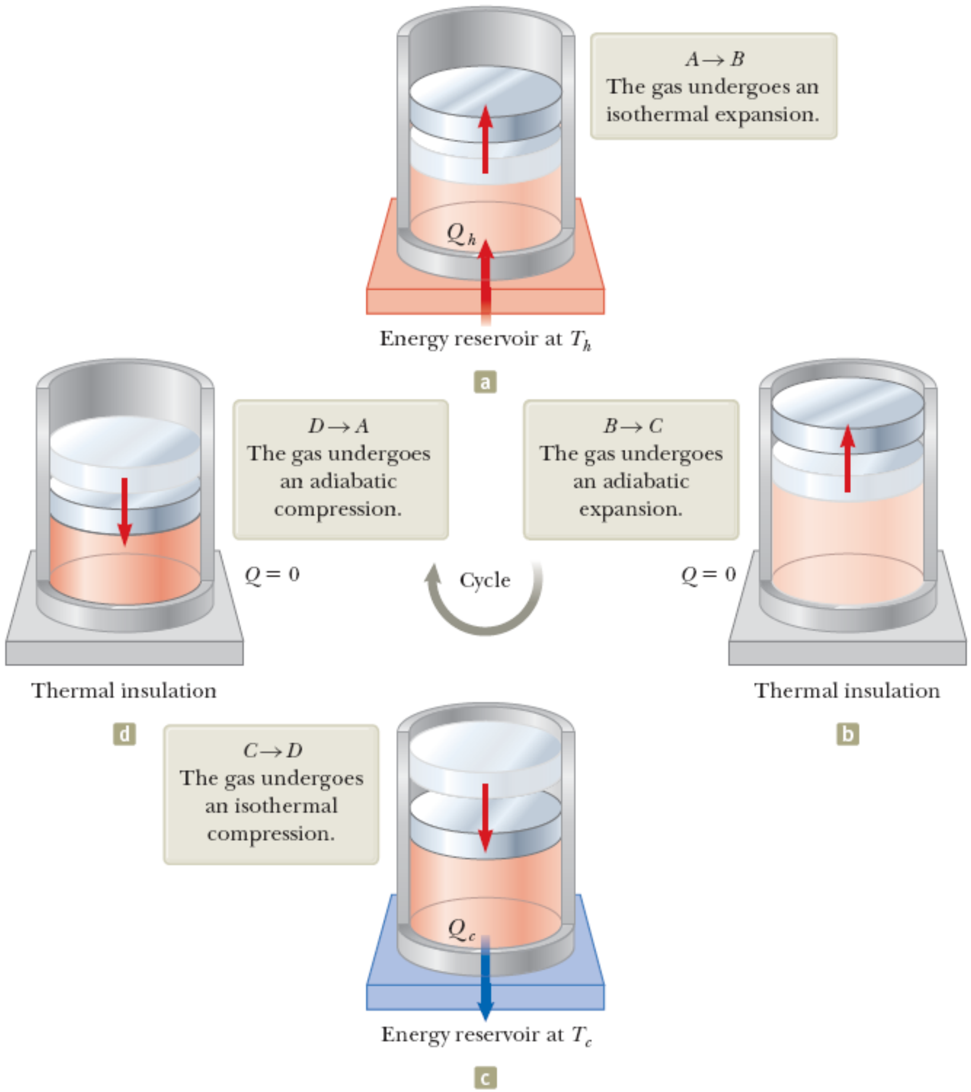
The **Carnot cycle** is a theoretical thermodynamic cycle shown to be the most efficient cycle for converting a given amount of thermal energy into work, or conversely, creating a temperature difference (e.g. refrigeration) by doing a given amount of work.

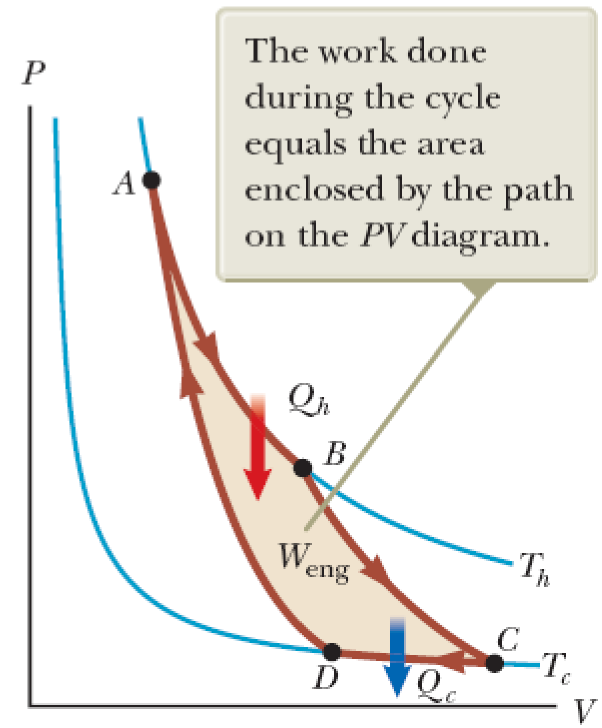
- Isothermal expansion of the gas at the "hot", T_H (isothermal heat addition or absorption).
- Adiabatic expansion of the gas (work output).
- Isothermal compression of the gas at the "cold" temperature, T_C. (isothermal heat rejection)
- Adiabatic compression of the gas (work input).

$$e_{Carnot} = 1 - \frac{T_C}{T_H}$$

Ideal Heat Engine: Carnot Cycle

$$e_{Carnot} = 1 - \frac{T_C}{T_H}$$





Carnot cycle example: 1.00 mol of a monatomic ideal gas undergoes a Carnot cycle with states:

1: (V_1 = 1.00 m^3, p_1 = 2.49x10^3 Pa)

2: (V_2 = 3.00 m^3, p_2 = 8.31x10^2 Pa)

3: (V_3 = 5.51 m^3, p_3 = 3.02x10^2 Pa)

4: (V_4 = 1.84 m^3, p_4 = 9.05x10^2 Pa).

a) Determine Q, $W_{by\ gas}$, and ΔU for each process and for the cycle.

b) Determine the efficiency of the cycle.

Process	**Q(J)**	**$W_{by\ gas}$(J)**	**ΔU (J)**
1→2	+2740	+2740	0
2→3	0	+1247	-1247
3→4	-1824	-1824	0
4→1	0	-1247	+1247
cycle	***+916***	***+916***	***0***

Efficiency? e=33%

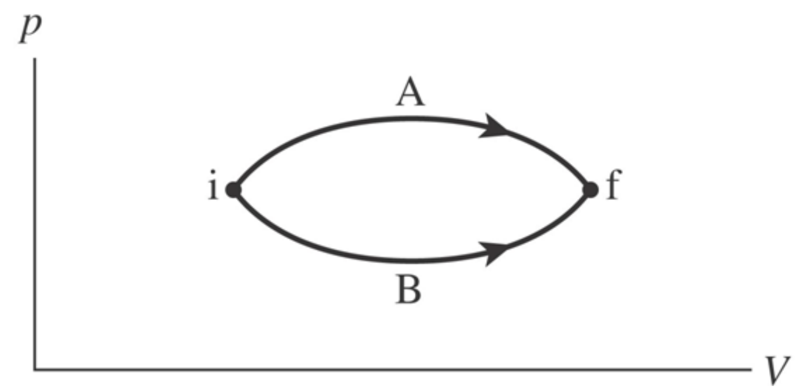
Three engineering students submit their solutions to a design problem in which they were asked to design an engine that operates between temperatures 300K and 500K. The heat input/output and work done by their designs are shown in the following table. Which design is not possible?

Student	Q_H	Q_C	W_{out}
1	250 J	140 J	110 J
2	250 J	170 J	90 J
3	250 J	160 J	90 J

A. Student 1
B. Student 2
C. Student 3.
D. All of them.
E. None of them.

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

A. $Q_A > Q_B$
B. $Q_A = Q_B$
C. $Q_A < Q_B$
D. Can not tell from the given information



Two containers hold equal masses of nitrogen gas at equal temperatures. You supply 10 J of heat to container A while not allowing its volume to change, and you supply 10 J of heat to container B while not allowing its pressure to change. Afterward, how does the temperature compare?

A. $T_A = T_B$
B. $T_A > T_B$
C. $T_A < T_B$
D. Can not tell from the given information

Entropy

Entropy is a measure of disorder.

- With a reversible process

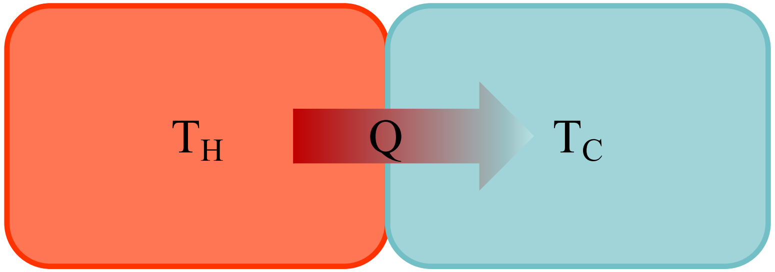
$$dS = \frac{dQ_r}{T}$$

$$\Delta S = \int_i^f \frac{dQ_r}{T}$$

A definition of a reversible process is a process that, after it has taken place, can be reversed and causes no change in either the system or its surroundings.

Entropy Statement of the Second Law of Thermodynamics:
The entropy of the Universe increases in all real processes

$$\Delta S = \frac{Q}{T_c} + \frac{-Q}{T_H} = Q\left(\frac{1}{T_C} - \frac{1}{T_H}\right) > 0$$



A thermodynamic process occurs in which the entropy of a system changes by −8 J/K. According to the second law of thermodynamics, what can you conclude about the entropy change of the environment?

A. It must be +8 J/K or less.
B. It must be between +8 J/K and 0.
C. It must be equal to +8 J/K.
D. It must be +8 J/K or more.
E. It must be zero.