21.1, 2

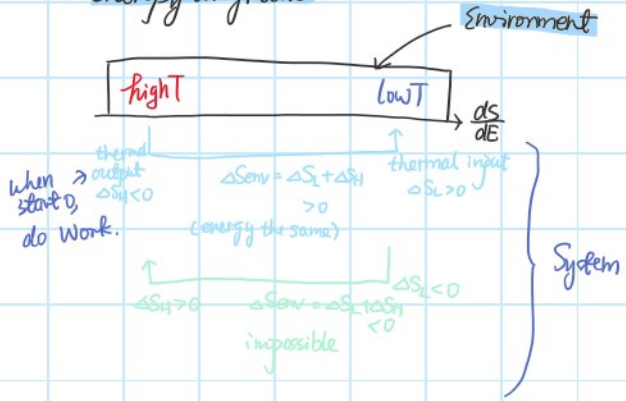
Thursday, March 14, 2019 8:29 AM

- **Energy input-output diagram**
  - Mechanical input/output of the diagram. $W = W_{in} - W_{out}$
  - Thermal input/output of the energy $Q = Q_{in} - Q_{out}$

- **Steady device** the state of the device remain the same or to return to the same state over some repeating time.
  - cycle : a series of process that bring it back to initial state.
  - Constrains :
    - (a) $E_{input} = E_{output}$
    - (b) $\Delta S_{environment} \geq 0$, which is caused by thermal input/output

- **Entropy gradient** $\frac{dS}{dE} = \frac{1}{k_B T}$
  - a measure of change in entropy caused by the change in energy.
  - Low T: high $\frac{ds}{dt}$

    high T: low $\frac{ds}{dt}$
  - entropy diagrams



    - A transfer of energy that points to the right in an entropy diagram causes an increase in the entropy of the environment.

causes an increase in the entropy of the environment.

to the left, decrease.

- Doing work doesn't change entropy ⇒ $\Delta S = 0$, $\frac{\Delta S}{\Delta E} = 0$

- **Quality of the energy** (the usefulness of energy)

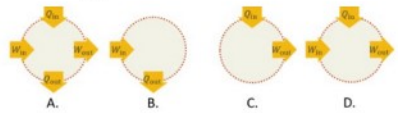
  $T\uparrow, \frac{dS}{dE}\downarrow$, quality of energy ↑

  - degradation of energy quality: the tendency of the entropy of the environment to increase and energy to shift from higher quality to lower quality.
  - upgrade of energy quality: lower-quality energy to higher quality energy.
    - Cannot occur in steady devices that have a single energy input and output.

★★★

many choice question

Which if the following steady device energy input-output diagrams represent processes that decrease the entropy of the universe (therefore would not be allowed)? Select all that apply.

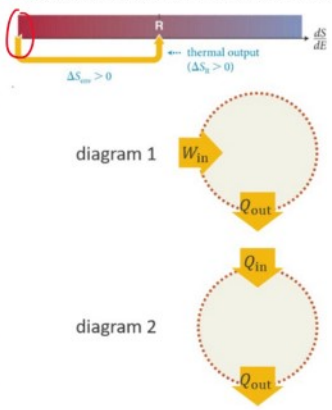


Need Q_{out} to increase the entropy CD

★★★★

many choice question

The entropy diagram shown has arrows at dS/dE=0 and at some other finite value. Which of the following statements is/are correct? Select all that apply.



A. The entropy diagram matches energy input-output diagram 1.

B. The entropy diagram matches energy input-output diagram 2.

C. The entropy diagram is not allowed.

D. The arrow at point R corresponds to Q_{in}

E. The arrow at point R corresponds to Q_{out}

$\frac{dS}{dE} = 0$, so must be work. AE

21.3 Heat Engine and Heat Pumps

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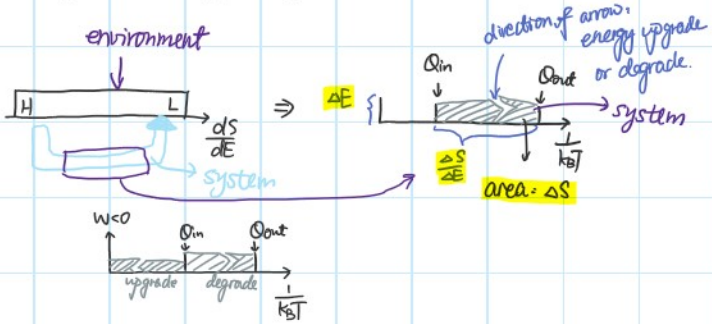
- **heat engine**: a steady device that satisfies $\Delta S_{env} = \Delta S_{upgrade} + \Delta S_{degrade} \geq 0$

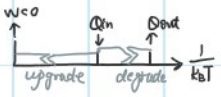
  (the only way for the steady device to upgrade energy)

- Simplified entropy diagram



- Process

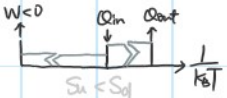
(1) **Reversible Process**



$S_u = S_d$

$\Delta S = 0$

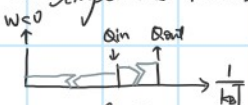
(2) **Irreversible Process**



$S_u < S_d$

$\Delta S > 0$

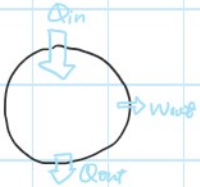
(3) Impossible Process



$\Delta S < 0$

(Impossible)

- **Efficiency of heat engine** $\frac{W}{E_{th\,input}} < 1$



  - a heat engine operating between two fixed-temperature reservoirs, the efficiency is greatest when the **thermal input** of energy takes place at the **highest** possible temperature and the $E_{th\,output}$ takes place at lowest possible temperature.

- **heat pump**: Mechanical Energy is degraded in order to thermally transfer energy from a lower-temperature region of the env to a higher T region.

  e.g. air-conditioner

e.g. air-conditioner

- Coefficient of performance of cooling $\frac{Q_{in}}{W_{in}}$

  Coefficient of performance of heating $\frac{Q_{out}}{W_{in}}$

★★★★

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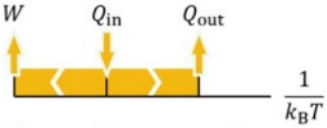
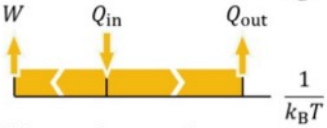
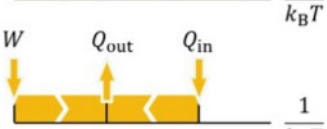
matching question

Match the entropy diagrams with the following devices.

I. 

II. 

III. 

IV. 

Reversible heat engine I.

Irreversible heat engine II

Reversible heat pump III.

Not possible IV

21.4 Thermodynamic Cycles

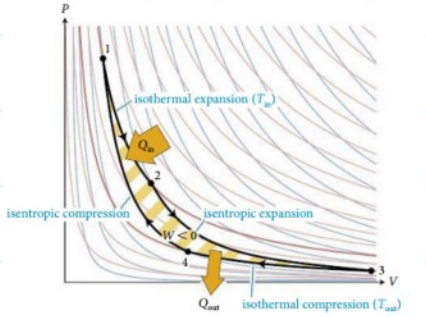
Thursday, March 14, 2019 11:43 AM

- Cyclic Process: a sequence of steps in which the working substance begins and ends in the same thermal equilibrium state.
- |W| = the area enclosed by the path that represents the cycle in a PV diagram.

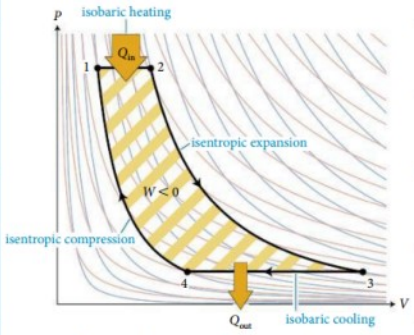
  (W) "+", counterclockwise ; "−", clockwise.

  The work down on system
- Carnot Cycle

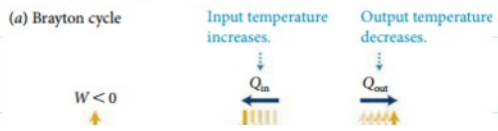
  isothermal → isentropic → isothermal → isentropic



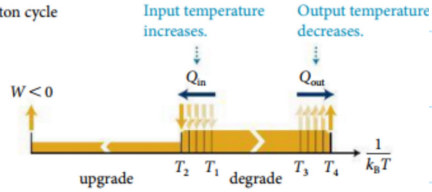
- Brayon Cycle
  - Replace isotherms by isobars
  - isobaric → isentropic → isobaric → isentropic



- Brayon Cycle delivers more energy than Carnot cycle does, but not as efficient as it.



(*a*) Brayton cycle



(*b*) Carnot cycle