Reversible and irreversible processes

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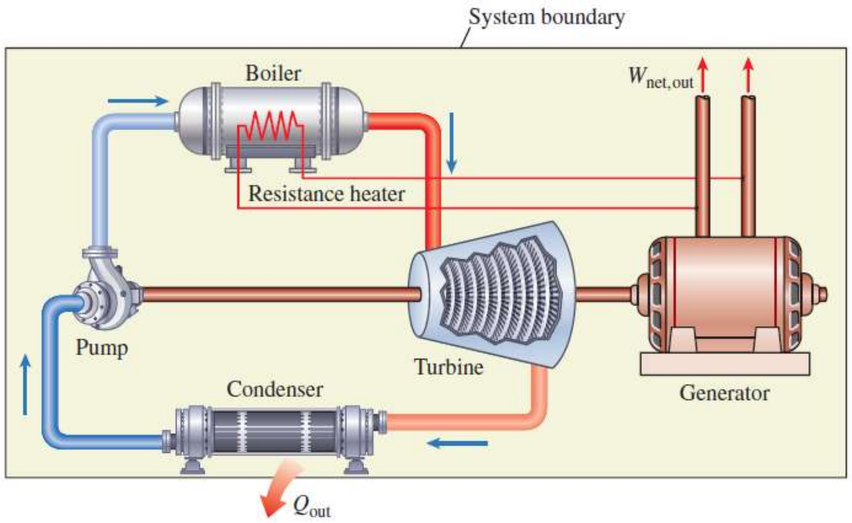
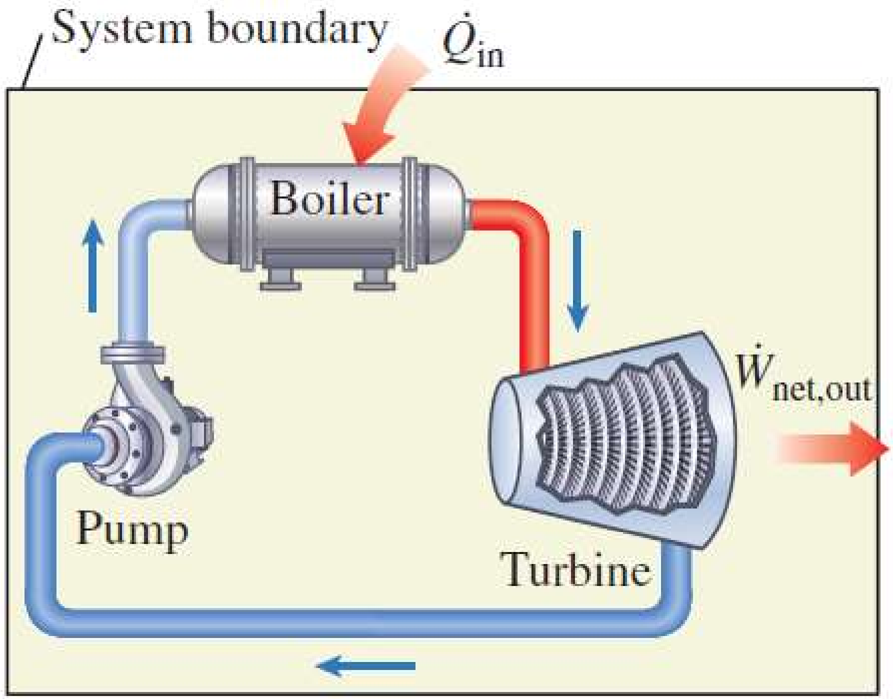
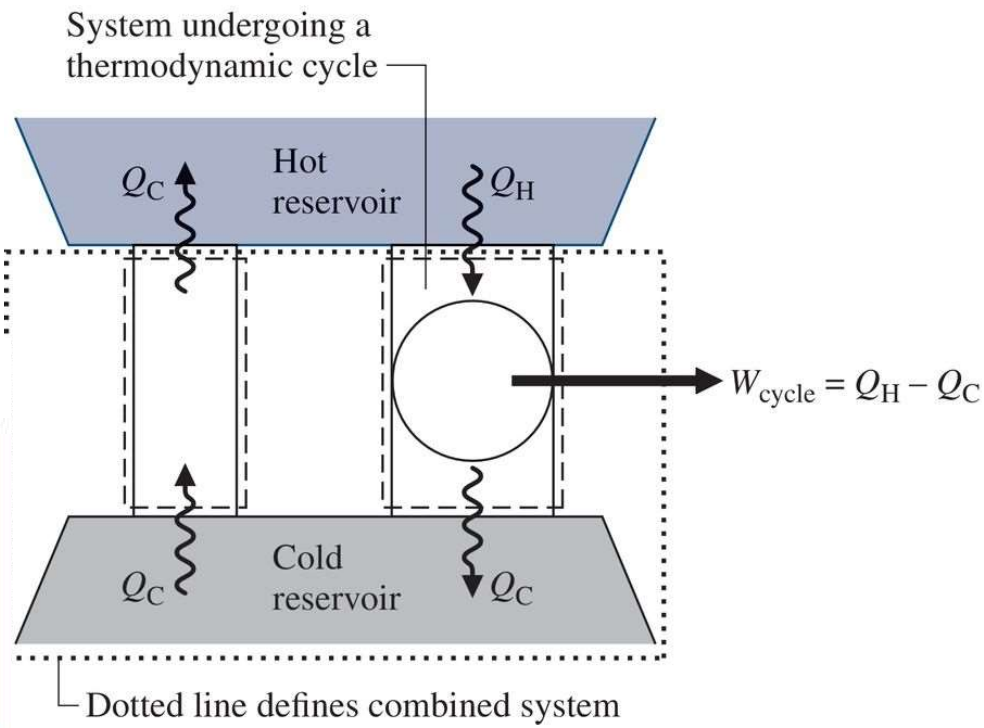
Previous Lecture: Clausius, K-P & perpetual motion







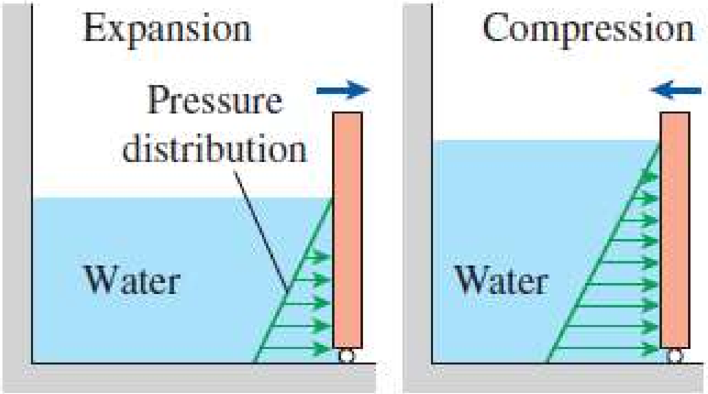
Figs:TD-Cengel & Boles; Moran, Shapiro, Boettner, Bailey

Where do we observe irreversible processes?

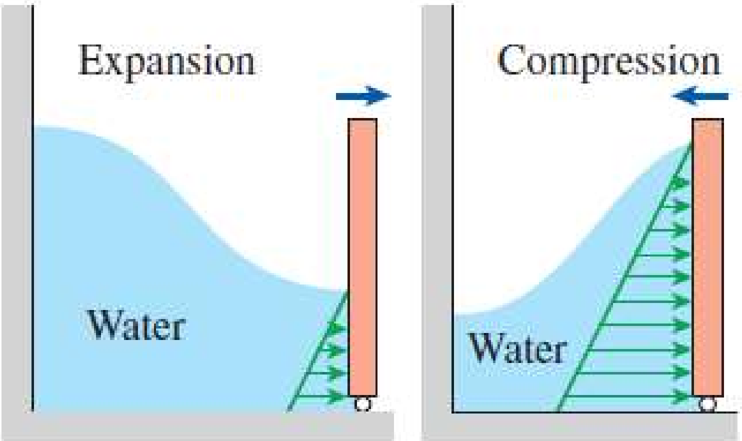
- Irreversible process: If both the system and surrounding cannot be restored to their respective initial states upon reversing the process

- Mechanical friction (solid-solid, drag, viscosity…)
- Electric current via a resistor
- Heat transfer under finite temperature difference
- Expansion under finite differences in pressure
- Inelastic deformation
- Spontaneous chemical reactions
- Mixing of gases (always spontaneous!)
- Magnetic hysterisis
- …Everywhere!

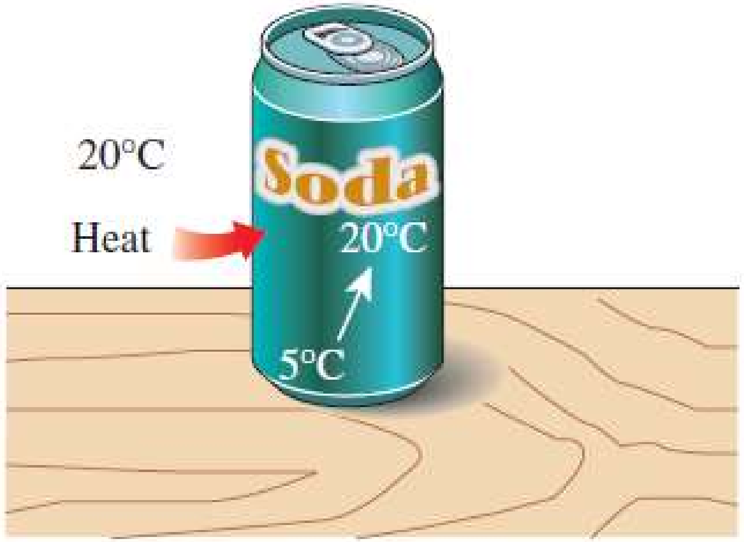
Characteristic of irreversible processes



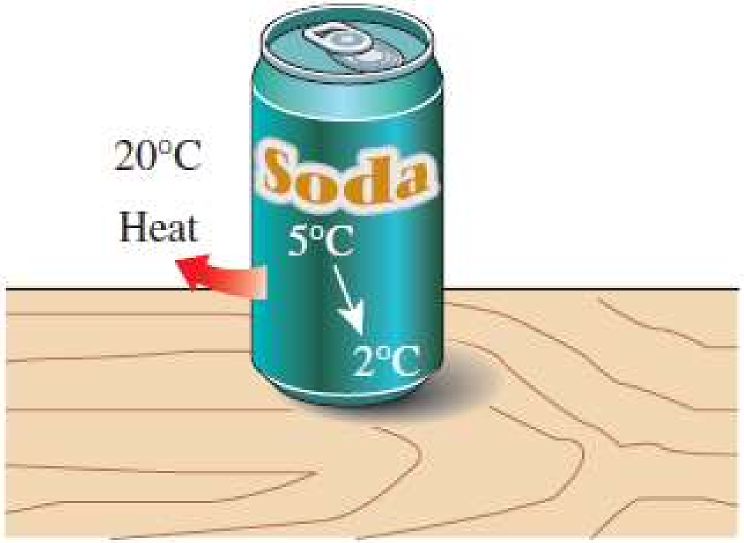
(*a*) Slow (reversible) process



(*b*) Fast (irreversible) process



(*a*) An irreversible heat transfer process



(*b*) An impossible heat transfer process

Fig:TD-Cengel & Boles

Demonstrating irreversibility of Unrestrained expansion

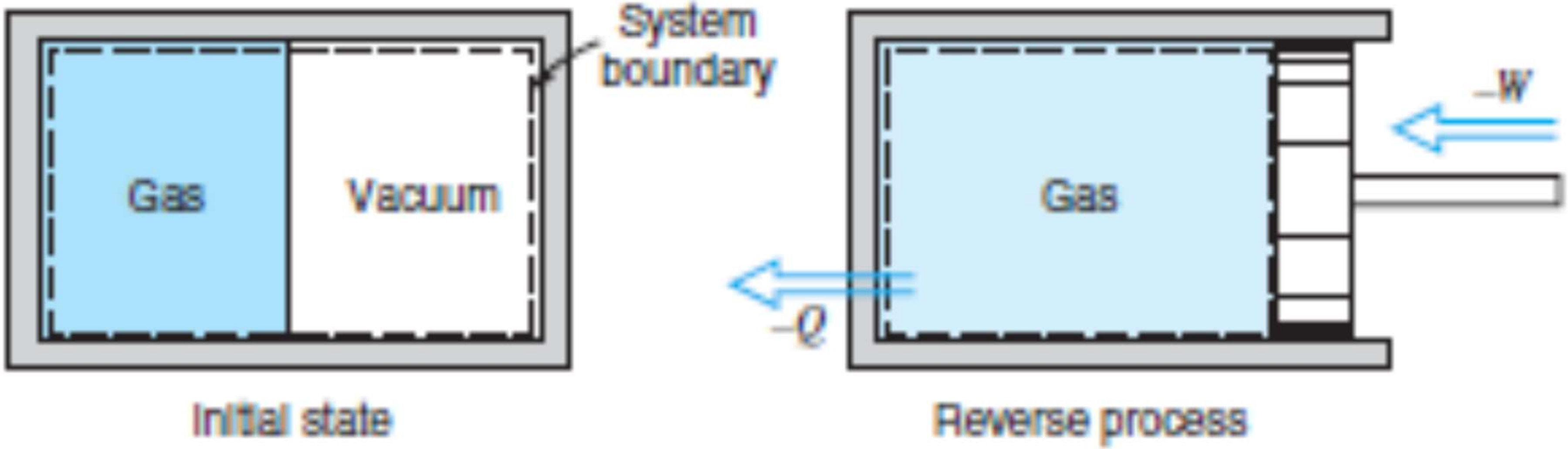


Fig:TD-Borgnakke & Sonntag

Demonstrating irreversibility of Friction

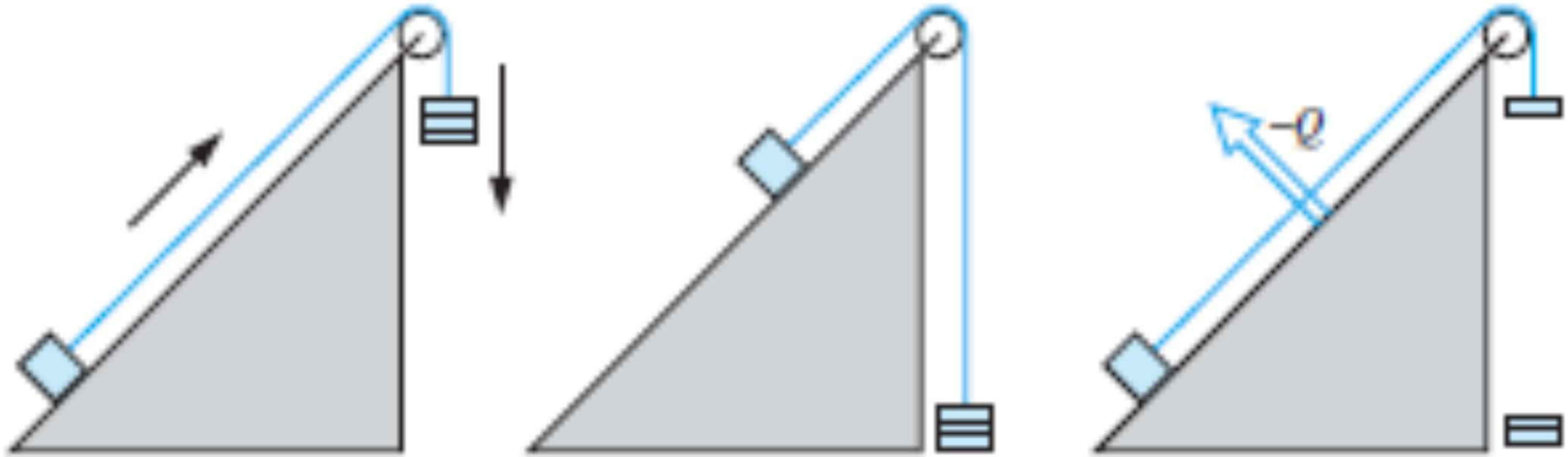
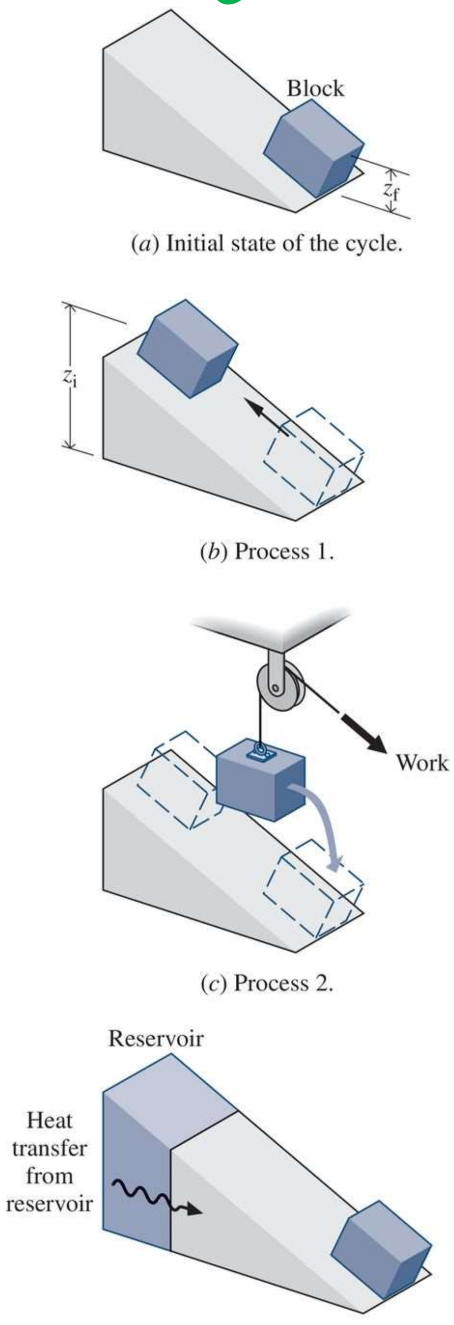


Fig:TD-Borgnakke & Sonntag

Friction & violation of K-P statement



(a) Initial state of the cycle.
(b) Process 1.
(c) Process 2.
(d) Process 3.

$$(U_f - U_i) + mg(z_f - z_i) + \cancel{(KE_f - KE_i)}^0 = \cancel{Q}^0 - \cancel{W}^0$$

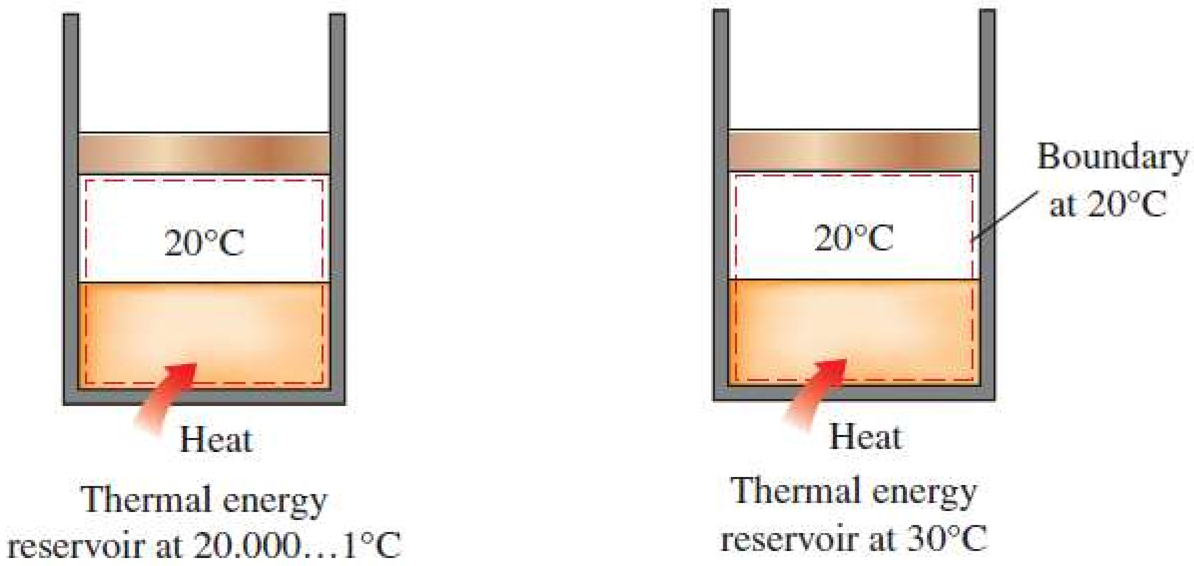
$$U_f - U_i = mg(z_i - z_f)$$

- Process 1: Spontaneous return to Z_i (is impossible)
- Process 2: $\text{Work}_{cycle} = mg(Z_i - Z_f)$
- Process 3: Heat transfer from reservoir $= U_f - U_i$

Net work in a cycle by exchanging heat with a single reservoir-Violation of K-P statement!

Figs:TD-Moran, Shapiro, Boettner, Bailey

Internally and externally reversible processes



(*a*) Totally reversible

(*b*) Internally reversible

Why & how to discuss irreversible processes?

- All real processes are irreversible!
- Quantifying Entropy changes in irreversible processes is challenging but possible (notion of local equilibrium is important)
- Note: Entropy is a state function
- Clausius, Pierre Duhem (1861-1916), L. Natanson & G. Jaumann made important contributions
- Overall, Restricted quantification in this course

De Donder (1872-1957)

Ilya Prigogine: Noble Prize-1977

What's next?

- Carnot cycle