Week 1: Lecture 3

Second Law of Thermodynamics

Fundamentals

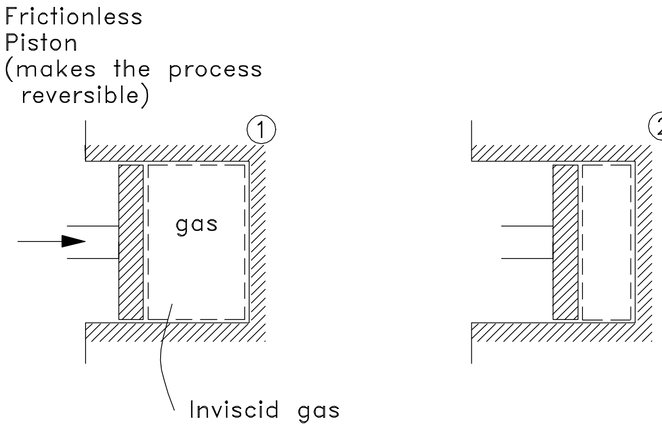
1. like mass and energy, every system has entropy. Entropy is a measure of the degree of microscopic disorder and represents our uncertainty about the microscopic state.
2. Unlike mass and energy, entropy can be produced but it can never be destroyed. That is, the entropy of a system plus its surroundings (i.e. and isolated system) can never decrease (2nd law).

$$(\Delta S)_{system} + (\Delta S)_{surr.} \geq 0$$

3. In a perfect crystal of a pure substance at $T = 0\ K$, the molecules are completely motionless and are stacked precisely in accordance with the crystal structure. Since entropy is a measure of microscopic disorder, then in this case $S = 0$. That is there is no uncertainty about the microscopic state.
4. For a given system, an increase in microscopic disorder results in a loss of ability to do useful work.
5. Energy transfer as heat takes place as work at the microscopic level but in a random, disorganized way. This type of energy transfer carries with it some chaos and thus results in entropy flow in or out of the system.

   Energy transfer by work is microscopically organized and therefore entropy-free.

Slow Adiabatic Compression of a Gas



A process $1 \rightarrow 2$ is said to be reversible if the reverse process $2 \rightarrow 1$ restores the system to its original state without leaving any change in either the system or its surroundings

$\rightarrow$ idealization where $S_2 = S_1 \Rightarrow \mathcal{P}_S = 0$

Analysis

$T_2 > T_1 \Rightarrow$ increased microscopic disorder

$V_2 < V_1 \Rightarrow$ reduced uncertainty about the whereabouts of molecules

The net effect is $S_2 = S_1$ and $\mathcal{P}_S = 0$. Therefore

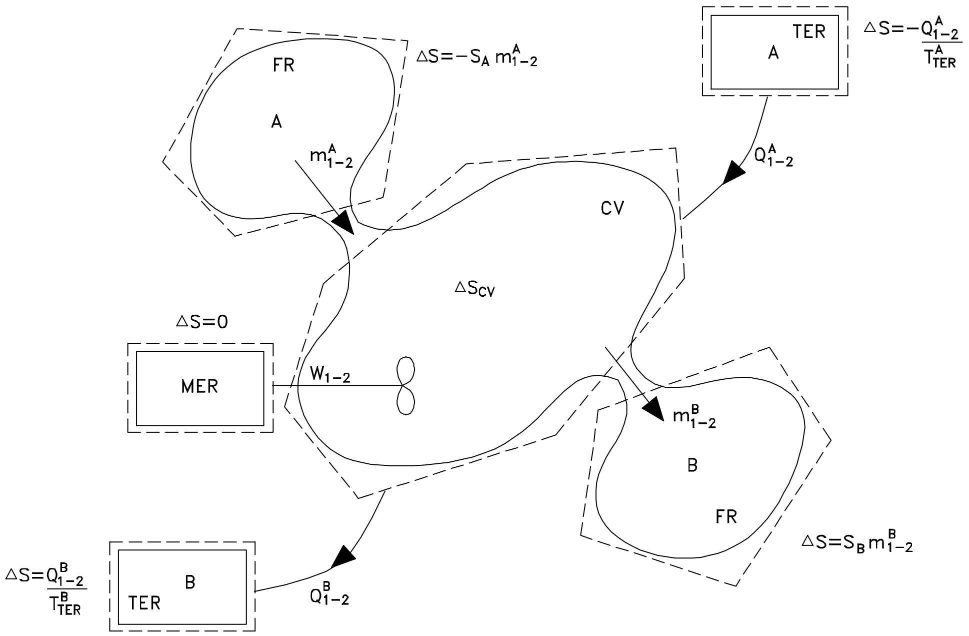
$$Reversible + Adiabatic\ Process \Rightarrow Isentropic\ Process$$

But does

$$Isentropic\ Process = Reversible + Adiabatic$$

NOT ALWAYS

Second Law Analysis for a Control Volume



$$\left(\frac{dS}{dt}\right)_{CV} = \left(s\dot{m} + \frac{\dot{Q}}{T}\right)_{in} - \left(s\dot{m} + \frac{\dot{Q}}{T}\right)_{out} + \dot{\mathcal{P}}_S$$

$$accumulation = in - out + generation$$