Week 1: Lecture 1

Review

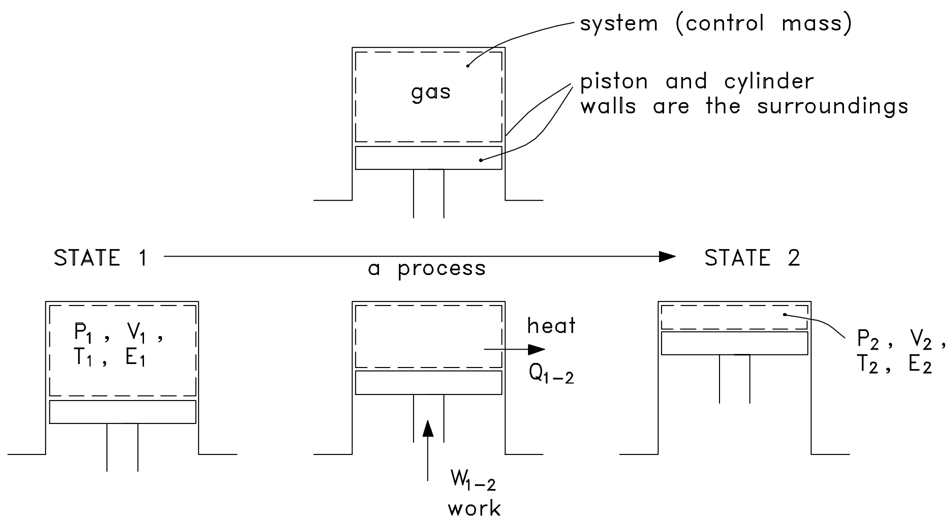
- any specified collection of matter under study is called a **system**
- all systems posses properties like mass, energy, entropy, volume, pressure, temperature, etc
- thermodynamics deals with these properties of matter as a system interacts with its surroundings through <u>work</u> and <u>heat transfer</u>
- work and heat transfer are not properties, they are the forms energy takes to cross the system boundary

First Law of Thermodynamics

Conservation of Energy: the energy content of an isolated system is constant

$$\textit{energy entering} \;-\; \textit{energy leaving} \;=\; \textit{change of energy within the system}$$

<u>Control Mass Analysis</u>



first law energy balance

$$\left\{\begin{array}{c}\text{Initial}\\ \text{Energy}\\ E_1\end{array}\right\} \begin{array}{c}+\\ \\ -\end{array} \left\{\begin{array}{c}\text{Energy gain } W_{1-2}\\ \\ \text{Energy loss } Q_{1-2}\end{array}\right\} = \left\{\begin{array}{c}\text{Final}\\ \text{Energy}\\ E_2\end{array}\right\}$$

$$\boxed{E_1 + W_{1-2} - Q_{1-2} = E_2}$$

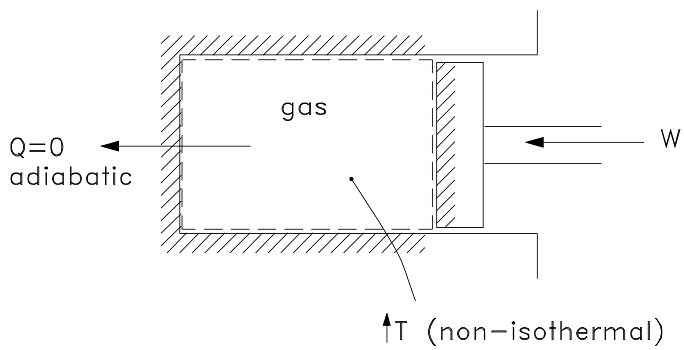
Week 1: Lecture 1

Some Interesting Points

- the internal energy of a system will depend to a large extent but not exclusively on temperature

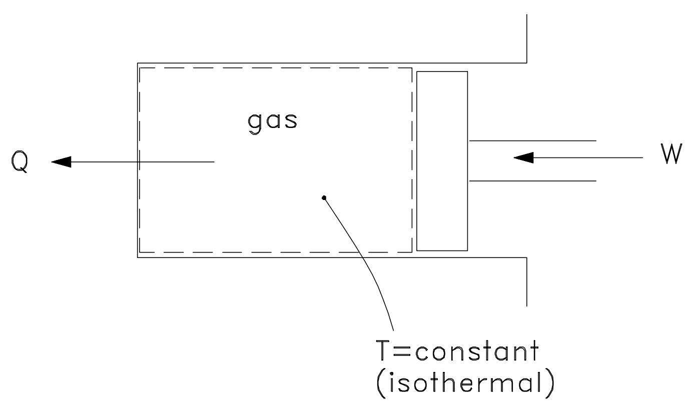
$$u = u(T) \;\; (only)$$

- a change in the system temperature does not necessarily imply that heat transfer is taking place



- no change in the system temperature does not necessarily imply "no energy transfer as heat" (isothermal compression of a gas)

  Isothermal Compression of a Gas

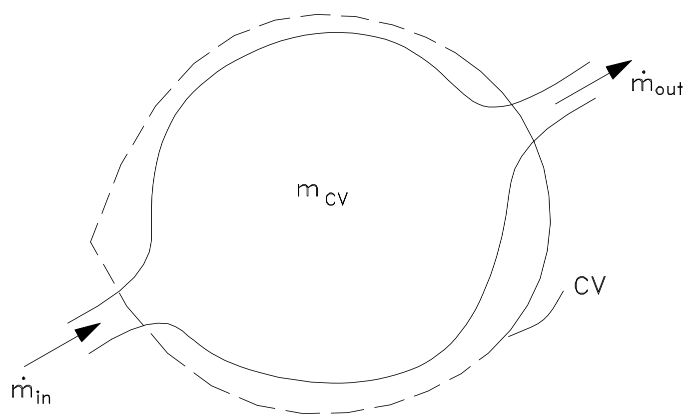


- Adiabatic does not always mean isothermal

Week 1: Lecture 2

Conservation of Mass

Control Volume Analysis



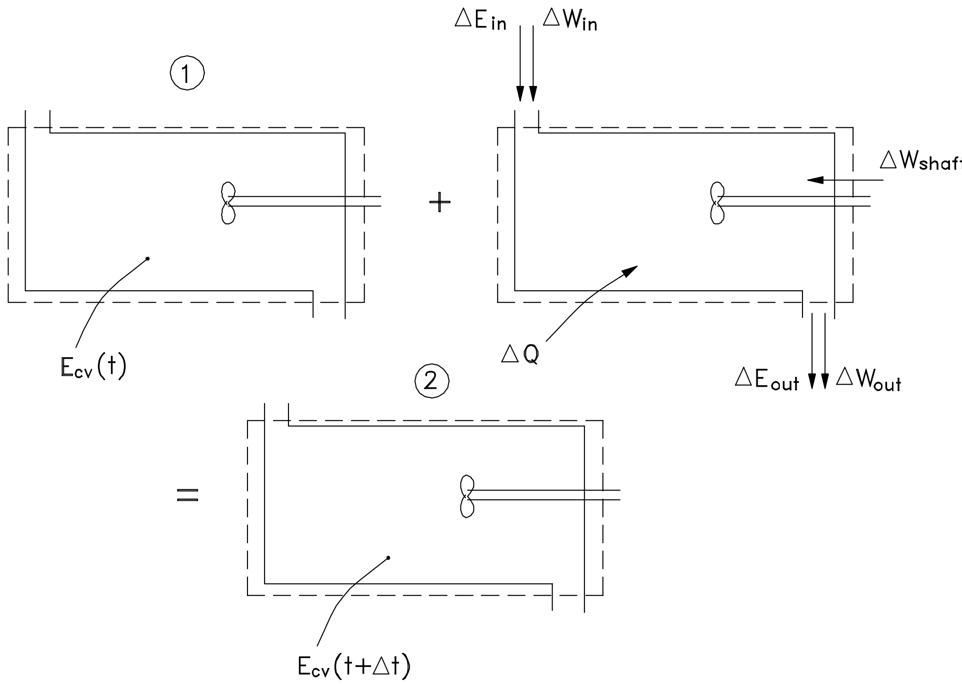
$$\left\{ \begin{array}{c} \text{Rate of Increase} \\ \text{of mass within} \\ \text{the CV} \end{array} \right\} = \left\{ \begin{array}{l} \text{Net rate of} \\ \text{mass flow} \\ \text{IN} \end{array} \right\} - \left\{ \begin{array}{c} \text{Net rate of} \\ \text{mass flow} \\ \text{OUT} \end{array} \right\}$$

$$\frac{d}{dt}(m_{CV}) = \dot{m}_{in} - \dot{m}_{out}$$

Week 1: Lecture 2

First Law of Thermodynamics

Control Volume Analysis



$$E_{CV}(t+\Delta t) - E_{CV}(t) = \Delta Q + \Delta W_{shaft} + \Delta m_{in}(e+Pv)_{in} - \Delta m_{out}(e+Pv)_{out}$$

The 1st law for a control volume can also be written as a rate equation by dividing the above equation by Δt and taking the limit as $\Delta t \to 0$

$$\frac{dE_{CV}}{dt} = \dot{Q} + \dot{W}_{shaft} + [\dot{m}(e+Pv)]_{in} - [\dot{m}(e+Pv)]_{out}$$

where $\dot{m} = \rho v^* A$

Note that

$$\begin{aligned} e + Pv &= \underbrace{u + Pv} + \frac{(v^*)^2}{2} + gz \\ &= h(enthalpy) + KE + PE \end{aligned}$$

Week 1: Lecture 3

Second Law of Thermodynamics

Fundamentals

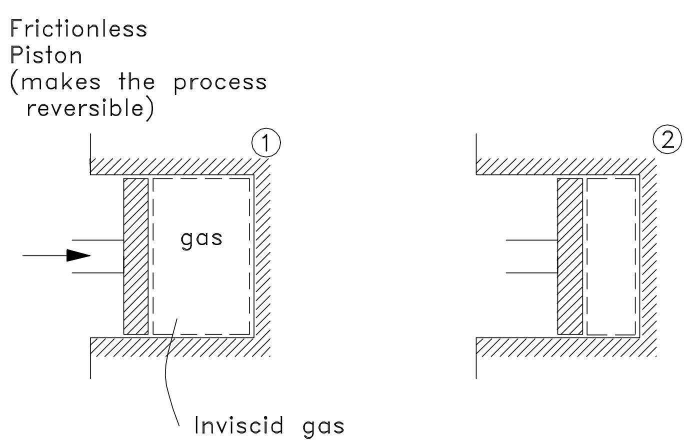
1. like mass and energy, every system has entropy. Entropy is a measure of the degree of microscopic disorder and represents our uncertainty about the microscopic state.
2. Unlike mass and energy, entropy can be produced but it can never be destroyed. That is, the entropy of a system plus its surroundings (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 $S_2 = S_1 \Rightarrow \mathcal{P}_S = 0$

Week 1: Lecture 3

<u>Analysis</u>

$T_2 > T_1 \Rightarrow$ 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

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

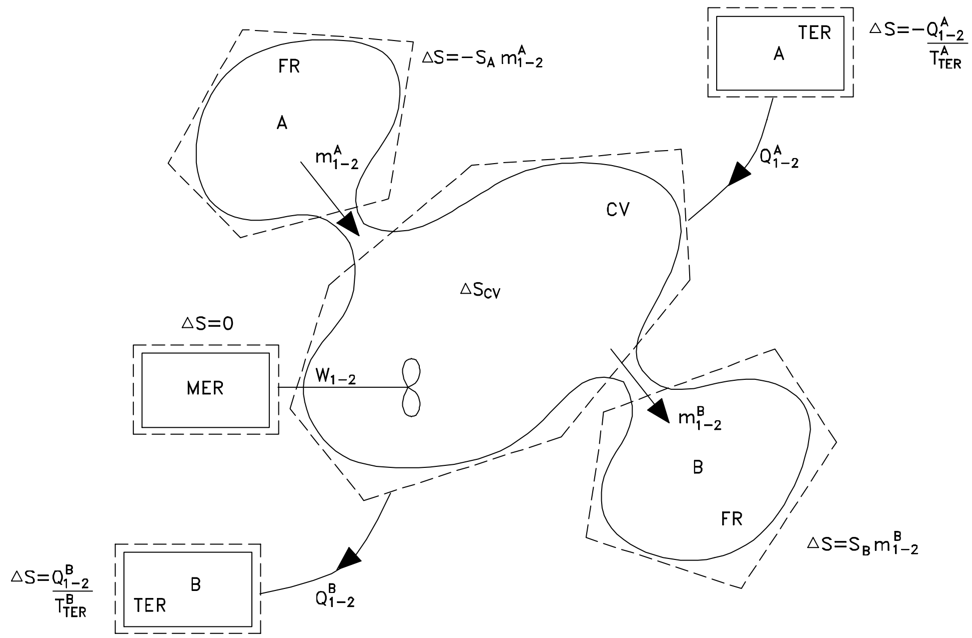
But does

$$Isentropic\ Process = Reversible + Adiabatic$$

NOT ALWAYS

Week 1: Lecture 3

Second Law Analysis for a Control Volume



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

$$accumulation = in - out + generation$$