Today

I. First take home exam due a week from this Friday

II. Our Stamina Breaks for the Semester: We will take Friday Oct 23rd off, Wed Nov 25th, and Fri Nov 27th.

III. Last Time

IV. The Thermodynamic Identity

V. Entropy and Heat Revisited

VI. A Major Application: Heat Engines

I. Gave a definition of pressure that was closely related to our definition of temperature:

$$\frac{1}{T} \equiv \left(\frac{\partial S}{\partial U}\right)_{V,N}, \qquad \frac{P}{T} \equiv \left(\frac{\partial S}{\partial V}\right)_{U,N}.$$

This allowed us to derive

$$PV = NkT.$$

I. We reviewed a road map:

1. Derive the multiplicity, and hence entropy, from combinatorial arguments about the system.
2. Then we can find the temperature via the derivative defintion.
3. Invert to find U as a function of $N, V,$ and $T,$ etc.
4. We can then predict the heat capacity:

$$C_V = \left(\frac{\partial U}{\partial T}\right)_{V,N}.$$

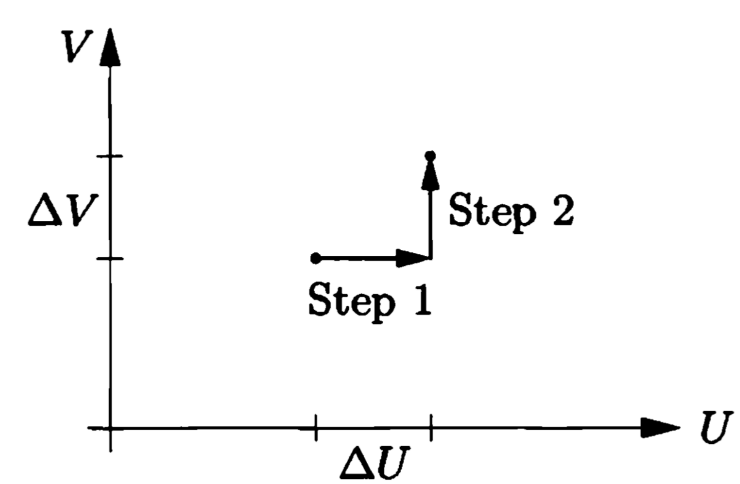
Discussed Clausius' definition of entropy:

$$dS = \frac{Q}{T} \quad \text{(for fixed volume this is } dS = \frac{C_V dT}{T}\text{).}$$

IV. The Thermodynamic Identity

Let's specify a two-step process:

$\Delta S = (\Delta S)_1 + (\Delta S)_2$



IV. The Thermodynamic Identity

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$\Delta S = (\Delta S)_1 + (\Delta S)_2,$

For our particular process we have

$$\Delta S(U,V) = \left(\frac{\Delta S}{\Delta U}\right)_V \Delta U + \left(\frac{\Delta S}{\Delta V}\right)_U \Delta V \quad \rightarrow dS = \left(\frac{\partial S}{\partial U}\right)_V dU + \left(\frac{\partial S}{\partial V}\right)_U dV$$

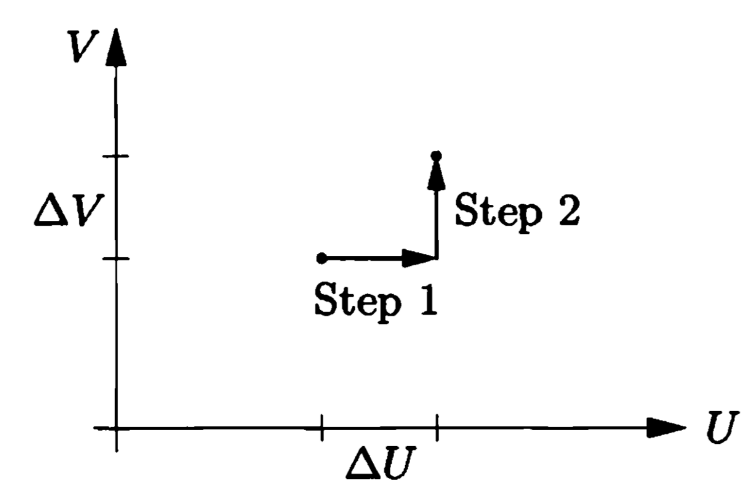
Then, the thermodynamic identity of thermodynamics states

$$dS = \frac{1}{T}dU + \frac{P}{T}dV \quad \text{or} \quad TdS = dU + PdV. \quad \text{(at fixed } N\text{)}$$

Let's turn this around and look at it another way

$dU = TdS - PdV$ (compares clearly with the 1st law).

This recovers the 1st law if the work done is quasistatic, i.e. $W = -PdV$, and then $Q = TdS$, Clausius' relation.



V. Heat and Entropy Revisited

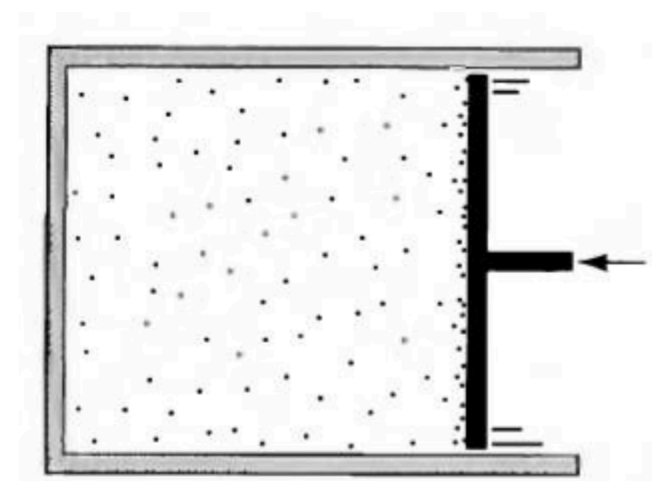
We've learned when Clausius applies then,

$$Q = TdS \text{ (quasistatic processes).}$$

What if we care about a constant pressure process?

$$(\Delta S)_P = \frac{Q}{T} = \int_{T_i}^{T_f} \frac{C_P dT}{T}.$$

What's a process where the work done is not quasi static? Rapid compression of an ideal gas:



$$dS > \frac{Q}{T} \quad \text{(when } W > -PdV\text{).}$$

A second example would be free expansion

$$TdS = PdV > 0. \quad (dU = 0).$$