Today

I. Last Time
II. Work and Heat
III. Temperature Anew

I. With a deeper understanding of entropy in hand we discussed several conceptual and practical subtleties in computing it:

1. Studied the entropy of an ideal gas (Sackur-Tetrrode)
2. Free expansion of an ideal gas: no work done, no heat is added or removed, hence no change in U.
3. Entropy of mixing: this helped us to see another piece of

evidence for the fact that elementary particles are truly identical. We've also seen that some states are vastly more probable than others, that is, they have huge multiplicities and hence the system evolves towards them, upon taking ln's this gives the 2nd law:

$$\Delta S \geq 0.$$

I. Some general observations about "choose problems":

Computing variances

$\sigma^2 \equiv \overline{x^2} - \bar{x}^2.$

We can also read the variance off of a gaussian

$$P(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2\sigma^2}x^2}.$$

$$\Omega(x) = \Omega_{\text{max}} e^{-N(2x/q)^2}$$

II. We can now carefully define two terms:
An irreversible process is one in which $\Delta S > 0$. This is irreversible because going back would decrease the entropy, which doesn't happen.

We call a process reversible if doesn't increase the entropy, that is, if $\Delta S = 0$.

Recall the definition of a quasi static, we proceed slowly enough that the system is in equilibrium throughout. Quasistatic processes where you don't add heat to the system are reversible. A good example is the quasistatic compression of a gas by a piston: here the work done is $W = -P\Delta V$.

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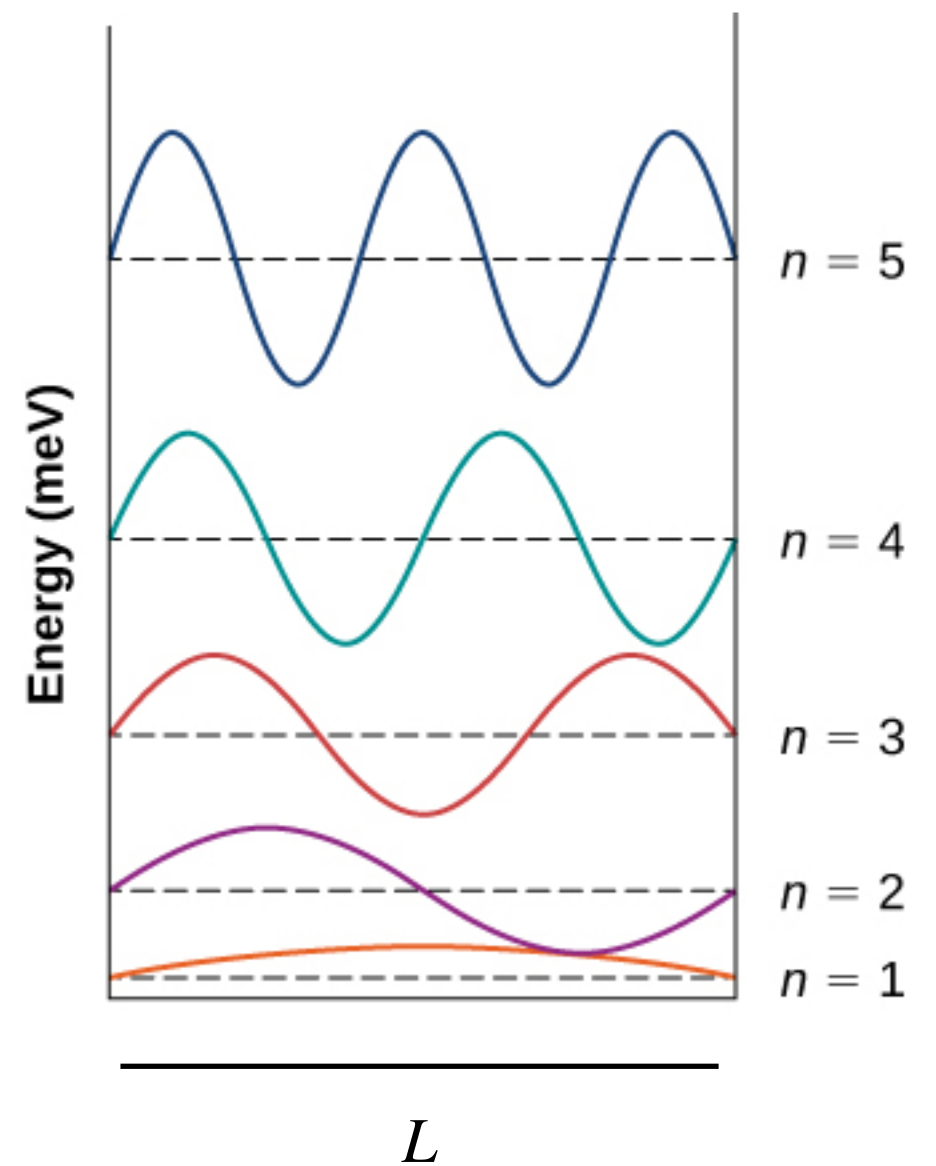
II. The latter can help us to see more about what we mean by work. What happens when I compress the box, that is, when I make L smaller?

If I compress the box slowly, I increase a particles energy, but only with the same scaling as $E_n \sim 1/L^2$. Contrast this with what happens if I compress the box quickly, which "kicks the particle" and changes which energy level it occupies.

$$E_n = \frac{n^2\pi^2\hbar^2}{2mL^2}$$



We call the first one, slow compression, work! Work changes the magnitude of the energy levels, but not their occupations!

By contrast, fast compression, changes their occupations, which is a change in multiplicity, hence entropy.

III. Temperature anew. Consider the recurring motif of putting two subsystems, call them A and B, together to form a larger total system.

Equilibrium of the total system is determined by $\dfrac{\partial S_{\text{total}}}{\partial q_A} = 0$, more generally $\dfrac{\partial S_{\text{total}}}{\partial U_A} = 0$. But, we know that $S_{\text{total}} = S_A + S_B$, so we have

$$\frac{\partial S_A}{\partial U_A} + \frac{\partial S_B}{\partial U_A} = 0.$$

Conservation of energy means that $\Delta U_A = -\Delta U_B$, so

$$\frac{\partial S_B}{\partial U_A} = -\frac{\partial S_B}{\partial U_B}.$$

Putting these results together we find that

$$\frac{\partial S_A}{\partial U_A} = \frac{\partial S_B}{\partial U_B} \implies \frac{1}{T_A} = \frac{1}{T_B}.$$