4th January 2024

Last class we derived -

$$U = KN \left(\frac{V}{N}\right)^{-2/3} \exp\left(\frac{2}{3}\frac{S}{NR}\right)$$

$$= f(N, V, S)$$

If $V \to \lambda V$; $S \to \lambda S$, $N \to \lambda N$,

then $\frac{V}{N} \to \frac{V}{N}$, $\frac{S}{N} \to \frac{S}{N}$, only $N \to \lambda N$.

(*) If we are given another $U = f(N, V, S)$ for another system, we should be able to tell if it is correct or not, and calculate T, P, μ.

○ Thermodynamics → Physics that cares about Macroscopic variables

To know a system completely - we need to know all $\sim 10^{29}$ is/s molecules, initial states, etc.

⇒ Thermodynamics resolves this into a few effective variables, not 10^{23} something variables.

Just like GTR reduces to NLM / N's theory of gravitation

But this works / is useful for when we have the timescale of measurement is much larger than atomic timescale.

timescale >> atomic timescale.

Also,

length scale >> Intermolecular distance.

So based on timescale and length scale, we worry about the effective DOF, not the fundamental DOF

Finding these effective DOF is essential to good application.

Equilibrium → The system does not change parameters in scales used.

What are good choices to guide the selection of DoF of a system at equilibrium?

→ Constant quantities in an 'Equilibrium' states.

⇒ Conserved quantities ⇒ Due to some <u>symmetries</u> of the system.

⊛ → Other quantities may also emerge, which are good descriptors of the system.

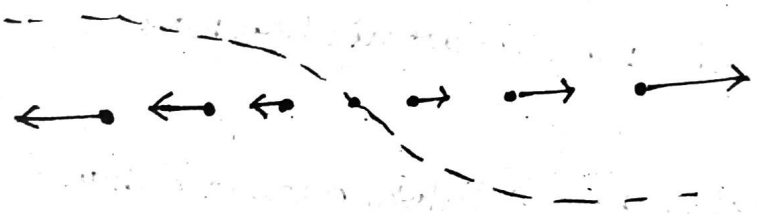
○ Emergence of macroscopic variables:

Let us consider a system of nine atoms.

wave has the amplitude proportional to the distance these atoms move

Or something like,

Or,



9* particles in a system ⊛ <u>coupled</u> to each other with spring-like connections — any arbitrary motion of these can be expressed as a combination of these 3 waves → <u>normal modes</u>

(*) But this depends on the resolution (scales) that we use to measure this system.
If it is large, we may resolve only the third one.
⇒ Your observation scale determines the mode that you observe.
⇒ System will be effectively described by that mode.
⇒ That is the only DOF that is effective
This is akin to the 'Emergence' of Thermodynamic variables.