THERMODYNAMICS & STATISTICAL MECHANICS

It's all about TIME SCALES.....

Lots of different Timescales....

Slow Stream

Fast Stream

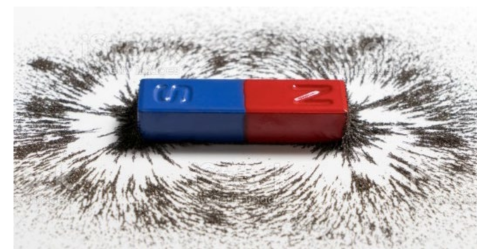
Galaxies

Fire

Star

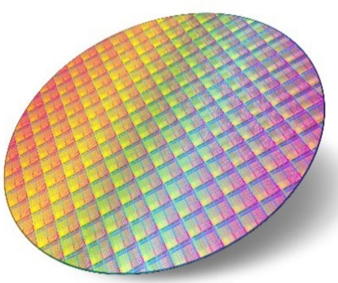
Piece of Wood

Piece of Glass

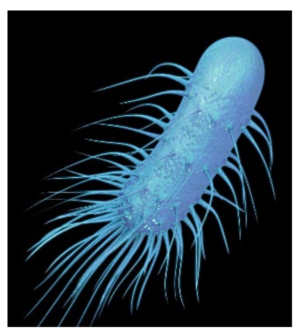


Bar Magnet

Litre of Air



Si wafer



Bacterium

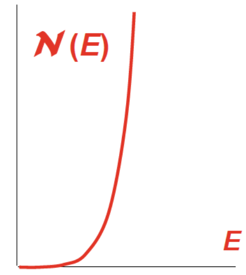
Block of Ice in Water

STATISTICAL MECHANICS – a SUMMARY

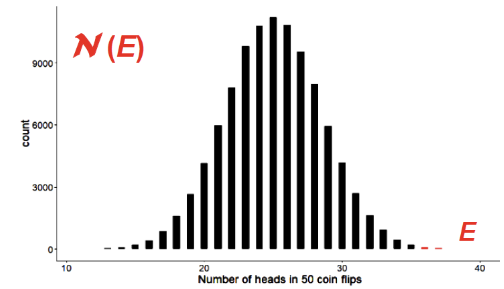
A. MICROSCOPIC APPROACH: Based on counting states, & assigning them probabilities

The number of discrete microstates is counted using simple rules.

We can classify the states by their different energies, and define a "density of states", which tells how many states there are with a given energy – and energy is a macroscopic extensive variable



Unbound spectrum

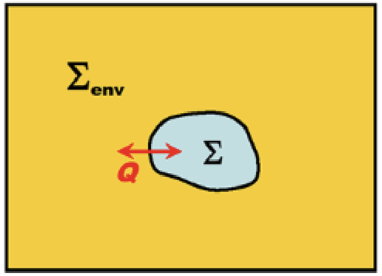


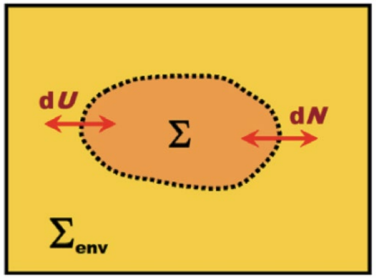
Bound spectrum

N-particle densities of states

The system can be isolated (microcanonical ensemble) or connected to a "heat bath". In the latter case various things can be allowed to pass between system and bath.

The probability that a microstate occurs depends on how it is coupled to the bath.





Key Point: there are different statistics, for distinguishable particles, and for indistinguishable particles; the latter can be fermions or bosons

A. MACROSCOPIC APPROACH: One calculates the macroscopic properties directly from the probabilities, using a "partition function"

In this way one unites microscopic properties with macroscopic thermodynamic properties. One can also calculate fluctuations around the thermodynamic results

THERMODYNAMICS – a SUMMARY

A. EMPIRICAL APPROACH: Based on empirical observation

1. **Assume the system is near "Thermodynamic Equilibrium" (we will define this later)**
2. **Identify the "Thermodynamic Variables" and "state functions"**

Intensive quantities: these are variables such as temperature T, pressure p and density ρ. They are, by definition, independent of the system size.

Extensive quantities: these are variables such as mass M, internal energy U, volume V, magnetization M, and entropy S. They scale with the system size.

State Functions: these are functions of the thermodynamic variables which define the thermodynamic state of the system (eg energy U, free energy F, etc.).

B. DEDUCTIVE APPROACH: Based on a kind of axiomatic framework

0^{th} Law of thermodynamics: If 2 systems are each in thermal equilibrium with a 3rd system, they are in thermal equilibrium with each other – and have the same temperature (definition).

1^{st} Law of thermodynamics: When energy passes between systems, then the total energy is conserved.

2^{nd} Law of Thermodynamics: The sum of the entropies of interacting thermodynamic systems increases in time.

3^{rd} Law of thermodynamics: The entropy of a system approaches a constant value as the temperature T approaches absolute zero.