Course 0. Introduction

0A. What is statistical physics ?

statistics ⊕ physics laws ⊕ systems with many (huge) degrees of freedom (eg. many particles)

0B. Why do we need it ?

Let's classify our world by using length scale :

(ex) solid (eg. normal metal . cf. superconductivity)
cf. high energy physics (elementary particles and their interactions)

macroscopic ($\gtrsim \mu m$)	mesoscopic ($nm \lesssim L \lesssim \mu m$)	microscopic ($\lesssim nm$)
classical (no coherence) (no quantum interference)	from semiclassical to quantum (quantum mechanics) phase coherent	quantum
huge # of particles $\gtrsim 10^{24}$	intermediate	not so many

$\longleftrightarrow$
statistical treatment is required.

$\boxed{\text{Why ?}}$

① We know mechanics (classical, quantum) for single particle ⊕ field and two-particle interaction.

(a) But we have too many particles. - We can not solve all.
Then it could be better to choose something which characterize the total system and study it.

(b) Many-body systems often show unexpected phenomena $\left\{ \begin{array}{l} \text{phase transition} \\ \text{new states (QHE, superconducting, superfluid)} \end{array} \right.$

~~many-body~~

② Single particle in complex media (disordered system. ~~?~~ chaos)

In this case, single quantum-particle problem is nontrivial.

③ Indistinguishable identical quantum particles

boson / fermion / fractional statistics (anyon)

※ emphasize scales. (length / momentum. energy / time)

Thus, statistical mechanics is very very important and basic in current research.

0C. How to deal? ← in terms of probability - ensemble average

① define new concepts that can illuminate the essential characteristics of complex many-body systems.

(eg) entropy, temperature, equilibrium, free energy, ...

② find the physical rules between the new concepts by using basic physical laws and minimal postulates.

a. a classical system in equilibrium : thermodynamics

minimal # of postulates (equal a priori probability, thermodynamic laws)

$\downarrow$ ←...... without any detailed knowledge of microscopic properties

~~gen~~ general statements for the relations between macroscopic parameters of systems

b. a quantum system in equilibrium : statistical mechanics

microscopic properties

↓

large # of general relations, which cover the results of thermodynamics.

c. systems in nonequilibrium.

"irreversible processes" — study how equilibrium is approached.

how ~~fast~~ rapidly

master eq.

- understood only for limiting cases.

- not very known. current research topics with open problems.

d. Kinetic theory : study the interactions of all the particles in the system in detail and calculate macroscopic parameters.

equilibrium / nonequilibrium both the cases.

※ history of development of statistical mechanics.

※ Other things which will be met in graduate course.

density matrix formulation

phase transition described by critical phenomena

Landau approach

RG, scaling

superconductivity / superfluidity

Quantum field Theory