Introduction

P715

Solid State Physics (a.K.a. Condensed Matter)

Goal of CMP: Understand macroscopic and microscopic properties of $N \gg 1$ interacting degrees of freedom (e^-, ions, spins ...)

Originally, focus on solid state: electric and thermal conduction, thermodynamic properties, magnetism etc). Now a lot broader: Cold Atoms, soft matter etc ...

What do we need?

- Stat Mech + Quantum Mechanics: $N \gg 1$ and low T

We don't care about:

- Gravity (obviously), Weak and Strong forces and structure of the nucleus.
- We mostly don't care about special relativity with some very important exceptions (spin-orbit coupling).

Theory of everything: Non relativistic QM + electrodynamics

$$i\hbar \frac{\partial |\psi\rangle}{\partial t} = \hat{H} |\psi\rangle$$

$$\hat{H} = \sum_{j=1}^{N_e} \frac{\vec{p}_j^{\,2}}{2m} + \sum_{\alpha=1}^{N_i} \frac{\vec{P}_\alpha^{\,2}}{2M_\alpha} - \underbrace{\sum_{(j,\alpha)} \frac{Z_\alpha e^2}{|\vec{r}_j - \vec{R}_\alpha|}}_{e^- \text{ - ion}} + \underbrace{\sum_{(j,k)} \frac{e^2}{|\vec{r}_j - \vec{r}_k|}}_{e^- \text{ - } e^-} + \sum_{(\alpha,\beta)} \frac{Z_\alpha Z_\beta e^2}{|\vec{R}_\alpha - \vec{R}_\beta|}$$

(with N_e being either number of free electrons, with some e^- bound to nuclei at $\vec{R}_\alpha$, or total number).

→ Impossible to solve! ($N_e, N_i \sim 10^{24}$)

- Need Stat mech + physically motivated approximations,

Emergence:

UV "messy" ⟶ IR Effective theories

Large overlap with particle physics (QFT: not this course!)

Outline:

- Early days
- Crystal Structure and Band theory
- Phonons
- Electron dynamics
- Advanced topics: IQHE, TIs, second quantization, magnetism