Overview: The Big Picture & Our Course

Why we need to study QM

What we want to do/convey

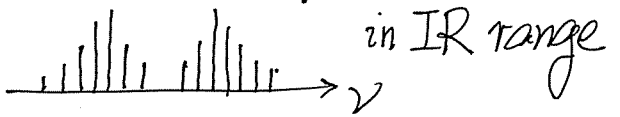
Quantum Mechanics

QMI
- Basics
- Essential Formalism
- Standard 1D, 2D, 3D problems

Applied QM
- Approximation Methods
- Matter - Light interaction

Atoms
- Existence of atoms, atomic spectrum, detailed structures due to spin (spin-orbit interaction) and magnetic (Zeeman) field, many-electron atoms & periodic table

Molecules
- Why are there molecules? Quantum theory of Bonding
- σ-bond, π-bond, π-electron physics
- Molecular spectrum



- Why?
- CO_2, H_2O are green house gases, O_2, N_2 are not. Why?

Nuclei
- Structure of nuclei, nuclear force, magic numbers for stable nuclei
- Decays and nuclear reactions
- Nuclear astrophysics ...

Quantum Mechanics

Solids

- Why are there solids?
- Electronic, optical, dielectric, magnetic properties (all are quantum in nature)
- Semiconductor physics & devices

Modern Solid State Physics

- Electron-electron interaction (strongly correlated systems)
- Superconductivity & Superfluidity
- Quantum Hall effect & extensions
- Topological insulators & extensions
- Many-body approaches (inter-connected with quantum field theory)

Materials Science

- Interplay among structure, fabrication, properties, functionalities
- Nanomaterials
- Computational Materials Science
- Energy materials

...

Quantum Mechanics

→ Advanced Formalisms

- Relativistic QM
- Quantum Field Theories
  - What is matter? What are photons?
  - How particles interact? (QED, QCD, electroweak)
  - particle physics

→ Future Technologies in the Making

- Quantum information, computing, sensing, teleportation...
- Quantum simulators by ultracold atoms/molecules

⋮

Your generation will make the list longer!

The points are...

- QM has passed all the tests so far (~100 years)
- QM has explained and predicted new phenomena, and opened up new fields
  (many engineering disciplines stemmed from QM)
- one can't do physics without knowing QM
- QM is best learnt by
  - knowing its basic theoretical structure [QMI]
  - manipulating QM calculations for simple/physical systems [QMI]
  - seeing how QM permeates into atomic, molecular, nuclear, solid state, and particle physics [QMI, Applied QM, ...]
  - appreciating how QM was established through the interplay between outstanding <u>experimentalists</u> and <u>theorists</u> [QMI, Applied QM]

<u>experimentalists</u>: physics is an experimental science!

<u>theorists</u>: turning observations into mathematical statements is what made physics physics!

Learning QM is a high point of physics students. Have fun!

QMI

- Focus on what QM

$$i\hbar\frac{\partial\Psi(x,t)}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi(x,t) + U(x,t)\Psi(x,t) \quad \text{[Time-dependent Schrödinger Eq. (1D)]}$$

and $$-\frac{\hbar^2}{2m}\frac{d^2}{dx^2}\psi(x) + U(x)\psi(x) = E\psi(x) \quad \text{[Time-independent Schrödinger Eq. (1D)]}$$

<u>can do</u> and <u>cannot do</u>

- Standard 1D, 2D, 3D problems
- Time evolution of quantum states
- Electron spin & QM angular momentum

- Develop your <u>quantum intuition</u> or <u>quantum sense</u>
- Enhance/Apply your analytical skill in handling QM problems

A word of warning-

- Don't let mathematics hinder your QM learning!
  - Seek help immediately (come to me or TAs)
  - Ask questions
  - Read pages of "friendly" mathematical method books [reserved in UL]

QM is easier than you think (at least at the manipulation level)!