Ch.0 : An Overview

- Learned basic QM concepts and skills in PHYS3021 (QMI)
- In PHYS3022 (Applied Quantum Mechanics), we apply the QM concepts in PHYS3021 and develop some approximation methods, so as to understand (and appreciate) a wide range of topics and important branches in physics.
- Modular form :
  - Approximation Methods
  - Atoms
  - Molecules
  - Others [nuclei OR/and solid states]

Quantum Mechanics [Based on PHYS3021, plus...]

- Approximation Methods
  - perturbation theories
  - Variation Method
  - Ideas behind Hartree Approximation (Independent particle Approx.) & Born-Oppenheimer approximation
  - LCAO (chemical bonds)
  - Ideas of finding ways out (Think like a physicist!)

Atomic Physics

- Details on Hydrogen
  - spin-orbit coupling
  - relativistic correction
  - fine & hyperfine structure
  - magnetic field (Zeeman) effect
- Other atoms (Periodic Table)
- Absorption/Emission
  - selection rules
  - stimulated emission (laser)

Molecular Physics

- Molecular QM problem
- Turning it into simpler QM problems
- Bonding, electronic states, molecular orbitals (MO)
- Vibrational and rotational states, molecular spectrum
- Greenhouse gases, Fats, DHA
- π-electrons in Benzene and other structures

Nuclear Physics[+]

- Structure, How big is a proton?
- Standard model of particles
- Stable nuclei, liquid-drop & shell models
- decays (tunneling, neutrinos)
- reactions (solar energy)
- Anti-particles

[+] OR Solid State Physics

Special Situation in Term 2 (2019-2020)

Due to abrupt termination of Term 1 (2019-2020), we will put back some Quantum Mechanics ideas into PHYS 3022

- Key quantum results & picture of Hydrogen atom[†]
- Properties and Applications of Hermitian Operators in QM[*]
- Spin angular momentum (of electron)[‡]

[†] Needed in understanding fine structure in H-atom, other atoms, and molecules

[*] Needed in developing approximation methods (perturbation theories)

[‡] Needed in understanding fine structure in atoms (spin-orbit interaction) & Zeeman effect, and modern technologies, multi-electron atoms (periodic table)

- Each module will be short [≈ 3 weeks]
- Make good use of QMI concepts and develop "quantum sense"
- Emphasize big picture and balance between QM & Quantum Physics
  - Although "brief", discussions will be deeper than those in "Quantum / Modern Physics" books (as we will do more QM) and yet more physical than in most "Quantum Mechanics" books (as we emphasize how QM explains physical phenomena).
- Students interested in a particular topic can learn more by reading recommended books in Book List (posted separately).

- Beyond subject matter, I will try to convey ...
  - Basic QM can do a lot of things
  - The art of "Thinking like a physicist"
  - The "Physical Picture" of physical phenomena and theories
  - The "painting" of a physical picture by equations
  - a sense on <u>what is happening</u> in the <u>frontiers of</u> physics
  - an appreciation of the effectiveness of QM and the revolution that it brought to our understanding in how Nature works
  - QM is much more than mathematical manipulations
  - a path to guide you to the next level via list of further reading

"Physical Sense" and "Math Manipulations" go hand in hand!

- Many QM problems can be formulated but <u>can't</u> be solved <u>exactly</u>.
- But many of them can be handled <u>approximately</u>
  e.g. basic QM [single-particle QM problems + Spin (Pauli Principle)]
  is the key to understand atoms, molecules, nuclei, solids
- How to do well?

- Be open minded in learning
  - Be brave in making approximations
    [the answer will tell us the validity]
  - Willing to take a physical picture and move on
- Be open minded in handling equations and Math
  - Math is needed to turn physical picture into formula
    - More important to understand the meaning and implications of a formula and how to use it (than to derive it)
  - Need to do derivatives, integrals, and matrix manipulations
    [even 2×2 matrices give much physics]

- Practice
  - Read examples (Sample Questions each week)
  - Read Questions in Problem Sets carefully and make a good attempt to solve them
- Clean up questions
  - Go to TAs or come to me to clean up questions every week
- Jump-in Reading
  - Train yourself to start reading a section in a book and learn, instead of start reading from the beginning

Background Assumed

- Concepts covered in PHYS 3021 Quantum Mechanics I
- TDSE, TISE, what can they do?
- Operators, Hermitian operators† and their properties†, measurements, expectation value and uncertainty, angular momentum in QM†
- Results of standard problems: 1D, 2D, 3D bound state problems, existence of bound states†, Boxes† and Finite Well†, Harmonic Oscillator†, rigid rotator†, Hydrogen atom†, U(r) problems, orbital angular momentum†, degeneracy†, spin† (Pauli matrices and their eigenfunctions)

† Concepts that are important for PHYS 3022

- Quick Review: Go to self-reading section
- Full Review: See PHYS 3021 QM I class notes