

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]

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)



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!)



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

- Each module will be short [≈ 3 weeks]
- Make good use of QM1 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 what is happening in the frontiers of 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 can't be solved exactly.
- But many of them can be handled approximately
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

To get ready, review for yourself the solutions of the following problems

- Particle-in-a-box (1D, 2D, 3D) [separation of variables]
when will it work?
- Harmonic Oscillator
- General $U(\vec{r}) = U(r)$ problems (what can be said about the solutions to general spherically symmetric problems)
- Hydrogen Atom $\left[-\frac{\hbar^2}{2m} \nabla^2 - \frac{e^2}{4\pi\epsilon_0 r} \right] \psi = E\psi$
 $\psi_{nlm}(r, \theta, \phi)$, E_n ?