PC3130 Quantum Mechanics II NUS

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Course Summary:

This module continues from PC2130 and completes the basic foundation in quantum mechanics. For the first part, we begin with a review of the foundations of single-particle quantum mechanics, and then develop a description of composite systems involving tensor products. This is followed by a discussion of angular momentum and the addition of angular momenta, as well as a description of systems of N identical particles. The second part will focus on approximation methods, in particular the variational principle, perturbation theory: time independent, both non-degenerate and degenerate, as well as time-dependent perturbation theory and its applications to describing light-matter interactions.

Prerequisites:

Students should be aware that linear algebra and to some extent, calculus, are prerequisites for this course. The mathematical background will be assumed in lectures.

Textbooks:

Several recommended and reference texts are provided below. Griffiths is a pedagogical text and students are encouraged to read the relevant parts of the book that are covered in lectures. Lectures will primarily be done by writing on the screen with discussions and quizzes, rather than with lecture slides. Marks are awarded to class participation and attendance.

Do note that students will find that several parts of the lecture are not covered in Griffiths, or covered slightly differently. Scanned pages from other texts will be provided (with permission) under "Course Readings" in Canvas and these are strongly recommended. Other parts are simply covered in the lectures, such as the application of the variational principle in computational physics and some basic intuition on many-electron interactions. The treatment of degenerate perturbation theory will follow more closely that in Liboff and Merzbacher.

<u>Recommended textbooks:</u>

Introduction to Quantum Mechanics by Griffiths (e-copy available)

Introductory Quantum Mechanics by Liboff (one in RBR, two on main shelves)

<u>Reference textbooks (e.g. for extra reading, projects):</u>

Quantum Mechanics, by Cohen-Tannoudji, Diu and Laloe

Quantum Mechanics by Eugen Merzbacher

Modern Quantum Mechanics by Sakurai

Quantum Mechanics: A Modern Development by Ballentine

Topics covered:

Foundations of QM (recap)

- Postulates of QM
- Matrix representations in QM
- Measurements
- Commutator relations and their implications
- Complete set of commuting observables
- Good quantum numbers
- Schrodinger's equation
- Hydrogen atom as an example

Orbital angular momentum

Multi-electron atoms

Symmetries in QM

- Inversion symmetry
- Translational symmetry; momentum as generator of translations
- Rotational symmetry; angular momentum as generator of rotations

General definition of angular momentum

- Generator of rotations
- Commutator relations

Ladder operators

- Harmonic Oscillator (recap)
- Angular momentum

Key properties of angular momentum derived from ladder operators

Matrix representations of angular momentum

Orbital versus spin angular momentum

Historical background of spin angular momentum

Magnetic moments

Spin-orbit coupling

Tensor products

Addition of angular momentum

Coupled and uncoupled representations

Clebsch-Gordan coefficients

Identical and indistinguishable particles in QM, and implications in many-body physics

Introduction to approximation methods

Born-Oppenheimer approximation

Central Potential approximation for multi-electron atoms

Variational principle

- Use of a trial wavefunction
- Numerical applications without a given trial wavefunction
- Euler-Lagrange methods (not tested)

Time-independent perturbation theory and its applications

- Non-degenerate perturbation theory
- Degenerate perturbation theory
    - Emphasis will be placed on finding a “good basis” for degenerate perturbation theory
    - Zeeman effect
    - Fine structure

Time-dependent perturbation theory and its applications

- Quantum dynamics
- Heisenberg, Schrodinger and Interaction pictures
- First order perturbation theory and transition amplitudes and probabilities
- Harmonic perturbations
- Rotating wave approximation
- Excitation and stimulated de-excitation
- Fermi’s golden rule

Selection rules

Adiabatic approximation

(Time-permitting) Dressed state approximation and Rabi oscillations