SPH 603: QUANTUM MECHANICS I

By

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GENERAL INTRODUCTION

Studying physics can be likened to Carpentry where using the right type of tool makes the job less tedious. The invention of quantum mechanics during the first 27 years of the twentieth century marked a revolutionary change in our understanding of phenomena on microscopic scales. Classical physics ideas held before then had instant limitations in their validity, as quantum mechanics became an alternative theory more richer both in scope and application. Although crucial to the understanding of quantum mechanics, we will not discuss the inadequacies of classical physics but will immerse ourselves directly into "a quantum-mechanical approach to thinking".

At a glance, quantum mechanics (QM) is a mathematical tool for predicting the behavior of the microscopic world and hence help us in understanding how this affects the macroscopic world around us. However, QM cannot be understood without developing appropriate requisite mathematical tools. Doing so would be similar to telling you to drill a well using a chisel. But QM is generally a difficult theory and solutions to standard textbook problems are relatively few and mostly approximations. I therefore suggest as a rule of thumb that its prudent to give you a shovel and instruct you to start digging yourselves. It may make your hands develop blisters at first, but its the only excellent and efficient way to learn QM. Indeed "one cannot discuss what QM *means* without developing a firm sense of what it *does*".

This course will provide you with an overview of the basic theory needed to *do* modern QM as well as introduce you to basic applications of QM and the commonly used approximation methods. It is assumed that you are familiar with rudimentary basics on: Linear Algebra, Complex numbers, Partial Differential equations, Fourier Analysis, Dirac Delta notation, elementary Classical Mechanics as well as some Electrodynamics concepts.

NOTE: The more knowledge of Mathematics and Physics you have, the much easier it will be to do QM and the more you will gain from the course. Reviewing of basic concepts in QM from the recommended texts is highly encouraged.

COURSE AIM

The aim of this course is to enable the learner develop special techniques for attacking more advanced realistic problems in QM that apply to microscopic phenomena and associated research. Familiarity with basic concepts covered in an undergraduate level QM course- from historical developments such as the Planck's radiation law, Einstein's Debye theory, the Bohr atom, de Broglie matter waves, the Compton effect, Frank-Hertz experiment, Davisson-Germer-Thompson experiment- to modern concepts such as the wave functions and its physical interpretation, the uncertainty principle, Hilbert Space, Dirac Notation etc will be assumed. For the learners who would wish to thesis research in theoretical Physics, a more advanced course in QM that will consider more challenging topics, will be offered in the second semester, and this course will form a useful pre-requisite. For a good review of undergraduate QM read chapters 1-3 in the text: *Introduction to Quantum Mechanics by D. J. Griffiths (2004).*

LEARNING OUTCOMES

At the end of this course, you should be able to:

1. Describe preliminary concepts of quantum mechanics
2. Explain the mathematical language of quantum mechanics
3. Describe the Schroedinger equation in 1-dimension and apply it to solve simple physical problems
4. Describe the various formulations of quantum mechanics
5. Discuss the concept of angular momentum and Spin in quantum mechanics
6. Describe symmetries in quantum mechanics
7. Explain the various approximation methods used in quantum mechanics and their applications
8. Describe in detail the theory of relativistic quantum mechanics and discuss its applications

COURSE CONTENT

1. Preliminary concepts in quantum mechanics

1.1 Introduction

1.2 Learning outcomes

1.3 The Stern-Gerlach experiment

1.4 Wave particle duality and Wave packets

1.5 Kets, Bras and Operators

1.6 Fourier Transforms

1.7 Matrix representation and Base Kets

1.8 Measurement, Observables and uncertainty relations

1.9 Position, Momentum and Translation

1.10 Summary

1.11 Activity

1.12 Further Reading

2. The mathematical language of quantum mechanics

2.1 Introduction

2.2 Learning outcomes

2.3 Vector Spaces

2.4 Probability Interpretation

2.5 Linear Operators

2.6 Summary

2.7 Activity

2.8 Further Reading

3. Quantum Dynamics

3.1 Introduction

3.2 Learning outcomes

3.3 Time evolution and Schroedinger equation in 1-dimension

3.4 Formulations of quantum mechanics

3.5 The Simple Harmonic Oscillator

3.6 Schroedinger equation in 3-dimensions

3.7 Propagators and Feynman Path Integrals

3.8 Potential and Gauge Transformation

3.9 Summary

7. Relativistic quantum mechanics