PSU - DEPARTMENT OF PHYSICS
PH 618 : QUANTUM MECHANICS (II)
WINTER 2011

(I) *GENERAL INFORMATION* :

Instructor : Peter Leung

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Office hours : Tue., Thur. : 12:15 p.m. - 1:15 p.m.

Course grade : Homework (3 problem sets in total) : 60%
Final (take home) : 40% (Due: **March 15, 2011, noon**)

Nature of the course : This will be sequential to the previous PH 617.
We shall start by finishing the topics left over from PH 617 which deal mainly with approximation methods for solving stationary problems.

Structure of the whole sequence PH 617, 618, 619 :

: PH 617 will study both (i) the general formulation and (ii) applications of QM mostly limited to ***time-independent*** problems in the wave-mechanical approach, including both exactly solvable ones and various approximation schemes.

: PH618 will deal with mainly ***scattering theory*** and ***time-dependent*** problems.
While students in PH 617 will have studied mostly the bound states of the TISE, it is the continuum (unbound) states that will be studied in this course with an application to quantum scattering problems. Following this the full TDSE will be explored.

: PH 619 will contain a variety of ***special topics*** in QM which may include the following list: ***different pictures of time evolution of QM systems; theory of angular momentum***; ***more on the general formulation of QM***; ***the geometric (Berry) phase***; ***introduction to path-integral formalism; relativistic QM; conceptual issues dealing with the foundation of QM (EPR paradox, Bell's inequality); and quantum comupters.***

Texts and References : .
***General Quantum Mechanics Texts** :*

P. M. Mathews and V. Venkatesan (MV) : " *A Textbook of Quantum Mechanics* ", (Tata McGraw-Hill, 1976)
S. Gasiorowicz (SG): " *Quantum Physics* ", (Wiley, 2003)
D. Griffiths (DG): " *Introduction to Quantum Mechanics* ", (Prentice-Hall, 2005)
P. J. E. Peebles: "*Quantum Mechanis* ", (Princeton, 1992)
E. Merzbacher : " *Quantum Mechanics* ", 3rd Ed., (Wiley, 1998)
R. P. Feynman et al : " *The Feynman Lectures on Physics v. 3 : Quantum Mechanics* ", (Addison-Wesley, 1965) - especially for the time-dependent two-state problem (Secs. 8.4 - 9.6)

***Some Classic References for Quantum Scattering Theory** (may be too advanced for beginning students)* :
R. G. Newton : " Scattering Theory of Waves and Particles " 2nd ed. (McGraw Hill, New York, 1982)
J. R. Taylor : " Scattering Theory " (John Wiley & Sons, New York, 1972)
T. Y. Wu and T. Ohmura : " Quantum Theory of Scattering " (Prentice-Hall, New Jersey, 1962)
M. L. Goldberger and K. M. Watson : " Collision Theory " (John Wiley & Sons, New York, 1964)

Our Text : N. Zettili (Z): " *Quantum Mechanics: Concepts and Applications* " (2nd ed., Wiley , 2009) --- a kind of "synergistic approach" mixing state vectors with wavefunctions

{another very good text adopting also roughly a "synergistic approach":
R. Shankar: "*Principles of Quantum Mechanics* " (2nd ed., Springer, 1994)}

We shall mainly cover (in order) Chapters 9, 11, and 10 from Zettili in Ph 618, with supplementary materials taken from the above and other references.

(II) *COURSE OUTLINE FOR PH 618* : *(whatever left behind will be carried over to PH 619)*

D. APPLICAITON (2) : (Z: Chap. 9; MV: Chap. 5; SG Chap. 11 and web materials: 4-A; DG: Chaps. 6,7,8)

9. Methods of approximation for stationary problems :

a. Perturbation (non-degenerate case).
b. Degenerate perturbation theory (first order).
c. Variation.
d. Others such as WKB, ...etc.

E. QUANTUM THEORY OF SCATTERING : (Z: Chap. 11; MV Chap. 6; SG Chap. 19; SG Chap. 11)

10. Basic concepts

a. Potential scattering formulated in wave mechanics
b. Concept of scattering cross-section and amplitude

11. Scattering amplitude obtained by the method of Green function

12. High energy scattering

a. The Born approximation
b. Improvements on the first Born approximation

13. Partial wave analysis for scattering from spherically symmetric potentials

a. Partial wave decomposition of wave function
b. Scattering amplitude in terms of phase shifts in the partial waves
c. Relation between the phase shifts and the scattering potential

14. Phase shift for potentials of finite range

15. Low energy scattering

a. Resonance in partial waves
b. s-wave resonance : concept of scattering length and effective range
c. p-wave resonance
d. The Ramsauer-Townsend effect

16. Some exactly solvable problems

a. Scattering by a square well potential
b. Coulomb scattering

17. Mutual scattering of identical particles

F. TIME EVOLUTION OF QUANTUM MECHANICAL SYSTEMS : (Z: Chap. 10; MV Chap. 9; SG Chaps. 15, 17, 18; DG Chap. 9)

18. The two-state problem (Ref. : Feynman Lectures vol. 3 , Secs. 8.4 - 9.6)

*19. Brief account on the formal approach using propagators : the Green function technique

*20. Quantum transition amplitude and the "sudden approximation"

****Only a brief introduction to this general treatment of time-dependent problems (19) will be presented with an example of application (20). Our main study here will involve only the simpler perturbation theory due first to Dirac as outlined in the following items. We will revisit this theory of propagators when we study the Feynman theory of Path Integrals in PH 619 in Spring.***

21. General time-dependent perturbation theory

22. First order transitions : the Fermi Golden Rule

23. Second order transitions

24. Scattering as a time-dependent process

25. Interaction of an atom with electromagnetic radiation

G. FORMULATION (3): REPRESENTATION, TRANSFORMATION, AND SYMMETRY IN QM : (Z: Chaps. 2, 3; MV: Chap. 7)

#26. Review of state vectors and Dirac's notation

#27. Theory of representations

#28. Transformation between representations

These topics have already been covered in Ph 617 to some extent. Here we shall only present a brief review on them. Our main focus here is on the following two topics which deal with the connection between symmetry and conservation laws in quantum mechanics.

29. Spatial and Temporal Transformations

30. Symmetry and conservation laws