PHYSICS 6105: QUANTUM MECHANICS I (FALL 2013)

Schedule for QMI

Instructor: Brian Kennedy, N119, Howey (office hours: MWF after class and when my office door is open)
Assistant: Mauricio Bedoya (mauricio@gatech.edu), G128G-J, MS&E Building, 404-357-9460 (office hours: TBA). As the door is usually locked, you will need to knock or call Mauricio to gain entrance.
Lectures: MWF 9.05-10.55 am L5

Course Objectives and learning outcomes

The laws of all physical systems are believed to be ultimately governed by quantum mechanics, while the strongest manifestations of quantum mechanical behavior are observed at the microscopic level. Phys 6105 is the first of a two semester sequence which is designed to provide a thorough graduate-level introduction to quantum mechanics, its mathematical formalism and applications to a variety of physical systems. Students will gain experience in advanced problem solving using a variety of techniques and learn how to describe various experimental systems in terms of quantum theory. The course provides the background for further studies in quantum field theory and various areas of specialist research.

Provisional Syllabus for QMI (Phys 6105) and QMII (Phys 6106)

Phys 6105

Introduction
A paradigm for state preparation and measurement: the Stern Gerlach experiment.
Mathematical formalism of quantum theory
Vector spaces, bases (discrete and continuous), inner product spaces, dual spaces, subspaces operators, eigenvalues and eigenvectors. Separable Hilbert space. Dirac's bra/ket notation. Commuting sets of observables. Representations and transformations between representations. Uncertainty relations. Pure states and Mixed states.
Quantum dynamics
Schrodinger picture time evolution, and examples e.g., coherent and squeezed states of the quantum harmonic oscillator. Unitary transformations in time: Heisenberg and interaction (Dirac) pictures, Dyson series and examples. Operator algebra. Path integral approach to quantum dynamics.
Continuous and discrete symmetries
Wigner's symmetry representation theorem, linear and antilinear operators. Symmetries and conservation laws, infinitesimal generators. Time, spatial translation and rotational symmetries. Commutation relations.
Angular Momentum (introduction)

Orbital angular momentum, algebraic theory and significance of integer and half-integer degrees of freedom. Central potentials, hydrogen atom and atomic structure.

Phys 6106

Composite quantum systems
Tensor product spaces. Entanglement. Bell inequalities, GHZ states. Quantum Information. Addition of angular momenta: Clebsch-Gordan series. Irreducible spherical tensors and the Wigner-Eckart theorem: selection rules for radiative transitions.
Identical particles
Statement of spin-statistics theorem: Bose and Fermi statistics. Structure of helium and multi-electron atoms. Quantum states of many fermion and many boson systems.
Approximation methods
Perturbation theory: time-independent and time dependent. Variational methods. JWKB approximation. Thomas-Fermi approximation.
Scattering theory
Potential scattering, elastic and inleastic scattering. Scattering at low and high energies. Partial waves, Born approximation.
Many particle physics
Fock space description of systems of nonrelativistic bosons and fermions. Field operators. Bose-Einstein condensation, superfluidity and superconductivity.
Relativistic quantum mechanics
Klein-Gordon and Dirac equations, electron spin. Quantum Lorentz transformations, one particle states. Space inversion and time-reversal symmetry. Causality and quantized fields.

Grading

Homework 30 points: - Homework assignments will be posted on t-square and you will be notified by email. They will be due on Mondays by 3pm and should be handed in at the Academic Office, W111, c/o Kevin Carter. Solutions will be made available for viewing at the office of the instructor and teaching assistant at a time of your convenience.
Class Tests 30 points: - Two quizzes at times to be determined.
Final 40 points: - Written, closed-book, comprehensive.

Useful References

I have recommended *Quantum Mechanics: Fundamentals (2nd edition)* by Kurt Gottfried and Tung-Mow Yan (Springer) and *Modern Quantum Mechanics, Second edition* by J.J. Sakurai and Jim Napolitano as the course texts. The former is a relatively new edition of the 1960's quantum mechanics text by Gottfried and covers a very wide range of topics at the level of a graduate physicist and researcher. I recommend the text for background reading, as a source of good problems (some of which will be assigned as homework), and as a general professional reference on quantum theory. It is not the easiest introduction, but it provides excellent insights into a variety of topics. I recommend that you persevere with it and you will find it more and more useful as your experience increases. *Modern Quantum Mechanics* is a recent revision of Sakurai's original text carried out by Napolitano.

The first edition of the book was one of the most widely used graduate level quantum mechanics texts in North America. I have recommended both books as they provide excellent, contrasting coverage of the two semester sequence. In addition to class notes, I will often provide handouts and references to other topics, appendices or specific items of interest, not covered in the texts. Handouts will often be deposited on the T-Square site under *Resources*.

A word about the relation of the lectures to the textbooks. The lecture course is not designed to follow the specific treatment, notation or order of presentation in the assigned textbooks, but I go to great effort to make the notation and class presentation as uniform as possible. My lectures on different topics have many sources. My hope is that readings from the text together with the lecture treatment will prove mutually beneficial. *It is therefore essential that each student keeps a complete set of notes of the lectures, so that reference to earlier materials and conventions are not lost.* I must admit that not all students followed my advice on this last year, but I noticed that the ones who did best did do so.

Apart from Gottried/Yan and Sakurai/Napolitano there are a host of other excellent texts on quantum mechanics with which you will need to become familiar in order to broaden your perspective: Isham's and Peres' books are delightfully written and focus on concepts and issues of principle rather than computational machinery. Shankar's book and that of Townsend are particularly clear and somewhat more elementary than the recommended texts. (If you are having trouble with the assigned texts, check out Shankar) The book *Quantum Mechanics, A modern development, 1998* by L.E. Ballentine, was recommended by several students from earlier classes. The book by Merzbacher is an alternative that I used some years ago as the required text. If you have difficulty getting access to a particular text, please come and see me as I can probably lend you a copy for a brief period.

The approach presented in the lectures will reflect the various points of view to be found in the texts mentioned above and the following:

General, advanced level

Lectures on Quantum Mechanics, 2013 by S. Weinberg
Quantum Mechanics (3rd edition), 1998 by E. Merzbacher
Lectures on Quantum Mechanics, 1969 by G. Baym.
Quantum Mechanics Vol I and II, 1961 by A. Messiah.
Quantum Mechanics Vol I and II, 1977 by C. Cohen-Tannoudji, B. Diu and F. Laloe.
The Principles of Quantum Mechanics, (4th edition) by P.A.M. Dirac
Quantum Mechanics (3rd edition), 1977 by L.D.Landau and E.M. Lifshitz.
Quantum Mechanics (3rd edition), 1968 by L.I. Schiff
Quantum Mechanics Volume I, 1966 by K. Gottfried
Principles of Quantum Mechanics (2nd edition), 1994 by R. Shankar
Quantum Mechanics, A modern development, 1998 by L.E. Ballentine
Quantum Mechanics symbolism of atomic measurements, 2001 (edited by B-G Englert) by Julian Schwinger
Quantum Mechanics, 1992 and Advanced Quantum Mechanics, 1999 by F. Schwabl
Modern quantum mechanics revised edition, 1994 by J.J. Sakurai
Feynman Lectures Vol III 1965, R.P.Feynman, R.B. Leighton and M. Sands.
Introductory Quantum Mechanics,(4th edition) R.L. Liboff.

Others:
Foundational
Lectures on quantum theory: mathematical and structural foundations, 1995 by C.J. Isham
Quantum theory: Concepts and Methods, 1995 by A. Peres
Speakable and unspeakable in quantum mechanics, 1987 by J.S. Bell
Quantum Computer Science, An introduction, 2007 by N.D. Mermin
Mathematical Physics (rigorous)
Linear operators for quantum mechanics, 1969 (Dover 2006) by T.F. Jordan
Perturbation theory for linear operators, 1980 by Tosio Kato
Theory of linear operators in Hilbert space, two volumes bound as one, 1961/3 (Dover 1993) by N.I. Akhiezer and I.M. Glazman
Introduction to Hilbert space, 2nd Edition, 1976 Sterling K. Berberian
Angular momentum
Angular momentum in quantum mechanics, 1960 by A.R. Edmonds
Elementary theory of angular momentum, 1957 by M.E. Rose
Atomic spectra and radiative transitions (2nd edition), 1991 by I.I. Sobelman
Appendix C of Quantum Mechanics Vol II by A. Messiah
Relativistic quantum mechanics, quantized fields
Quantum Field Theory, 2007, by Mark Srednicki
Quantum Field Theory, 1995, by M.E. Peskin and D. Schroeder
Quantum Theory of Fields I, Foundations, 1995 by S. Weinberg
Atomic physics and quantum optics
The physics of atoms and molecules, 1981 by B.H Bransden and C.J. Joachain.
The quantum theory of light, (3rd edition), 2000, by R. Loudon
Photons and Atoms, 1989 and Atom-photon interactions, 1992 by C. Cohen-Tannoudji, J Dupont-Roc and G. Grynberg
Atomic spectra and radiative transitions (2nd edition), 1991 by I.I. Sobelman
Many body theory
Statistical Mechanics, 1972 by R.P. Feynman

Undergraduate:
A Modern Approach to Quantum Mechanics (2nd edition), 2012 by J.S. Townsend
Introduction to Quantum Mechanics (2nd edition), 2005 by D. Griffiths
Quantum Physics (3rd edition), 2003 by S. Gasiorowicz
Quantum Mechanics, Concepts and Applications, 2001 by Nouredine Zettili (a good self-study reference)

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