Hong Kong Baptist University
Faculty of Science – Department of Physics

Title (Units): **PHYS 4046 QUANTUM MECHANICS (3, 3, 1)**

Course Aims: To learn the basic theory of quantum mechanics through formalistic Hilbert space and matrix mechanics: from the wave mechanics of a particle in one dimension (e.g., particle in a box and harmonic oscillator) to the three-dimensional hydrogen atom.

Pre-requisite: PHYS 3005 Atomic and Nuclear Physics, or consent of instructor.

Course Reviewed by: Dr. Kin-Yiu Wong and Dr. Changsong Zhou.

Course Intended Learning Outcomes (CILOs):

No.	Upon successful completion of this course, students should be able to:
1.	Find the energies and wavefunctions of one dimensional single particle systems by formulating an approach to solve the time-independent Schrodinger equation. The approach is not necessarily analytical. The systems are modeled by standard potentials such as infinite and finite square wells, and harmonic oscillators.
2.	Make use of the formalisms of states, observables and measurements to generalize the energy eigenvalue problem (Schrodinger equation) to other dynamical variables and relate the wavefunctions to physical observables via the probabilistic interpretation of $\|\psi(x)\|^2$ and its generalization.
3.	Find the wavefunctions and energies of three dimensional single particle systems such as the Coulomb potential of the hydrogen atom.
4.	Demonstrate progressive development of the above CILOs, from recalling definitions and explaining concepts, through plugging in equations, to modeling real world systems.

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Teaching & Learning Activities (TLAs)

CILOs	TLAs will include the following:
1-4	**Lectures.** Given the mathematical and conceptual difficulties of the subject, the instructor will use the following teaching approaches: • *Orient and motivate* the students whenever a new idea is introduced, verbally explaining why it is needed, where it comes from and where it is leading to. • Move *from familiar to exotic*. For example, start with everyday three-dimensional space and generalize to Hilbert space. • Relate new concepts to the overall logical structure, much like *mind maps*. • *Visualization.* Big sketches and tables will be used as frequently as possible to illustrate physical systems, concept comparisons, mind maps etc. • Do *worked examples* as much as possible. Will first describe and rationalize the approach before plugging in equations. Will show ways to check the consistency of answers. Will invite student participation throughout. • Crowning applications. One or two *real world problems* will be presented near the end of each chapter. The instructor will guide the students to understand the system, identify the essence, formulate the model, and analyze it qualitatively and quantitatively. • *End-of-chapter summary*. A summary will be given at the end of each chapter, typically within one A4 page. It serves as the skeleton of the logical structure as well as the breadth requirement of the course.
1-4	**Tutorials.** Given the smaller class size, students can learn interactively through • Questions and answers. • Worked examples with student participation. • Small group discussions. Students are encouraged to adopt the instructor's strategies of (1) verbal explanation, (2) visualization, (3) mind maps, and the sort.

1	**Numerical solutions.** For potentials where analytical solution is demanding or impossible, the Schrodinger equation will be solved numerically in class. User-friendly programming language will be used. Emphasis will be placed on making sense of the solution rather than on programming algorithm and syntax.
1-4	**Homework assignments.** Students are assigned readings and problem sets. Solving homework problems is probably the most important learning activity. Students are encouraged to discuss with classmates and consult the instructor and TA though they have to write up their solution independently. In some cases, students are required to verbally explain their approach. Problems requiring numerical computation will also be assigned. Homework solutions will be posted on the web soon after the due date.

Assessment:

No.	Assessment Methods	Weighting	CILOs to be addressed	Remarks
1	Continuous Assessment (e.g., homework, mid-term test)	50%	1-4	Problem sets that measure how well the students have learned the basic concepts and fundamental theory of quantum mechanics. A mid-term test that assess students more on the first two CILOS. Less emphasis on real world applications.
2	Final Examination	50%	1-4	Final Examination questions are designed to see how far students have achieved their intended learning outcomes.

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Learning Outcomes and Weighting:

Content	**CILO No.**	**Teaching (in hours)**
I. Review elementary wave mechanics and basic probabilities.	1	4
II. Schrodinger equation for 1-dimensional and single particle cases.	1, 4	13
III. States, observables, and measurements.	2, 4	14
IV. 3-D quantum mechanics, hydrogen atom	3, 4	5

Textbook: D. J. Griffiths, Introduction to Quantum Mechanics, 2^{nd} Ed., Pearson Prentice Hall, 2005.

References:

1. R. L. Liboff, Introductory Quantum Mechanics, 4^{th} Ed., Addison-Wesley, 2002.
2. N. Zettili, Quantum Mechanics: Concepts and Applications, Wiley, 2^{nd} Ed., 2009.
3. D. A. B. Miller, Quantum Mechanics for Scientists and Engineers, Cambridge U. Press, 2008.
4. R. Shankar, Principles of Quantum Mechanics, 2^{nd} Ed., Plenum Press, 2008.
5. S. Gasiorowicz, Quantum Physics, 3^{rd} Ed., John Wiley and Sons, 2003.
6. R. P. Feynman, R. B. Leighton and M. Sands, The Feynman Lectures on Physics, Volume III, the New Millennium Edition, Basic Books, 2011.
7. A. Beiser, Concepts of Modern Physics, 6^{th} Ed., McGraw Hill, 2003.
8. Eisberg and R. Resnick, Quantum Physics, 2^{nd} Ed., Wiley 1985.

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Course Content in Outline:

	Topic	**Hours**
I.	The Wave Function	4
	A. The statistics of discrete variables.	
	B. The statistics of continuous variables.	
	C. Statistical interpretation of the wavefunction.	
	D. (Optional) Is the moon there when no one looks?	
II.	The Time-Independent Schrodinger Equation	13
	A. Stationary states.	
	B. Particle in a box.	
	C. The harmonic oscillator.	
	D. Free particle and wave packets.	
	E. Bound states in a finite square well.	
	F. One dimensional barrier problems, scattering and tunneling.	
III.	The Formalism of Quantum Mechanics	14
	A. Review of linear algebra.	
	B. Function spaces, Hilbert space, orthonormality and completeness.	
	C. Postulates of quantum mechanics, states, observables, and measurements.	
	D. Commutation relations and the uncertainty principle.	
	E. Dirac notation and matrix mechanics.	
IV.	Three Dimensional Quantum Mechanics	5
	A. The Schrodinger equation in spherical coordinates.	
	B. The hydrogen atom.	