Hong Kong Baptist University
Faculty of Science – Department of Physics

Title (Units): **PHYS 3005 ATOMIC AND NUCLEAR PHYSICS (4,4,1)**

Course Aims: This course begins by introducing the key concepts of quantum physics including the wave-particle duality, the Heisenberg uncertainty principle and the Schrödinger equation. Using the language of quantum physics, students will then explore the structure and properties of atoms and nuclei. This course also introduces the basic concepts of radioactivity and nuclear reactions and lays a foundation for understanding the working principles of nuclear power generation.

Pre-requisite: PHYS 2005 Heat and Motion or consent of instructor

Course Reviewed by: Dr Alex Mok and Dr Wong Kin Yiu

Course Intended Learning Outcomes (CILOs):

No.	Upon successful completion of this course, students should be able to:
1	Illustrate the limits of classical physics by explaining how the origin and basic concepts of quantum physics can replace it, including blackbody radiation, the photoelectric effect, X-ray diffraction, Compton scattering, line spectra, and the wave-particle duality of light and matter.
2	Solve the Schrödinger equation in simple cases and interpret the results.
3	Explain the electron configuration of an atom and the structure of the periodic table.
4	Examine the properties and models of atomic nuclei, and the nature of radioactive decay.
5	Illustrate the basic principles of nuclear reactions by describing how they apply to a nuclear power reactor.

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Teaching & Learning Activities (TLAs)

CILOs	TLAs will include the following:
1, 5	Videos and online resources will be used in the lectures to introduce the basic physical concepts.
1	There will be class discussions on the historical development of quantum theory to highlight why quantum theory is essential to explain experimental observations of the microscopic world.
2-4	A series of lectures will be given on the atomic model detailing how it provides the basic characteristics of an atom. The hydrogen atom will be used as the classic example.
1-5	Students working in small groups solve problems involving the basic concepts of atomic and nuclear physics such as determining the electron configuration of an atom in the ground state. They will learn how to analyze the given problem and evaluate the technique that should be used for solving it.

Assessment Methods (AMs):

Type of Assessment Methods	Weighting	CILOs to be addressed	Description of Assessment Tasks
Assignments, Quizzes and Participation	40%	1-5	Assignments and quizzes are designed to measure students' understanding of the basic concepts in atomic and nuclear physics and to enhance their analytical skills.
Mid-term Test	20%	1-3	This test aims to measure students' ability to solve problems that relate to basic concepts in quantum physics. It also serves to provide some feedback to the instructor and students.
Final Examination	40%	1-5	Students will solve a set of problems to show how far they have achieved their intended learning outcomes.

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Learning Outcomes and Weighting:

Content	CILO No.	Teaching (in hours)
I. Origin and basic concepts of quantum physics	1	6
II. The Bohr model and the wave-particle duality	1	9
III. The Schrödinger equation and the atomic structure	2, 3	12
IV. Properties of nuclei	4	9
V. Radioactivity and nuclear reactions	5	12

Textbook: S. T. Thornton and Andrew Rex, *Modern Physics for Scientists and Engineers*, 4th ed., Cengage Learning, 2013.

References:

1. A. Beiser, *Concepts of Modern Physics*, 6th ed., McGraw Hill, 2002.
2. F.J. Blatt, *Modern Physics*, McGraw Hill, 1992.
3. R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles*, 2nd ed., Wiley, 1985.
4. K.S. Krane, *Modern Physics*, 3rd ed., Wiley, 2012.
5. R.A. Serway, C.J. Moses and C.A. Moyer, *Modern Physics*, 3rd ed., Brooks Cole, 2004.
6. K.S. Krane, *Introductory Nuclear Physics*, 3rd ed., Wiley, 1987.
7. E.E. Lewis, *Fundamentals of Nuclear Reactor Physics*, Elsevier, 2008.

Course Content in Outline:

	Topic	Hours
I.	Origin and basic concepts of quantum physics	6
	A. Blackbody radiation.	
	B. The photoelectric effect.	
	C. X-ray diffraction.	
	D. Compton effect.	
II.	The Bohr model and the wave-particle duality	9
	A. Rutherford scattering	
	B. The Bohr model	
	C. The de Broglie relation	
	D. The uncertainty principle	
	E. The wave-particle duality and complementarity	
	F. Applications (electron microscope, spectral lines, etc).	

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III.	The Schrödinger equation and the atomic structure	12
	A. The Schrödinger equation	
	B. Physical interpretation of the wave function.	
	C. The hydrogen atom: energy levels and degeneracy	
	D. Electron spin, fine structure and spin-orbit coupling	
	E. The Pauli exclusion principle	
	F. The electron configuration and the periodic table	
IV.	Properties of nuclei	9
	A. Nuclear sizes and shapes	
	B. Mass and abundance of nuclides	
	C. Nuclear force and binding energy	
	D. Nuclear models	
V.	Radioactivity and nuclear reactions	12
	A. Radioactive decay law	
	B. Half-life and activity	
	C. Alpha, beta and gamma decays	
	D. Types of nuclear reaction	
	E. Fission and fusion	
	F. Nuclear power reactors	