Semester	**6**
Course	**Major**
Paper Code	
Paper Title	**Nuclear Physics & QM-II**
No. of Credits	**4**
Theory / Practical / Composite	**Theory**
Minimum No. of preparatory hours per week a student has to devote	4
Number of Modules	2
Syllabus	**Module A: Nuclear Physics [24 L]** **Nuclear Properties and Forces** Constituents of nuclei: mass, charge, size, density, spin, parity, magnetic and electric moments. Mass defect, binding energy and the variation of binding fraction with mass number; N-Z plot for stability analysis. Characteristics of nuclear force, nucleon-nucleon potential. [**4 Lectures**] **Nuclear Models** Liquid Drop Model: assumptions, Bethe–Weizsäcker semi-empirical mass formula, conditions for nuclear stability. Shell Model: evidence for shell structure, magic numbers, single-particle states, ground state spins, and Nordheim's rules. Fermi gas model: concept of degenerate fermion gas and mean field. [**4 Lectures**] **Radioactivity** Law of radioactive decay, mean life, and half-life, successive disintegration. Alpha decay: basics of emission, quantum tunnelling, Geiger-Nuttall law (qualitative). Beta decay: energy spectra, neutrino hypothesis, Gamma decay: multipole transitions, internal conversion, and nuclear isomerism. [**3 Lectures**] **Nuclear Reactions** Types of nuclear reactions, conservation laws, Q-value, cross-section of reaction. Compound nucleus model (Bohr's postulate) and its implications. Direct and resonance reactions. Optical model. Rutherford scattering: Qualitative discussions. [**4 Lectures**] **Nuclear Fission and Fusion** Fission: fission fragments, energy release, chain reactions and basic operation principle of nuclear reactors. Fusion: energetics, thermonuclear reactions, proton-proton chain & CNO cycle, Fusion based reactor. [**3 Lectures**] **Interaction of Radiation with Matter** Energy loss of charged particles: ionization, Bethe-Bloch formula

	(qualitative), stopping power & range. Gamma ray interactions: photoelectric effect, Compton scattering and pair production: basic characteristics. Neutron interactions: elastic and inelastic scattering. [3 Lectures] **Detectors and Accelerators** Ionization chamber, Geiger-Müller counter, scintillation detectors, semiconductor detectors. Linear accelerator, cyclotron, synchrotron. [3 Lectures] **Module B**: Quantum Mechanics II **[24 L]** Formalism: Hilbert space, State vectors, Bra Ket notation, Operators, Representation and Transformation, CSCO, Time evolution, Pictures: Schrodinger, Heisenberg, Interaction (Dirac). Particle in a 3D box; Delta-function Potential: Bound and Scattering states. [7 Lectures] Harmonic Oscillator: Uncertainty relation and zero point energy; Solution by analytical Method (Hermite functions); Solution by algebraic method (Creation and Annihilation operators); 3D Harmonic Oscillator. [5 Lectures] Angular momentum: Orbital angular momentum operator, commutating observables, eigenvalues, eigenfunctions in terms of Legendre Polynomials and azimuthal functions. General angular momentum: Algebraic method of solution; Raising and Lowering Operators. Spin Angular Momentum: Spin ½. Addition of Angular Momentum; Clebsch Gordon coefficients. [9 Lectures] The Hydrogen atom problem: Laguerre polynomials. Hydrogen spectrum. [3 Lectures]
Learning Outcomes	Module A: By studying this module on nuclear physics, the students will acquire knowledge regarding: 1) General properties of nuclei and various nuclear models. 2) Characteristics of radioactivity. 3) Nuclear reactions of various types and related calculations. 4) Fission, Fusion (related energy emission) & Interaction of radiation with matter.

	5) Detectors & accelerators used in various modern experiments performed to probe the nuclei. Module B 1. Students will get a quick view of the formulation of quantum mechanics in the language of vector space. 2. Students will learn to solve the eigenvalue problems for a 3D box and delta function potential. 3. Eigenvalue problem of the harmonic oscillator will be solved by analytic and algebraic methods. 4. Students will learn about the angular momentum operators and addition of angular momentum and will apply it for Hydrogen atom.
Reading/Reference Lists	**Reference Books** **<u>Module A</u>:** 1. Introductory Nuclear Physics, Kenneth S. Krane, Wiley India Pvt. Ltd., 2008. 2. Concepts of Nuclear Physics, Bernard L. Cohen, Tata McGraw Hill, 1998. 3. Introduction to the Physics of Nuclei & Particles, R.A. Dunlap, Thomson Asia, 2004. 4. Basic Ideas and Concepts in Nuclear Physics, K. Heyde, IOP, 2004. 5. Nuclear Physics, S.N. Ghoshal, S. Chand & Co., 2006. 6. Theoretical Nuclear Physics, J.M. Blatt & V.F. Weisskopf, Dover Publications, 1991. 7. Nuclear Radiation Detectors, S.S. Kapoor & V.S. Ramamurthy, New Age International, 1986. 8. Radiation Detection and Measurement, G.F. Knoll, John Wiley & Sons, 2000. 9. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed, Academic Press, 2007. 10. Techniques for Nuclear and Particle Physics Experiments, William C. Leo, Narosa, 1995. 11. Particles and Nuclei: An Introduction to the Physical Concepts, Bogdan Povh, Frank Zetsche and Klaus Rith. (Springer @2015)

	12. Atomic Physics, J. Yarwood **<u>Module B</u>**: 1. S.N Ghoshal, Quantum Mechanics, 2e, Springer 2. A. Ghatak & Loknathan, Quantum Mechanics, Theory and applications, Springer 3. R. Shankar, Principles of Quantum Mechanics, 2e, Springer 4. B.H. Bransden and C.J Joachain, Prentice Hall, India 5. N. Zettili, Quantum Mechanics, Concepts and Applications, Wiley India. 6. D.J. Griffiths and Darrell F. Schroeter, Introduction to Quantum Mechanics, Cambridge University Press 7. Claude Cohen-Tannoudji, Bernard Diu and Frank Laloe, Quantum Mechanics, Vol 1,Wiley-VCH 8. Feynman, Leighton and Sands, Feynman Lectures in Physics, Vol 3, also available freely online 9. J.Binney and D. Skinner, The Physics of Quantum Mechanics: Free textbook 10. A.S. Davydov, Quantum Mechanics: Free textbook.	
Evaluation	CIA 30 (2 x 10 + 5 Assignment +5 Attendance) SEM Exam 70	
Paper Structure for Theory Semester Exam	For each module of 35 Marks: 15 marks from 3 mark questions (5 / 7) 20 marks from 10 mark questions (2 / 3)	