Course: M.Sc (Physics)

Semester	3
Paper Number	10 (MPHC4312)
Paper Title	Nuclear and Particle Physics and Advanced lab I
No. of Credits	6
Course description/objective	**Group A:** One of the objectives for Nuclear and Particle Physics (i.e., Module-A of MPHC4312) is to teach the students the quantum mechanical explanation for the characteristics of beta decay, in the light of Fermi's theory. Students should also learn thoroughly the quantum mechanical interpretation of the properties of the simplest nucleus, deuteron, and thereby estimate the attractive force between the two nucleons in it. Students must learn the dependence of nucleon-nucleon interaction upon their relative spin orientation, through a study of the findings of low-energy collisions between two nucleons. To have an understanding of the interactions between nucleons, the students should study the theories of scattering and reaction cross sections, scattering length and effective range, optical model for scattering. Nuclear models should be discussed briefly. Regarding the topic of Elementary Particles, the students should initially be taught the classification of particles, Meson and Baryon octets, Baryon decuplet. They must study the conservation rules and particle kinematics. They must be made sufficiently familiar with the Standard Model for elementary particles. **Group B:** Understanding the nuclear behavior and the effect of external fields on polarization of light.
Course Outcome	**Group A** CO1: Fermi's theory of beta decay. CO2: Properties of deuteron: estimating the force of attraction between two nucleons. CO3: Low energy nucleon-nucleon scattering: dependence of nucleon-nucleon interaction upon spin. CO4: Scattering and reaction cross sections. Scattering length and effective range. Optical model for scattering. Various Nuclear models (liquid drop, shell structure etc). CO5: Physics of Elementary Particles: Classification, Meson and Baryon octets, Baryon decuplet. Conservation rules. Particle kinematics. Standard Model. Quark structure. Discrete symmetry. CPT invariance. **Group B** CO1: Handling with precautions nuclear sources CO2: Understanding the concept of spin resonance CO3 : Developing the concept of polarization of light and thus verifying Malus law CO4: Understanding the concept of rotation of polarized light by applying magnetic Field
Syllabus	**Group A: Nuclear Physics & Particle Physics** **Nuclear Physics** **[24 lectures**] Nuclear Properties: Basic information regarding nuclear radius and charge distribution, binding energy, angular momentum, parity, magnetic dipole moment and electric quadrupole moment. [2 lectures]

	Deuteron: Properties of deuteron, Schrodinger equation and its solution for the ground state of deuteron assuming the interaction potential to be represented by a three-dimensional square well, non-existence of excited bound state of an n-p system. Non-existence of a state with non-zero orbital angular momentum. Estimation of force between nucleons. Deuteron radius. Calculation of probability for a certain separation between the nucleons [3 lectures] Nucleon-nucleon scattering: Low-energy n-p scattering cross section: experimental observation, partial wave analysis and phase shifts, scattering length and the significance of its sign, effective range theory, determination of cross section for S-wave n-p scattering, singlet and triplet interaction of nucleons, spin dependence of nuclear forces, tensor (non-central) potential, determination of energy of a neutron-proton bound state for singlet spin orientation [5 lectures] Beta decay: Energetics of beta decay, experimentally observed energy and momentum distribution of beta particles (both positive & negative). Pauli's neutrino hypothesis. Energy and momentum distribution from Fermi's theory of beta decay. Fermi-Kurie plot. Fermi integral and comparative half-life. Determination of strength parameter of nuclear interaction for beta decay. Estimation of neutrino mass. Allowed and forbidden transitions, selection rules for Fermi and Gamow-Teller transitions, parity non-conservation and Wu's experiment [6 lectures] Nuclear models: Liquid drop model, Bethe-Weizsacker semi-empirical mass formula, Bohr-Wheeler's theory of fission, Spherical Shell model, brief introduction to Collective model [4 lectures] Nuclear reactions: Determination of scattering cross section and reaction cross section based on partial wave analysis, Shadow scattering. Bohr's compound nuclear hypothesis. Breit-Wigner formula for resonance scattering. Optical model of nuclear reaction [4 lectures] **Particle Physics** **[12 lectures]** Classification of hadrons by isospin and hypercharge, Baryon octet, Baryon decuplet, Pseudo-scalar and Vector Mesons. The quark model, SU(2), SU(3) and their representations. Young tableaux. Discrete symmetries, Parity, Charge conjugation, G-parity. Charm quark, charmed mesons, Bottom quark, B mesons, discovery of top quark. The states of the neutral kaons, strangeness oscillations, elementary idea of CP violation. Relativistic kinematics: elementary idea of Mandelstam variables. **Group B: Advanced lab I[36 lectures]** 1. BETA particle absorption using a GM counter (table top) or other counters. 2. ALPHA particle absorption using semiconductor detectors and multichannel analyser. 3. GAMMA spectrometry with scintillation detectors and single-channel/ multi-

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<tr><td></td><td>channel analysers.
4. Faraday effect of a given material.
5. Spectroscopic splitting factor of a given sample using electron spin resonance spectrometer.
6. Verification of Malus law and Provostaye and Desains formula.
7. BETA spectrometry using magnetic field.
8. BETA spectrometry with scintillation detectors and multi-channel analysers</td></tr>
<tr><td>References</td><td><u>Group A:</u>

<u>Nuclear Physics:</u>

1. Introductory Nuclear Physics by Kenneth S. Krane John Wiley & Sons, 1988
2. Nuclear Physics by I. Kaplan Narosa, 2002
3. Nuclear Physics by S N Ghoshal S. Chand & Co., 1994
4. Elements of Nuclear Physics by W E Burcham Longman, 1979
5. Concepts of Nuclear Physics by, B Cohen McGraw Hill, 2000
6. Nuclear Physics: Theory and Experiment by, Roy & Nigam, New Age, 1996

<u>Particle Physics:</u>

1.Introduction to Elementary Particle Physics by A. Bettini
2. Elementary Particle Physics: An intuitive introduction by A. Larkovski
3. Introduction to High Energy Physics by D.H. Perkins
4. An Introduction to Quarks and Partons by F.E. Close

<u>Group B:</u>

1. Polarization of light by Serge Huard
2. Nuclear Physics By S. N. Ghosal
3. Electron Spin Resonance Elementary Theory and Practical Applications by John E. Wertz and James R Bolton</td></tr>
<tr><td>Evaluation</td><td>Total: 100
<u>Group A: Theory</u>
CIA: 10 marks (Group A)
End Semester Examination: 40

<u>Group B: Lab</u>
CIA: 10 (LNB) + 20 (Lab performance)
End Semester Examination: 20</td></tr>
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