GENERIC ELECTIVE (GE - 19): NUCLEAR AND PARTICLE PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Nuclear and Particle Physics GE – 19	4	3	1	0	Class XII Pass with Science	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This course imparts the understanding of the sub atomic particles and their properties; introduces various nuclear phenomena and their applications, interactions of basic building blocks of matter through fundamental forces, the inherent discrete symmetries of particles and complements each and every topic with applications and problems.

LEARNING OUTCOMES

After completion of this course, students are expected to have an understanding of,

- Nuclear charge and mass density, size, magnetic and electric moments
- Theoretical principles and experimental evidences towards modelling the nucleus
- Kinematics of nuclear reactions and decays
- Energy loss of radiation during propagation in medium
- Principles of nuclear detection technique
- Classification of fundamental forces based on their range, time-scale and mediator mass.
- Scattering cross-sections of 2 to 2 processes and their inherent symmetries.
- Angular and energy distributions for three body decay process.
- Discrete symmetries of nature and associated conservation laws
- Colour triplet quarks and anti-quarks as constituents of observed colour singlet baryons and mesons.

SYLLABUS OF GE 19

THEORY COMPONENT

Unit – I **(5 Hours)**

General properties of nuclei: Constituents of nucleus and their Intrinsic properties: quantitative facts about mass, radii, charge density, matter density, binding energy, N/Z plot, angular momentum, parity, magnetic moment, electric moments.

Unit – II **(5 Hours)**

Nuclear models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, evidence for nuclear shell structure and the basic assumptions of shell model, magic numbers.

Unit – III **(7 Hours)**

Radioactivity decay: Decay rate and equilibrium (secular and transient)
(a) Alpha decay: basics of α-decay processes, Gamow factor, Geiger Nuttall law, α-decay spectroscopy, decay Chains.
(b) β-decay: energy kinematics for β-decay, β-spectrum, positron emission, electron capture, neutrino hypothesis.
(c) Gamma decay: Gamma ray emission from the excited state of the nucleus and kinematics, internal conversion.

Unit – IV **(5 Hours)**
Nuclear reactions: Kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct reaction, Coulomb scattering (Rutherford scattering).

Unit – V **(8 Hours)**
Interaction of nuclear radiation with matter: Energy loss due to ionization (Bethe-Block formula), energy loss of electrons, Cerenkov radiation; Gamma ray interaction through matter Detector for nuclear radiations: Basics of types of detectors: gas detectors, scintillation detector, semiconductor detector (principle, schematics of construction and working)

Unit – VI **(15 Hours)**
Particle Physics: Overview of particle spectrum and their interactions in the Standard Model; range, time-scale and relative strength of interactions; interactions at a distance mediated by virtual particles (Exchange Force)
Kinematics for 2 -> 2 scattering processes and crossing symmetries of scattering amplitudes; angular and energy distributions of decaying particles in 1 -> 3 decay processes (muon decay/beta decay); identification of invisibles (neutrinos) from energy and transverse momentum distributions
Lepton and Baryon quantum numbers; isospin, strangeness and hypercharge; Gell-Mann-Nishijima formula; parity and charge conjugation of a particle state; time reversal and general CPT theorem
Valence quark model of Murray Gell-Mann and Yuval Ne'eman, current and constituent masses of quarks, flavor symmetry isospin triplets, baryon octet, decuplet and meson octet; existence of Δ^{++} baryon as a clue for necessity of colour quantum number; evidence for colour triplet quarks from e^+e^- annihilation experiment; confinement of quarks, antiquarks and gluons in hadrons
High energy scattering experiments at linear and circular colliders, inelastic collisions at hadron colliders; elastic and inelastic neutrino-nucleus scattering experiments

References:
Essential Readings:
(A) For Nuclear Physics
1) Basic ideas and concepts in nuclear physics: An introductory approach, K. Heyde, 3rd edition, 1999, IOP Publication
2) Introductory Nuclear Physics, K. S. Krane, 2008, Wiley-India Publication
3) Nuclear Physics, S. N. Ghoshal, 1st edition, 2010, S. Chand Publication
4) Nuclear Physics: Principles and applications, J. Lilley, 2006, Wiley Publication
5) Concepts of Nuclear Physics, B. L. Cohen, 1974, Tata McGraw Hill Publication
6) Radiation detection and measurement, G. F. Knoll, 2010, John Wiley and Sons

(B) For Particle Physics
1) Modern Particle Physics, M. Thompson, 2013, Cambridge University Press