Gyanmanjari Innovative University

Course Syllabus
Gyanmanjari Science College
Semester-3 (M.Sc.)

Subject: Nuclear and High Energy Particle Physics -MSCPH13513

Type of course: Major

Prerequisite: Knowledge of Quantum Mechanics and basics of nuclear reactions.

Rationale: The course aims to train the learner the phenomena relevant to sub-atomic domain and the learners theoretical and experimental techniques of nuclear and sub-nuclear particles

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks					Total Marks
CI	T	P	C	Theory Marks		Practical Marks		CA	
				ESE	MSE	V	P	ALA	
4	0	0	4	60	30	10	00	50	150

Legends: CI-Class Room Instructions; T – Tutorial; P - Practical; C – Credit; ESE - End Semester Examination; MSE- Mid Semester Examination; V – Viva; CA - Continuous Assessment; ALA- Active Learning Activities.

Continuous Assessment:

Sr. No	Active Learning Activities	Marks
1	**Binding Energy Investigation** Students have to analysis of binding energy for 5 different isotopes for each isotope find mass defect, binding energy, binding energy per nucleon and graph showing binding energy per nucleon vs. mass number and upload report to GMIU web portal.	10
2	**Fission vs. Fusion – Reactor Design Poster** Students have to prepare comparison poster on nuclear fission and nuclear fusion, The following must be included Descriptions and equations, A comparative analysis of energy output and reaction mechanisms, Real-world applications and Diagrams illustrating both fission and fusion reactor designs and upload report to GMIU web portal.	10

3	**Quantum Field Theory Concept Map** Students have to prepared concept map to visually organize and interrelate the following topics: Schrödinger equation and its quantization, Second quantization, Klein-Gordon and Dirac fields and Fermions and bosons and upload report to GMIU web portal.	10
4	**Particle Zoo – Quark Model Cards** Students have create minimum of 10 particle cards, each displaying the following information: Name of the particle, Quark composition (if applicable), Mass, charge, spin, and particle classification, Associated quantum numbers and diagram or visual representation and upload report to GMIU web portal.	10
5	**Nuclear Reactor Simulation Report** Students have to do simulation-based study of a nuclear reactor must be conducted using an available online simulator and The following aspects must be observed and analyzed during the simulation The effect of neutron speed on fission events, behavior of control rods and their role in maintaining the chain reaction, The balance between neutron production and absorption and The impact of fuel type and configuration on reactor output and upload report to GMIU web portal.	10
	Total	**50**

Course Content:

Unit No	Course content	Hrs	% Weightage
1	**Chapter-1 Nucleus Basics:** Basic notion about nucleus, Classification, Nuclear mass, Density and Radius, Energy-mass equivalence, Binding energy per nucleon, Binding and separation energy, Magnetic moments, Concept of parity, Electric moments, Nucleus shape and electric quadrupole moment, Magic number, Illustrations. Particle in a box-Schrödinger wave equation and its solution, Ground state wave function of D2, Radius of deuteron, Low energy n-p scattering, Low energy p-p scattering, spin dependence of nuclear forces, Mixing of orbitals in deuteron, Non-central forces, Charge independence and concept of isospin, Yukawa theory of nuclear forces and concept of mesons, Exchange forces, Single particle shell model, Successes and failures of shell model.	15	25%

2	**Chapter-2 Nuclear Reaction and Energy:** Resume of nuclear decay process: Alpha, beta and Gamma decay, Nuclearear Reaction mechanism, pre-equilibrium reaction mechanism, Compound nucleus nuclear reaction theory, Direct interaction process in nuclear reactions, Coupled channel theory of inelastic scattering. **Nuclear Energy:** Nuclear fission, Compound nucleus, Nuclear Fission mechanism, Spontaneous fission and potential barrier, Emission of neutron in fission, Self-sustaining chain reaction–Nuclear reactor, Neutron balance in reactor, Fission rate and reactor power. Nuclear Fusion, Sources of energy in stars, Nucleosynthesis processes, Controlled fusion, Lawson Criterion, Plasma confinement.	15	25%
3	**Chapter-3 Field Theory and Fundamental Particles:** Resume of classical field theory and its quantization, Second quantization, Quantization of Schrödinger equation, Nrepresentation, Relativistic fields: Klein-Gordon field, Dirac field, Classification of fundamental forces and fundamental particles, Systems of identical particles, Symmetric and anti-symmetric wave functions, Bosons and Fermions, Pauli's exclusion principle, Interactions between relativistic fields, Relativistic kinematics, SU(2) and SU(3) groups.	15	25%
4	**Chapter-4 High-Energy Particle Physics:** Leptons and Hadrons, Mesons and Baryons, Excited state and resonances. Quark model, Baryon spectrum, Meson spectrum, Quantum numbers, Conservation laws: isospin, strangeness, charm, baryon numbers, quarks, Gellmann-Nishijima formula, Hadron spectroscopy, Necessity of color, mesons as quarkantiquark pairs, Parity non-conservation in weak decays, CP and CPT invariance, elementary ideas of QCD, Elementary ideas about electroweak theory, Spontaneous symmetry breaking, Concept of Higgs boson.	15	25%

Suggested Specification table with Marks (Theory):60

Distribution of Theory Marks **(Revised Bloom's Taxonomy)**						
Level	Remembrance (R)	Understanding (U)	Application (A)	Analyze (N)	Evaluate (E)	Create (C)
Weightage	20%	40%	30%	10%	-	-

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Course Outcome:

After learning the course the students should be able to:	
CO1	Understand the fundamental properties of atomic nuclei such as mass, density, radius, magnetic and electric moments.
CO2	Illustrate the concept of plasma confinement and challenges in achieving sustainable nuclear fusion.
CO3	Analyze relativistic fields such as Klein-Gordon and Dirac equations and apply them to particle behavior.
CO4	Distinguish between leptons, hadrons, mesons, and baryons and explain their properties using quark models.

Instructional Method:

The course delivery method will depend upon the requirement of content and need of students. The teacher in addition to conventional teaching method by black board, may also use any of tools such as demonstration, role play, Quiz, brainstorming, MOOCs etc.

From the content 10% topics are suggested for flipped mode instruction.

Students will use supplementary resources such as online videos, NPTEL/SWAYAM videos, e-courses, Virtual Laboratory

The internal evaluation will be done on the basis of Active Learning Assignment

Practical/Viva examination will be conducted at the end of semester for evaluation of performance of students in laboratory.

Reference Books:

[1] Fundamentals of Nuclear Physics: J. C. Verma, R. C. Bhandari and D.R.S. Somayajulu (CBS Publishers & Distributers, New Delhi).
[2] Nuclear Physics: Kaplan (Addison Wesley Pub. Company).
[3] Nuclei and Particles: C Segre (Dover Publications Inc.).
[4] Concepts of Particle Physics: Gottfried and Weisskoff (Oxford University Press).
[5] Introductory Nuclear Physics: K. S. Krane (John Wiley & Sons, Singapore)
[6] Fundamentals of Nuclear Physics: Jahan Singh (Pragati Prakashan, Meerut 1st ed.).
[7] Introduction to Particle Physics: M. P. Khanna (Prentice Hall of India, New Delhi)
[8] Introduction to High energy Physics: D. H. Perkins (Addison Wesley).
[9] Introduction to Elementary particles: D. Griffiths (John Wiley and Sons Singapore).