Course Handout Part-II

15th January 2021

Course Number : ***PHY F343***

Course Title : ***NUCLEAR AND PARTICLE PHYSICS***

Instructor-in-charge: ***BISWANATH LAYEK***

Course Description:

The course is designed to give a pedagogical overview and some working knowledge of theoretical (mainly) and experimental aspects of Nuclear & Particle Physics. Knowledge of quantum mechanics and basics of special relativity are essential to understand the topics covered in this course. This course will prepare/motivate students to take advanced courses either in Nuclear and/or Particle Physics, later on, in their career in preparation for pursuing active research in these areas.

Objective and Scope of the Course:

- Understanding the basic concepts behind the various Nuclear & Particle Physics phenomenon, structure and constituent of the nuclei.
- This course will enable the students to understand the general properties of nuclei, physics behind nuclear processes e.g., alpha decay, beta decay, nuclear scattering, nuclear fission, fusion etc.
- It will finally prepare the students to take advanced course in the area of Nuclear Physics/Particle Physics and help them in making career in teaching/research in the above fields.

Text and reference books :

(**Note : For the topics on nuclear physics, you are advised to purchase the book by D .C. Tayal**)

3. Text Book: (I) Theoretical Nuclear Physics; J. M. Blatt & V. F. Weisskopf, Dover Publications, New York

(II) Introduction to Elementary Particle Physics, David J. Griffiths, 2nd Revised Ed., Wiley, 2008

4. Reference Book:

(I) Nuclear Physics by D. C. Tayal by Himalaya Publishing House, 5th Edition 2008 (purchase this book, if possible)

(II) Nuclear Physics; S. N. Ghoshal, S. Chand Company Ltd.

(II) Quarks and Leptons: An Introductory Course in Modern Particle Physics, F. Halzen and A. Martin, Wiley, 2008

5. Course Plan: In the reference column CN stands for Class Notes.

Module No.	Lecture Session	Reference	Learning Outcomes
1. Overview, The needs, overall structure of the course and finally	L1 : Brief introduction of the course in view of its necessity in the context of fundamental physics, the course structure will be briefed to have an idea what are on offer	CN	Students will be able to understand how does this course fit into the overall scheme of fundamental physics
2. Addition of Angular Momentum	L2 - L3 : Angular momentum (spin and orbital) algebra : A brief review	CN	Possible values of nuclear spin can be realized through the 'addition' of spin of its constituents, namely proton & neutron and can be compared with observations of nuclear spin.
3. General Properties of Nuclei	L4-L6 : Nuclear size, charge, spin, magnetic moments, binding energies, packing fraction and separation energy L7 - L8 : Nuclear electric dipole moment, quadrupole moment, calculation of quadrupole moment spherically symmetrical &	Text1 : Chapter-I, CN	This gives an overview of the general static properties of the nuclei. Derivation of mass and binding energy formula etc.

	ellipsoidal charge distribution		
4. Semi-empirical Mass Formula	L9 - L10 : Bethe-Weizsacker Nuclear Mass formula and its applications in understanding the fission, nuclear decay, concept of mirror nuclei & its application,	Ref1 : Chapter – 9.6	Students should appreciate that importance of binding energy curve which is the heart of nuclear physics
5. Deuteron Problem	L11 - L12 : Deuteron as a two body problem, Its radial wave function using central potential L13: Quadrupole and magnetic moments of the deuteron	Text1 (Chap-II) on Deuteron Problem and Nuclear Force	It is devoted to the study of nuclear force via the solution of Deuteron as a two body problem.
6. Nuclear Scattering	L14-L16. Nuclear scattering, scattering amplitude, cross-sections, phase shift & partial wave analysis, optical theorem& low energy n-p scattering, Scattering length & spin dependence of n-p scattering	Ref. (I) and CN	It enables them to learn basics of nuclear scattering processes (which is another way to get information about nuclear force among its constituents), low energy n-p scattering and physics involved in these.
7. Radioactive Decay of Nuclei : Alpha decay	L17-L18 : Energetics of alpha decay, Geiger's law, Geiger-Nuttal Law & Gamow's theory of alpha decay	Text/Ref. Chap on Nuclear alpha & beta Decays	Learning about physics involved in the alpha and beta decays. Gamow's theory of alpha

8. Radioactive Decay of Nuclei : Beta decay	L19-L21: Energetics of beta decay, energy and angular momentum conservation in beta decay, Pauli's Neutrino hypothesis, Fermi's theory of beta decay, selection rules, allowed and forbidden transitions, Fermi & Gamow-Teller types of beta decays	Text/Ref. Chap on Nuclear alpha & beta Decays	.Pauli's neutrino hypothesis in the contex of beta decay . Fermi's theory of beta decay
9. Nuclear Reactions	L22 - L23 : Nuclear Reactions, Nuclear Fission & Fusion, Criticality Condition	Ref. Chap on Nuclear Reaction	Enable them to become familiar by the concepts of nuclear fission & fusion and various types of nuclear reactions.
10. Nuclear Shell Model	L24 : Nuclear stability and existence of magic numbers, Independent Particle Nuclear Shell Model	Ref. : Chap on Nuclear Models	It gives the concept of existence of magic numbers related to the stability of the nuclei.
11. Relativistic Kinematics	L25 : A brief review of relativistic kinematics, conservation of energy-momentum in non-relativistic and relativistic collisions	Text-II, CN	It tells how to solve problems related to relativistic nuclear collisions using conservation of four momentum and concept of special relativity.
12. Subatomic objects and Elementary particles	L26 - L31 : Brief history of 'Particles', Classification of particles based on interaction (strong, EM, & weak) , various quantum numbers & conservation laws, Gell-Mann's eightfold-way of Hadrons.	Text-II, CN	It gives a brief history about particles and development of particle physics. It also gives ways of classification of particles.

13. Quark Model of Hadrons	L32 - L33 : Introducing quarks, 'Fitting' quarks inside the hadrons.	Text-II, Ref-II, CN	Outcomes of DIS experiments & Quark Model of hadrons enable them to know the constituents of the hadrons as per the modern particle physics perspectives.
14. SU(2) & SU(3) quark flavor symmetry.	L34 - L35 : Introducing the concept of flavor symmetry and it's consequences. Understanding eightfold-way within flavor symmetry.	Ref-II	Understanding or explaining various kinematic properties of hadrons by imposing flavor symmetry.
15. Hadron Spectroscopy	L36 - L37 : Construction of hadron wave-function and introducing 'color' degree of freedom.	Text-II	Phenomenological understanding of magnetic moments of hadrons within quark model. The necessity of color and it's dynamical role in strong interactions.

Evaluation Scheme:

EC No.	Evaluation Component	Duration	Weight (%)	Date, Time & Venue	Nature of Component
1.	Tutorials/Quiz - 4	20 mins	30 %	Lect/Tut Hour	Open Book
2.	Mid Term Test	90 mins	30 %	<TEST>	Open Book
3.	Comprehensive	2 hours	40 %	<COMPRE>	Open Book

	Examination				

Notices: Notices/assignments/solutions etc. will be displayed only *on Google Classroom.*

Make-up Policy: No Make-up for tutorial tests. Make up for regular tests will be granted to genuine cases only with prior *intimation to / permission (if possible) from me.*

Instructor-in-Charge

BISWANATH LAYEK

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