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**Department of Physics**

**College of Science**

**University of Salahaddin**

**Subject: Nuclear Physics**

**Course Book – (Year 4)**

**Lecturer's name: Ali Hassan Ahmed**

**Academic Year: 2018/2019**

**Course Book**

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| **1. Course name** | **Nuclear Physics** | |
| **2. Lecturer in charge** | **Ali Hassan Ahmed** | |
| **3. Department/ College** | **Physics- General / Science** | |
| **4. Contact** | **e-mail: ali.ahmed@su.edu.krd**  **Tel: 07504611899** | |
| **5. Time (in hours) per week** | **Theory: 3**  **Practical: 0** | |
| **6. Office hours** | **4** | |
| **7. Course code** |  | |
| **8. Teacher's academic profile** | My Academic studies starts with the acceptance in the B.Sc. program in 1984 as an undergraduate student in Physics department and extended as I finished the following education degrees  **Education:**   |  |  | | --- | --- | | Physics- College of Science | B.Sc, 1988 | | Nuclear and Radiation Physics | M.Sc.1992 | | Nuclear Reactions and Radiation Physics | Ph.D. 2006 |   As I awards my first Academic title in 1993 and later on  **Academic titles attained:**   |  |  | | --- | --- | | **Academic title** | **Date of attainment** | | Assistant Lecturer | 20/5/1993 | | Lecturer | 16/7/2003 | | Assistant Professor | 21/11/2009 |   I starts my Academic role as a staff member giving lectures in my specialization through theoretical and practical modules to the students in different undergraduate stages, M.Sc. students, and Ph.D. students having different study areas    **Main Teaching Areas:**  \* Atomic Physics  \* Nuclear Physics (for B.Sc., M.Sc., Ph.D. students)  \* Quantum Mechanics (for B.Sc., M.Sc., Ph.D. students )  \* Elementary Particles  \* Statistical Mechanics  \* Medical Physics  \* General Physics  Beside my teachings I had different activities implying research performance in my interest areas  **Research Interests:**  \* Natural Background Radiations  \* Nuclear Reactions  \* Health Physics  \* Environmental Pollution  as well as I participate in scientific conferences, work shop, training courses, doing researches and supervising the postgraduate students as:   1. six ( 3 local + 3 international) scientific conferences, 2. Eleven different workshop and training courses ( 8 local + 3 international), 3. Twenty Eight published Research papers ( 19 local + 9 international) 4. Supervising 6 postgraduate students ( 5 M.Sc. + 1 Ph.D.)   In my outside university activities I gave consultation to the administration of health in Erbil concerning the radiation protection and measurements, and since 2007 and till now I worked as a volunteer consultant with the ministry of Environment to establish the national environmental laws and standards and supervise works concerning the radiation contamination and measurement filed. | |
| **9. Keywords** | **Nuclear Physics, Nuclear properties and forces, Nuclear structure, Nuclear Models, Radioactivity, Nuclear Reactions.** | |
| **10. Course overview:**    The course will start with a brief description of nuclear concepts: label, nomenclature, size, mass, density, charge, and spin of nuclei. The next topic which forms the principle of the subject is the nuclear structure involving a necessitate elements of quantum mechanics (as an introduction to understanding nuclear physics), nuclear constituent, nuclear force, nuclear binding energy, and nuclear models. The former topics imply the time-independent nuclear properties. The basic of nuclear radiation detection methods will be reviewed through studying the interactions of different types of nuclear radiation with matter.  The nuclear radioactive decay, nuclear transmutations, and nuclear reactions which represent the time-dependent properties of nuclei will be treated as extensions of the nuclear structure. Both of the fission and fusion processes and their applications will be introduced and reviewed. The detection mechanism of nuclear radiations by different types of nuclear detectors will be explained and assessed principally, as well as the radiation dosimetry and the biological effects of radiation constitutes a brief overview of the medical and environmental applications of nuclear radiations. | | |
| **11. Course objective:**  After the student studied and takes Atomic Physics lectures in their previous stage, they are ready now to understand the differences between the Atomic scale and Nuclear scale and then prepare to understand the actual source of nuclear force and power.  The world in which we live today proceeds with inventing new technological aspects and ideas, and nuclear physics is one of the most attracted and focused branch due to its important application as a new energy resource and a mass destruction weapon that all the society and countries are in effort to obtaining this technology. For this the study and taking this course will be in need for students to have the elementary information concerning the physical aspects concerning this modern branch of science. | | |
| **12. Student's obligation**  The class attendance on time is the first obligation of the student. During the two courses three compulsory written exams will be done beside three or more pop quizzes inside the lectures. As well solving exercises and given problems is the student duties. In this yea I have a plan to classify the students into several groups, each group will take a relative advance subject in Quantum Mechanics to prepare a common report and seminar which is presented in lectures and all students will take part and participate in the discussions. | | |
| **13. Forms of teaching**  All the lecture outlines are prepared and will be a subject of open discussion inside the lectures. In the beginning of each lecture a brief summary of the previous lecture will be remembered and the headlines of the forward lecture is identified and determined. The materials given in the lecture is always accompanied by the illustrations and detail derivations with the aid of white board and available animations; beside this for every physical phenomenon there will be scientific and live discussion which assists the student to understand the subjects. The lectures will be given mainly in the English language. Throughout the lectures as well as at the end of each chapter there will be home work problems given to the students as a review and assessments. In the last half hour of each lecture there will be a seminar prepared by a student whom selects a nuclear subject to be prepared as a presentation and will be open to discussion. | | |
| **14. Assessment scheme**  Knowledge of assigned readings, satisfactory completion of short assignments, class participation, and in-class work will constitute the students assessment program.  Grades will be based on timely completion of assignments, improvement over the study year, the quality of the discussions, and class attendance and participation.  There will be at least three written assignments in this class and a final examination, So that the final grade will be based upon the following criteria:  Mean of three examination: 40% (+ attendance and participation)  Final examination: 60%  Attendance and participation in class will also be averaged into your final mean grade former to the final examination.‌ | | |
| **15. Student learning outcome:**  The Nuclear courses are academic theoretical courses. The student enters the course should have a good mathematical skills especially the linear Algebra and differential equations beside the well understanding of Atomic Physics Principles. As it’s known, the Physics have a crucial roles in all the applicable science branches like communication, medicine, industry, environment, Information technology, astronomy …etc.; the understanding of exact role of modern physics is not complete unless the physicist will be familiar with the Nuclear physics and elementary particles. Moreover, the theories concerning the philosophy of life creation and universe evolution based on the knowledge extracted from nuclear reaction yields which form new and heaver elements. Thus throughout the course syllabus the student will haves the principal and basic information which enables him to understand and use the theoretical and practical concepts and applications in various branches of physics and life. | | |
| **16. Course Reading List and References‌:**     1. W.E. Meyerhof, Elements of Nuclear Physics, McGraw-Hill, Inc. USA, 1967. 2. K.S. Krane, Introductory Nuclear Physics, John Willey & Sons, Inc., Singapore and Canada 1988. 3. Ronald G. and William S., Theory and Problems of Modern Physics, McGraw-Hill, Inc. USA, 1999. 4. J.S. Lilley, Nuclear Physics: Principles and Applications, John Willey & Sons, Inc., England 2001. 5. J.K. Shultis and R.E. Faw, Fundamentals of Nuclear Science and Engineering, Marcel Dikker, Inc., USA, 2002. 6. J.L. Basdevant. J. Rich, M. Spiro, Fundamentals in Nuclear Physics, Springer Science+Business Media, Inc. U.S.A., 2004. | | |
| **17. The Topics:** | | **Lecturer's name** |
| **1. Fundamental Concepts**  1.1 Introduction  1.2 Basic Nuclear Properties   * + 1. Nuclear Mass and Charge     2. Nuclear Size     3. Intrinsic Angular Momentum of a Nucleus   1.2.4 Dynamic Properties of Nuclei  1.2.5 Nomenclature | | Ali Hassan Ahmed  ex: (6 hrs)  ex: 06/10/2018  weeks (1 + 2) |
| **2. Basic Nuclear Structure**  2.1 Elements of Quantum Mechanics  2.1.1 De Broglie Waves  2.1.2 Shrodinger Equation  2.1.3 Particle in a Closed Cubical Box  2.1.4 Barrier Penetration of a Particle  2.1.5 Parity  2.2 Nuclear Binding Energy  2.2.1 Binding Energy  2.2.2 Nuclear and Atomic Masses  2.2.3 Binding Energy of the Nucleus  2.2.4 Average Nuclear Binding Energies  2.2.5 Nucleon Separation Energy  2.2.6 Abundance Systematics of Stable Nuclides | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (3 + 4) |
| 2.3 Liquid-drop Model, Semiempirical Mass Formula  2.3.1 Coulomb Energy of a Spherical Nucleus  2.3.2 Asymmetry Energy  2.3.3 Mass Parabolas, Stability Line  2.3.4 Shell Effects  2.4 Shell Model  2.4.1 Experimental Basis of the Shell Model  2.4.2 Single Particle Shell Model  2.4.3 Spin Orbit Coupling Model  2.4.4 Other Nuclear Models | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (5 + 6) |
| 2.5 Energy Levels of Nuclei  2.6 Charge Symmetry and Independence of Nuclear Forces | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (7 + 8) |
| **First Examination** | | Ali Hassan Ahmed  (2 hrs)  week (9) |
| **3. Interactions of Nuclear Radiations with Matter**  3.1 Attenuation of Neutral Particle Beams  3.1.1 The Linear Interaction Coefficient  3.1.2 Attenuation of Uncollided Radiation  3.1.3 Average Travel Distance before an Interaction  3.1.4 Half-Thickness  3.1.5 Scattered Radiation  3.1.6 Microscopic Cross Sections  3.2 Photon Interactions  3.2.1 Photoelectric Effect  3.2.2 Compton Scattering  3.2.3 Pair Production  3.2.4 Photon Attenuation Coefficients | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (10 + 11) |
| 3.3 Neutron Interactions  3.3.1 Classification of Types of Interactions  3.3.2 Energy Loss of Neutrons  3.3.3 Energy Distribution of Neutrons After Collision  3.4 Attenuation of Charged Particles  3.4.1 Interaction Mechanisms  3.4.2 Particle Range  3.4.3 Stopping Power  3.4.4 Estimating Charged-Particle Ranges | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (12 + 13) |
| **4. Radioactivity**  4.1 Overview  4.2 Types of Radioactive Decay  4.3 Energetics of Radioactive Decay  4.3.1 Gamma Decay  4.3.2 Alpha-Particle Decay  4.3.3 Beta-Particle Decay  4.3.4 Positron Decay  4.3.5 Electron Capture  4.3.6 Neutron Decay  4.3.7 Proton Decay  4.3.8 Internal Conversion  4.3.9 Examples of Energy-Level diagrams | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (14 + 15) |
| 4.4 Characteristics of Radioactive Decay  4.4.1 The Decay Constant  4.4.2 Exponential Decay  4.4.3 The Half-Life  4.4.4 Decay Probability for a Finite Time Interval  4.4.5 Mean Lifetime  4.4.6 Activity  4.4.7 Half-Life Measurement  4.4.8 Decay by Competing Processes  4.5 Decay Dynamics  4.5.1 Decay with Production  4.5.2 Three Component Decay Chains  4.5.3 General Decay Chain | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (16 + 17) |
| 4.6 Naturally Occurring Radionuclides  4.6.1 Cosmogenic Radionuclides  4.6.2 Singly Occurring Primordial Radionuclides  4.6.3 Decay Series of Primordial Origin  4.6.4 Secular Equilibrium | | Ali Hassan Ahmed  ex: (3 hrs)  week (18) |
| **Second Examination** | | Ali Hassan Ahmed  (2 hrs)  week (19) |
| **5. Nuclear Reactions**  5.1 Introduction  5.2 Application of Conservation Laws  5.2.1 Energetics, Conservation of Linear Momentum  5.2.2 Other Conservation Laws  5.3 Types of Nuclear Reactions  5.4 Cross Sections | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (20 + 21) |
| 5.5 Compound Nucleus Reactions  5.6 Direct Reactions  5.7 Fission Reactions | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (22 + 23) |
| 5.8 Characteristics of the Fission Reactions  5.8.1 Fission Products  5.8.2 Neutron Emission in Fission  5.8.3 Energy Released in Fission  5.9 Fusion Reactions | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (24 + 25) |
| **6. Nuclear Force**  6.1 Introduction  6.2 Meson Theory of Nuclear Forces | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (26 + 27) |
| **7. Radiation Doses and Hazard Assessment**  7.1 Historical Roots  7.2 Dosimetric Quantities  7.2.1 Energy Imparted to the medium  7.2.2 Absorbed Dose | | Ali Hassan Ahmed  (3 hrs)  week (28) |
| 7.2.3 Calculating Absorbed Doses  7.2.4 Exposure  7.2.5 Relative Biological effectiveness  7.2.6 Dose Equivalent  7.2.7 Quality Factor  7.2.8 Effective Dose Equivalent  7.2.9 Effective Dose  7.3 Natural Exposures for Humans | | Ali Hassan Ahmed  ex: (6 hrs)  weeks (29 + 30) |
| **18. Practical Topics (If there is any)** | |  |
| In this section The lecturer shall write titles of all practical topics he/she is going to give during the term. This also includes a brief description of the objectives of each topic, date and time of the lecture | |  |
| **19. Examinations:**  ***Q1.*** Choose the correct answer. (The false answer will cancel a correct one).(40 marks)   1. The effect of shell closer is represented by the ………… term in the semi-empirical mass formula. 2. pairing b. asymmetry c. magic d. surface 3. The contribution of the volume energy term to the total binding energy of the nuclei ……….. with decreasing the mass number. 4. increases b. decreases c. remain constant d. approaches zero 5. The neutron separation energy is lower for the nuclei having   a. N= magic no. b. N=magic no.+1 c. N=magic no.-1 d. None of the above   1. The appearance of the shell structure in the nuclei energy levels were established by the ……….. model 2. Single particle shell model b. liquid drop model c. collective model 3. None of the above 4. From the plot of the mass difference between mirror nuclei, one can evaluate 5. η b. ac c. δ d. as 6. The energy needed to remove the last tightly bound neutron in  equals 7. 4.44MeV b. 1.14MeV c. 4.14MeV d. 1.41 MeV 8. The total binding energy for the  nucleus equals 9. 0.684GeV b. 8.64MeV c. 4.68MeV d. 0.847GeV 10. The most stable isobar for A=43 is 11. b.  c.  d. None of the above     ***Q2.*** Determine the mass difference between two mirror nuclei having N and Z differing by one unit. (30 marks)  **Answer:**  Z1 = Z2 +1 so Z2 = Z1 – 1  M(A,Z1) = Z1 MH + (A - Z1) Mn – Btot (A, Z1)  = Z1 MH + A Mn – Z1 Mn – av A + as A2/3 + ac (Z1(Z1 – 1) /A1/3) +    aa ((N – Z1)2 / A) ± δ - η  M(A,Z2) = Z2 MH + A Mn – Z2 Mn – av A + as A2/3 + ac (Z2(Z2 – 1) /A1/3) +    aa ((N – Z2)2 / A) ± δ - η  = Z1 MH – MH + A Mn – Z1 Mn + Mn – av A + as A2/3 +  ac (Z1- 1) (Z1 – 2) /A1/3) + aa ((N – (Z1-1))2 / A) ± δ - η  [M(A,Z1) – M(A,Z2)] c2 = (MH – Mn) C2 + (ac/A1/3) [- (Z1-1) (Z1-2)+Z1(Z1-1)]  [M(A,Z1) – M(A,Z2)]c2 = (Z1-1) (3e2/5R) [ Z1 – Z1 +2] + (MH – Mn)c2  = (Z1-1) (6e2/5R) + (MH – Mn) c2  ***Q3.*** Find the expected angular momentum and parity of the, nuclei.  (30 marks)  **Answer:**    1P3/2  1/2  1d5/21/2  1P1/2  1/2  1S1/2  Jπ (8O15) = (1/2)- Jπ (8N14) = (1)+  Mn=1.008665u, Mp=1.007825u, M(16O)=15.994915u, M(17O)=16.999133u,  M(98Mo)=97.905409u. ac=0.58MeV, aa=19.3MeV.  **GOOD LUCK Ali H. Ahmed** | | |
| **20. Extra notes:**  Here the lecturer shall write any note or comment that is not covered in this template and he/she wishes to enrich the course book with his/her valuable remarks. | | |
| **21. Peer review پێداچوونه‌وه‌ی هاوه‌ڵ**  This course book has to be reviewed and signed by a peer. The peer approves the contents of your course book by writing few sentences in this section.  *(A peer is person who has enough knowledge about the subject you are teaching, he/she has to be a professor, assistant professor, a lecturer or an expert in the field of your subject).*  ئه‌م کۆرسبووکه‌ ده‌بێت له‌لایه‌ن هاوه‌ڵێکی ئه‌کادیمیه‌وه‌ سه‌یر بکرێت و ناوه‌ڕۆکی بابه‌ته‌کانی کۆرسه‌که‌ په‌سه‌ند بکات و جه‌ند ووشه‌یه‌ک بنووسێت له‌سه‌ر شیاوی ناوه‌ڕۆکی کۆرسه‌که و واژووی له‌سه‌ر بکات.  هاوه‌ڵ ئه‌و که‌سه‌یه‌ که‌ زانیاری هه‌بێت له‌سه‌ر کۆرسه‌که‌ و ده‌بیت پله‌ی زانستی له‌ مامۆستا که‌متر نه‌بێت.‌‌ | | |