Department of Physics

College of Science

University of Salahaddin

Subject: Nuclear Reactions
Course Book – 4th Year General

Lecturer's name: Dr. Mohammed I. Hussein

Academic Year: 2022/2023 /Second Semester

Course Book

<table>
<tr><td>1. Course name</td><td>Principles of Nuclear Physics</td></tr>
<tr><td>2. Lecturer in charge</td><td>Dr. Mohammed Issa Hussein</td></tr>
<tr><td>3. Department/ College</td><td>Physics- General / Science</td></tr>
<tr><td>4. Contact</td><td>e-mail: mohamm.hussein@su.edu.krd</td></tr>
<tr><td>5. Time (in hours) per week</td><td>Theory: 4 (3 theoretical+1 tutorial)
Practical: 0</td></tr>
<tr><td>6. Office hours</td><td>4</td></tr>
<tr><td>7. Course code</td><td></td></tr>
<tr><td>8. Teacher's academic profile</td><td>My Academic studies starts with the acceptance in the B.Sc. program in 1998 as an undergraduate student in Physics department and extended as I finished the following education degrees

<u>Education:</u>
<table>
<tr><td>B.Sc, 2003</td><td>Physics</td></tr>
<tr><td>M.Sc.2012</td><td>Nuclear Physics</td></tr>
<tr><td>Ph.D. 2020</td><td>Nuclear Physics</td></tr>
</table>
As I awards my first Academic title in 2012 and later on
<u>Academic titles attained:</u>
<table>
<tr><th>Academic title</th><th>Date of attainment</th></tr>
<tr><td>Assistant Lecturer</td><td>24/4/2012</td></tr>
<tr><td>Lecturer</td><td>27/7/2020</td></tr>
<tr><td></td><td></td></tr>
</table>
I have more than 18 years’ experience teaching, during my academic life I have tough, the following subjects for undergraduate students such as: General Physics of the first year Environmental department, General Physics lab. of the 1st year physics, , General Physics lab. of the 2nd year Gelogy and Environment Science Dept., Modern physics Lab of the 2nd year students, Nuclear physics lab for 3rd medical physics, Nuclear physics and Nuclear physics lab. for the 4th year of physics students, also I have five papers are published in different local and foreign journals.

I participated in many international and local conferences and I published many scientific articles..</td></tr>
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	- I awarded B.Sc. in Physics (College of Science) in 2003 Salahaddin University-Erbil. **- M.Sc. in 2012 (Salahaddin University-Erbil).** **- Assist. Lecturer from 2012 to 2020.** **- PhD. in 2020 (Salahaddin University-Erbil).** **Lecturer from 2020 until now.**
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.

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/Weeks Number per chapter**
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	Dr. Mohammed I. Hussein weeks (1 , 2, 3 and 4)
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	

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	Dr. Mohammed I. Hussein weeks (5, 6,7,8, 9 and 10)
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	
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	
First Examination	Dr. Mohammed I. Hussein (2 hrs)
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	Dr. Mohammed I. Hussein weeks (11 and 12)

5.4 Cross Sections	
6. Nuclear Force 6.1 Introduction 6.2 Meson Theory of Nuclear Forces	Dr. Mohammed I. Hussein weeks (13 + 14)
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:

Salahaddin University-Erbil	**Midterm Exam**	**Subject: Nuclear Reactions**
Science College	**2021-2022**	**4th Year Students (General)**
Physics Department		**Time: 60 Minutes**

Q.1: Explain the following in brief: (10 marks)

1. Bremsstrahlung radiation. 2. Stopping power. 3. Linear attenuation coefficient.
4. Half-value thickness. 5. Compton wavelength.

Q.2: Write an equation for each of the following (10 marks)

1. Stopping power due to ionization–excitation for p, d, t, α
2. Stopping power due to ionization–excitation for electrons
3. The recoil kinetic energy of the electron in Compton Effect.
4. The minimum energy of the scattered photon in Compton Effect
5. The kinetic energy of the pair

Q.3: The gamma-ray photon collides with an electron at rest. It is scattered through 90^0, what is it frequency after collision, if it's initial frequency is (3×10^{19} Hz)? (5 marks)

Q.4: Draw the figure of summarizes the energetics of the three beta-decay (β^- , β^+ , and EC) processes? (15 marks)

Q.5: Determine the predominant decay mode of the gamma radiation of the $\frac{3}{2}^{-} \rightarrow \frac{3}{2}^{+}$?
(10 marks)

Q.6: Which of the following decay modes $\alpha - decay,\ \beta^{-}\ decay,\ \beta^{+}\ decay,\ and\ EC$ are possible for ${}^{40}_{19}K$? (10 marks)

where:

$M({}^{4}_{2}He) = 4.0026033\ u$
$M({}^{36}_{17}Cl) = 35.96830811\ u$
$M({}^{40}_{18}Ar) = 39.96238325\ u$
$M({}^{40}_{19}K) = 39.96399893\ u$
$M({}^{40}_{20}Ca) = 39.96259152\ u$

GOOD LUCK **Dr. Mohammed I. Hussein**

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 پێداچوونەوەی هاوەڵ

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).

ئەم کۆرسبووکە دەبێت لەلایەن هاوەڵێکی ئەکادیمیەوە سەیر بکرێت و ناوەرۆکی بابەتەکانی کۆرسەکە پەسەند بکات و جەند ووشەیەک بنووسێت لەسەر شیاوی ناوەرۆکی کۆرسەکە و واژووی لەسەر بکات.

هاوەڵ ئەو کەسەیە کە زانیاری هەبێت لەسەر کۆرسەکە و دەبیت پلەی زانستی لە مامۆستا کەمتر نەبێت.