Course Title:	**Nuclear and High Energy Physics**
Course Code:	*Enter Course Code.*
Program:	Master **of Science in Nuclear Physics**
Department:	**Physics**
College:	**Sciences**
Institution:	**Umm Al-Qura University**
Version:	**2nd**
Last Revision Date:	**January 2025**

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: (3)					
2. Course type					
A.	☐University	☐College	☒ Department	☒ Track	
B.	☒ Required		☐Elective		
3. Level/year at which this course is offered: (3rd semester /2nd year)					

4. Course General Description:

This course provides an introduction to the fundamental concepts of nuclear and high-energy physics, focusing on the structure and dynamics of nuclei, particle interactions, and the principles governing particle accelerators and detectors. The course emphasizes conceptual understanding and practical applications while minimizing advanced mathematical derivations.

Key topics include the historical development of nuclear and high-energy physics, nuclear stability and decay, models of nuclear structure, and the forces governing particle interactions. Students will explore the physics of particle accelerators, detection techniques, and high-energy nuclear reactions.

In the final weeks, the lecturer will choose one or more elective topics tailored to advanced or applied areas of interest, including:

1. New Particles and Neutrino Physics: Exploration of the Higgs boson discovery and neutrino oscillations.
2. Dark Matter and Dark Energy: Introduction to the theoretical and experimental efforts in understanding these phenomena.
3. Experimental Techniques and Monte Carlo Simulations: Basics of data analysis, event reconstruction, and the use of simulation tools like PYTHIA and Geant4.
4. Future Trends in High-Energy Physics: Discussions on emerging technologies and cutting-edge research.

By the end of the course, students will gain a comprehensive understanding of nuclear and particle physics, preparing them for further study or careers in physics research and applied fields.

5. Pre-requirements for this course (if any)**:**

6. Pre-requirements for this course (if any)**:**

7. Course Main Objective(s):

1. Understand the Fundamental Concepts of Nuclear Physics:
   a. Introduce students to the properties of nuclei, such as mass, size, spin, and stability.
   b. Explore nuclear forces and their role in nuclear reactions and decay processes.
2. Explain Models of Nuclear Structure:
   a. Provide an intuitive understanding of key nuclear models, including the liquid drop model, shell model, and collective model.
   b. Discuss the applications of these models in explaining experimental results.
3. Explore the Basics of High-Energy Physics:
   a. Introduce students to the Standard Model and the fundamental forces (gravitational, electromagnetic, strong, and weak).
   b. Discuss the roles of quarks, leptons, and force carriers in particle interactions.
4. Introduce Particle Accelerators and Detectors:
   a. Explain the working principles of particle accelerators, such as cyclotrons and synchrotrons.
   b. Provide an overview of detector technologies and their applications in identifying particles.
5. Discuss Applications of Nuclear and High-Energy Physics:
   a. Highlight the relevance of nuclear physics in energy production, medicine, and industry.
   b. Explore high-energy physics applications in cosmology, particle accelerators, and cutting-edge research.
6. Foster Engagement with Advanced Topics:
   a. Provide flexibility through elective topics, including neutrino physics, dark matter, and Monte Carlo simulations, tailored to the lecturer's expertise and student interests.
7. Prepare Students for Further Study and Research:
   a. Develop students' conceptual understanding, critical thinking, and analytical skills, enabling them to pursue advanced studies or careers in physics-related fields.

These objectives aim to provide a balanced and accessible approach to nuclear and high-energy physics, focusing on the core concepts and practical applications while minimizing advanced mathematical complexity.

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2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100
2	E-learning		
3	Hybrid		

No	Mode of Instruction	Contact Hours	Percentage
	1. Traditional classroom 2. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
1.	**Lectures**	45
2.	**Laboratory/Studio**	
3.	**Field**	
4.	**Tutorial**	
5.	**Others (specify)……**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Describe nuclear properties and nuclear models.	**K1-I**	Demonstrate the basic information and principles through lectures. 2.Keep the question "why" or "how" to explain always there	Discussions Quizzes Exams
1.2	Explain different forms of radioactivity and account of their occurrence	**K2-I**		
1.3	Describe the principles of particle accelerators and detectors with their use in HEP	**K1-P**		
2.0	**Skills**			
2.1	To know how to assess, or calculate nuclear binding	**S1-P**	1.Build a strategy to solve problems	Homework assignments Exam

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
	energy, proton/neutron configurations, spins.		2. Define duties for each chapter.	
2.2	Calculate decay rates ,cross section , momentum and enrgy	**S2-P**		
2.3	Apply theoretical concepts to practical problems in particle collisions, detector design, and energy scales.	**S1-M**		
3.0	**Values, autonomy, and responsibility**			
3.1	Participate effectively in team to deliver project in time	**V1-P**	Give students tasks of duties.	Discussions and assignments reading or summarizing subject
3.2	Inspire students to pursue innovative ideas and contribute to the ongoing evolution of the field.	**V2-M**		

C. Course Content:

No	List of Topics	Contact Hours
1	**Introduction and History of Nuclear and High-Energy Physics**: Historical milestones in nuclear and particle physics; overview of particle accelerators and detectors and their importance in research.	3
2	**Basic Concepts of Nuclear Physics**: Explanation of nuclear masses, sizes, spins, and dipole moments; qualitative understanding of nuclear stability, instability, and forces.	3
3	**Binding Energy and Nuclear Properties**: The binding energy per nucleon curve; concepts of nuclear density and spin explained through accessible examples.	3
4	**Nuclear Models I**: Introduction to the liquid drop model and Fermi gas model; the shell model with harmonic oscillator and spin-orbit interaction concepts.	3
5	**Nuclear Models II and Collective Model**: Explanation of rotational and vibrational modes in the collective model; applications of these models to real-world nuclear reactions.	3

6	**Radioactive Decay**: Types of radioactive decay (alpha, beta, gamma); simplified explanation of Fermi theory and decay chains; introduction to gamma emission concepts.	3
7	**Nuclear Reactions**: Qualitative understanding of fusion, fission, and scattering processes; explanation of reaction cross-sections, rates, and energy applications without mathematical complexity.	3
8	**Fundamental Forces and Particle Interactions**: Overview of gravitational, electromagnetic, weak, and strong forces; qualitative explanation of force carriers and energy scales.	3
9	**Particle Accelerators and Detectors I**: Introduction to types of accelerators (cyclotrons, linear accelerators, and synchrotrons); simple explanation of beam dynamics and luminosity in colliders.	3
10	**Particle Accelerators and Detectors II**: Types of detectors (calorimeters, tracking detectors, timing detectors, and scintillators); practical applications in particle identification and measurements.	3
11	**High-Energy Nuclear Reactions**: Overview of proton-proton, proton-nucleus, and heavy-ion collisions; simple explanation of cross-sections, reaction rates, and hadronization.	3
12	**Elective Topic 1: New Particles and Neutrino Physics**: Qualitative exploration of the Higgs boson discovery and its implications; introduction to neutrino oscillations and mass determination.	3
13	**Elective Topic 2: Dark Matter and Dark Energy**: Overview of dark matter detection methods and technologies; introduction to dark energy and its role in cosmology.	3
14	**Elective Topic 3: Experimental Techniques in High-Energy Physics**: Basics of data acquisition, event reconstruction, and signal processing; introduction to Monte Carlo simulations.	3
15	**Elective Topic 4: Monte Carlo Simulations and Future Trends**: Introduction to simulation tools (e.g., PYTHIA, MadGraph, Geant4); future directions in high-energy physics research.	3
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	Quizzes	All week	10
2.	Homework	All week	10
3.	Midterm	8th week	30
4	Final exam	**18th week**	50

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	1. Perkins, Donald H. Introduction to High Energy Physics (Cambridge University Press, 2000), 4th edition. ISBN-10. 0521621968 2. A. Das and T. Ferbel, Introduction to nuclear and particle physics (second edition) World Scientific (2003) ISBN 981-238-744-7. 3. R.C. Verma & S.C. Gupta, V.K. Mittal, Introduction to nuclear and particle physics 4th Edition, Kindle Edition (2018) ISBN-13: 978-9387472617 4. Books Wagon, Basic Ideas And Concepts In Nuclear Physics: An Introductory Approach 3Rd Edition (Series In Fundamental And Applied Nuclear Physics) (2017). ISBN 0 7503-0534 7 hbk, 07503 0535 pbk. 5. Burcham, Nuclear and Particle Physics: An Introduction 2nd Edition (2009) ISBN-13: 978-0470742754. 6. **"Nuclear Physics"** Anwar Kamal, *Year*: 2014 *ISBN*: 978-3-642-38655-8
Supportive References	• **"The Basics of Nuclear and Particle Physics"** *Authors*: Alexander Belyaev, Douglas Ross, *Year*: 2021 *ISBN*: 978-3-030-80116-8. Springer Link • **"Nuclear and Particle Physics"** *Author*: S. L. Kakani *Year*: 2021, *ISBN*: 978-3-030-58313-2
Electronic Materials	http://particleadventure.org/ (The Particle Adventure) http://hepweb.rl.ac.uk/ppUK/ (Particle Physics in the UK) http://pdg.lbl.gov/ (Particle Data Group home page) http://www.hep.net/ (High Energy Physics Information Center)
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	1. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 2. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 3. Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	

Items	Resources
	1. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	1. Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys to gather students' perceptions of teaching methods, clarity of explanations, and engagement.
Effectiveness of students' assessment	Course Instructor	Compare assessments (quizzes, assignments, projects) with course learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	Track student engagement with electronic materials (e.g., downloads, page visits) and physical resources.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates on the applicability of course content and learning outcomes in research or professional practice.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	**JANUARY 2025**

Course Title:	**Elementary Particle Physics**
Course Code:	*Enter Course Code.*
Program:	**Master of science in Nuclear Physics**
Department:	**Physics**
College:	**Sciences**
Institution:	**Umm Al-Qura University**
Version:	**2nd**
Last Revision Date:	**January 2025**

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: (3hrs)					
2. Course type					
A.	☐University	☐College	☒ Department	☒ Track	
B.	☒ Required			☐Elective	
3. Level/year at which this course is offered: (3rd semester /2nd year)					
4. Course General Description:					

This course introduces the fundamental concepts of elementary particle physics, covering its historical development, key principles, and modern applications. Topics include the discovery of fundamental particles, the dynamics of the four forces, and the Standard Model's principles. Students will explore particle properties, symmetries, conservation laws, and basic relativistic kinematics.

In the final weeks, the lecturer will select one of three electives:

- Feynman Diagrams Simplified: Visualizing particle interactions.
- Applications of Particle Physics: Uses in accelerators, medical imaging, and cosmology.
- Beyond the Standard Model: Topics like dark matter and neutrino physics.

By the end, students will understand the principles governing the universe at its most fundamental level, preparing them for advanced studies or applications in particle physics.

5. Pre-requirements for this course (if any):

6. Pre-requirements for this course (if any):

7. Course Main Objective(s):

1. Introduce the historical development of particle physics, highlighting milestones from fundamental particle discoveries to the Standard Model.
2. Explain key concepts, including particle properties, conservation laws, symmetries, and the dynamics of fundamental forces.
3. Connect particle physics theory to practical applications in technology, medical imaging, and cosmology.
4. Explore advanced topics, such as dark matter, neutrino oscillations, and areas beyond the Standard Model.
5. Prepare students for further studies by fostering critical thinking, analytical skills, and research readiness in particle physics.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 1. Traditional classroom 2. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
3.	**Lectures**	45
4.	**Laboratory/Studio**	
5.	**Field**	
6.	**Tutorial**	
7.	**Others (specify)……**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Describe different types of elementary particles and their properties.	**K1-I**	Demonstrate the basic information and principles through lectures. 2.Keep the question "why" or "how" to explain always there	**1**.Discussions 2.Quizzes 3.Exams
1.2	Explain particle phenomenology	**K2-P**		
1.3	Demonstrate elementary particle dynamics.	**K3-M**		
2.0	**Skills**			
2.1	Apply conservation of energy and momentum in particle dynamics.	**S1-P**	**1**.Build a strategy to solve problems 2. Define duties for each chapter.	Homework assignments
2.2	State the basic difference between SU(3) and SU(6) symmeteries .	**S2-I**		
2.3	Calculate decay rates and scattering cross section using Feynman diagrams..	**S3-M**		
3.0	**Values, autonomy, and responsibility**			
3.1	Participate effectively in multidisciplinary and/or interdisciplinary teams	**V1-P**	Give students tasks of duties.	Discussions and assignments (reading or summarizing subject)
3.2	Be able to self-learning, analysis and synthesis of data and information using of the necessary technology	**V2-M**		
...				

C. Course Content:

No	List of Topics	Contact Hours
1	**Historical Introduction to Elementary Particles (Part 1)**: The discovery of the electron (1897), the photon (1900-1924), and early quantum theory concepts.	3
2	**Historical Introduction to Elementary Particles (Part 2)**: Development of meson theory (1934-1947), antiparticles, and neutrinos.	3
3	**Historical Introduction to Elementary Particles (Part 3)**: Strange particles, the Eightfold Way, and the quark model.	3
4	**Overview of the Standard Model**: Qualitative understanding of the Standard Model, discovery of quarks, leptons, bosons, and their roles.	3
5	**Elementary Particle Dynamics - The Four Forces**: Simplified overview of gravitational, electromagnetic, strong, and weak forces; qualitative differences and strengths.	3
6	**Elementary Particle Dynamics - Quantum Electrodynamics (QED)**: Basics of photons and electrons, their interactions, and electromagnetic scattering in simple terms.	3
7	**Elementary Particle Dynamics - Quantum Chromodynamics (QCD)**: Introduction to quarks, gluons, and color charge; basic concepts of confinement and strong force.	3
8	**Weak Interactions and Conservation Laws**: Introduction to weak force; conservation laws (e.g., lepton number, baryon number) explained with examples.	3
9	**Relativistic Kinematics - Basics**: Simplified explanation of Lorentz transformations and four-vectors with examples (space-time, energy-momentum).	3
10	**Relativistic Kinematics - Applications**: Examples of two-body decays, energy and momentum conservation in particle reactions; thresholds explained qualitatively.	3
11	**Symmetries and Conservation Laws (Part 1)**: Introduction to symmetries and conservation laws (energy, momentum, angular momentum); qualitative discussion of parity.	3
12	**Symmetries and Conservation Laws (Part 2)**: Overview of CP violation, charge conjugation, time reversal symmetry, and implications for particle physics experiments.	3
13	**Elective Topic 1: Feynman Diagrams Simplified**: Visual representation of particle interactions; qualitative explanation of scattering and decay processes.	3
14	**Elective Topic 2: Applications of Particle Physics**: Use of particle physics in accelerators, medical imaging technologies, and cosmology.	3
15	**Elective Topic 3: Beyond the Standard Model**: Introduction to cutting-edge research topics like dark matter, neutrino oscillations, and supersymmetry.	3
Total		

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	Term works	All weeks	20%
2.	Mid-term exam	7th week	30%
3.			
4.	Final exam	End of the term	50%

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	1. David Griffiths, Introduction to elementary particles (2008) Wiley-VCH Verlag GmbH and Co. K GaA, Weinheim, ISBN-13: 978-3527406012. 2. Robert Purdy, "Particle Physics: An Introduction (Essentials of Physics Series)", (2018) ISBN-13: 978-1683921424. 3. Brian R. Martin and Graham Shaw, "Particle Physics (Manchester Physics Series) 4th Edition" (2017) ISBN-13: 978-1118912164. 4. A modern introduction to particle physics, Fayyazuddin and Riazuddin, World Scientific, 1992. 10. 9810210736. 5. **"Introduction to Elementary Particle Physics" by Alessandro Bettini**, 3rd Edition, (2024) **ISBN**: 978-1-009-44073-8 6. **"Modern Elementary Particle Physics: Explaining and Extending the Standard Model" by Gordon Kane**, 2nd Edition (2017), **ISBN**: 978-1-107-16508-3
Supportive References	7. **"Elementary Particle Physics" by Andrew J. Larkoski** 1st Edition (2023) **ISBN**: 978-1-108-84245-3 8. **"Elementary Particles and Their Interactions" by Stephen P. Martin**, 1st Edition, (2022), **ISBN**: 978-3-031-14367-0.
Electronic Materials	9. **The Particle Adventure** a. **URL**: https://www.particleadventure.org/ 10. **PhET Interactive Simulations** a. **URL**: https://phet.colorado.edu/ 11. **"Particle Physics" OpenLearn Course by The Open University** a. **URL**: https://www.open.edu/openlearn/science-maths-technology/particle-physics/content-section-0

	12. **"Elementary Particle Physics" YouTube Playlist** a. **URL:** https://www.youtube.com/playlist?list=PLRN3HroZGu2lkRDsRxzqy_WU8NRk6evbD
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	13. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 14. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 15. Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	1. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	1. Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys to gather students' perceptions of teaching methods, clarity of explanations, and engagement.
Effectiveness of students' assessment	Course Instructor	Compare assessments (quizzes, assignments, projects) with course learning outcomes (CLOs) to ensure alignment.

Assessment Areas/Issues	Assessor	Assessment Methods
Quality of learning resources	Course Instructor	Track student engagement with electronic materials (e.g., downloads, page visits) and physical resources.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates on the applicability of course content and learning outcomes in research or professional practice.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)
Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	**JANUARY 2025**

Course Title:	**Quantum Field Theory**
Course Code:	*Enter Course Code.*
Program:	**Master of Science in Nuclear Physics**
Department:	**Physics**
College:	**Science**
Institution:	**Umm Al-Qura University**
Version:	**2nd**
Last Revision Date:	**January 2025**

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: (3)					
2. Course type					
A.	☐University	☐College	☒ Department	☒ Track	
B.	☒ Required		☐Elective		
3. Level/year at which this course is offered: (3rd Semester/2nd year)					
4. Course General Description:					

This course introduces Quantum Field Theory (QFT) principles in an accessible way, focusing on field quantization, particle interactions, and QFT applications in modern physics. It covers topics like the quantization of electromagnetic fields, the Klein-Gordon and Dirac equations, and Lagrangian and Hamiltonian field theory, with an emphasis on conceptual and visual understanding.

In the final weeks, the lecturer will select one elective topic:

1. Feynman Diagrams in QFT: Visual representation of particle interactions.
2. S-Matrix Theory: Connection to observable quantities in scattering experiments.
3. Feynman Rules in QED: Applications in quantum electrodynamics.
4. Future Directions in QFT: Topics like gauge theories and effective field theories.

By the end, students will have a strong conceptual foundation in QFT, preparing them for further studies or applications in theoretical and particle physics. The course is adaptable to student interests.

5. Pre-requirements for this course (if any)**:**

6. Pre-requirements for this course (if any)**:**

7. Course Main Objective(s):

1. Provide a conceptual understanding of Quantum Field Theory (QFT), emphasizing its connection to quantum mechanics, relativity, and field quantization.
2. Introduce key frameworks like the Klein-Gordon and Dirac equations, along with simplified approaches to Feynman diagrams and S-Matrix theory.
3. Highlight practical applications of QFT, including radiative transitions, Compton scattering, and photon dynamics in quantum electrodynamics.
4. Offer flexibility through advanced elective topics, such as gauge theories and effective field theories, tailored to student interests and lecturer expertise.
5. Prepare students for further studies or research by developing critical thinking and problem-solving skills in theoretical and particle physics.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 6. Traditional classroom 7. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
8.	**Lectures**	45
9.	**Laboratory/Studio**	
10.	**Field**	
11.	**Tutorial**	
12.	**Others (specify)……**	

	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Recognize the fundamental formalism and concepts of quantum field theory.	**K1-I**	**Lectures:** Deliver structured explanations of key concepts with real-world examples.	Tests (Multiple Choice/Short Answer), Essays, Problem Sets, Discussions/Presentations, Online uizzes
1.2	Explain the use of Feynman diagrams in describing electromagnetic interactions.	**K2-P**		
1.3	Understand field quantization and its role in reproducing calculations	**K3-M**		
2.0	**Skills**			
2.1	Quantize the electromagnetic field using Fourier analysis, with and without charges.	**S1-P**	**Problem Solving:** Practice field quantization, commutation relations, and S-matrix derivations.	8. Assignments 9. Problem Sets 10. Lab Work
2.2	Impose harmonic oscillator commutation relations and understand their implications.	**S2-I**		
2.3	Analyze interactions via the electric dipole moment of charge systems.	**S3-M**		
3.0	**Values, autonomy, and responsibility**			
3.1	Intellectual Curiosity: Encouraging continuous exploration of quantum field theory concepts.	**V2-P**	**Intellectual Curiosity:** Foster open discussions, research projects, and guest lectures.	Intellectual Curiosity and Scientific Integrity: Assessment: Research
3.2	Scientific Integrity: Committing to honesty and ethical research practices.	**V3-M**		

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
				projects, peer reviews,

C. Course Content:

No	List of Topics	Contact Hours
13.	**Introduction to Quantum Field Theory**: Historical development of QFT; review of quantum mechanics and relativity as precursors; motivation for field quantization.	3
14.	**Advanced Concepts in Electromagnetic Fields (Part 1)**: Quantization of radiation fields; interaction of electric dipoles with external fields; classical and quantum perspectives on electromagnetic fields.	3
15.	**Advanced Concepts in Electromagnetic Fields (Part 2)**: Radiative transitions in atoms; introduction to Thomson scattering; examples from atomic and particle physics applications.	3
16.	**Foundations of Lagrangian Field Theory (Part 1)**: Basics of relativistic formalism in field theory; review of Lagrangian and Hamiltonian mechanics with simple examples.	3
5.	**Foundations of Lagrangian Field Theory (Part 2)**: Symmetries and conservation principles; introduction to Noether's theorem and its physical implications; basic field quantization concepts.	3
6.	**Klein-Gordon Fields (Part 1)**: Formulation of the neutral Klein-Gordon field; physical interpretation of field dynamics; interaction of charged Klein-Gordon fields with external fields.	3
7.	**Klein-Gordon Fields (Part 2)**: Advanced topics in Klein-Gordon fields; commutation relations; conservation principles and physical invariance.	3
8.	**The Dirac Equation (Part 1)**: Derivation of the Dirac equation; connection to spin-½ particles; physical examples, including electron dynamics and applications.	3
9.	**The Dirac Equation (Part 2)**: Canonical quantization of the Dirac field; introduction to the fermion propagator; applications in particle physics.	3
10.	**Classical and Covariant Foundations of Electromagnetic Fields**: Basics of classical electromagnetic field theory; covariant quantization of the electromagnetic field; physical insights.	3
11.	**Photon Dynamics**: The photon propagator: its structure, derivation, and applications; introduction to quantum electrodynamics (QED) concepts.	3
12	**Elective Topic 1: Feynman Diagrams in QFT**: Basics of Feynman diagrams in configuration and momentum space; rules and simple applications; examples such as Compton scattering.	3

13	**Elective Topic 2: S-Matrix Theory**: Structure of the S-Matrix; dimensional analysis and natural units; application of the S-Matrix to observable quantities in scattering experiments.	**3**
14	**Elective Topic 3: Feynman Rules in QED**: Overview of Feynman rules applied to QED processes; practical examples such as electron-photon scattering; simplified computational frameworks.	**3**
15	**Elective Topic 4: Future Directions in QFT**: Discussions on advanced topics such as effective field theories, gauge theories, and applications of QFT in modern physics.	**3**
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
17.	Exercises & Home works	All weeks	10%
18.	Quizes	4th & 9th weeks	10%
19.	Midterm	8th week	30%
4.	Final Exam	18th week	50%

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	. Graham Shaw and Franz Mandl, Quantum Field theory, John Wiley and Sons (2016), ISBN-13: 978-8126565061 2. **"Quantum Field Theory: An Introduction"**, Eduardo Fradkin *Edition*: 1st (2023) *ISBN*: 978-981-99-5409-4 3. **"Quantum Field Theory and the Standard Model"** *Author*: Matthew D. Schwartz, *Edition*: 1st (2014) *ISBN*: 978-1-107-03473-0
Supportive References	4. Bipin R. Desai, Quantum Mechanics with basic field theory (2010) Cambridge university press, ISBN 978-0-521-87760-2 5. Andrei Smilga, Quantum Field Theory for the Gifted Amateur (2015) ISBN-13: 978-0199699339. 6. Andrei Smilga Digestible Quantum Field Theory 1st ed. (2017) Edition" ISBN-13: 978-3319599205. 7. Hagen Kleinert, "Particles and Quantum Fields ", (2016) ISBN-13: 978-9814740906 .

	8. Eberhard Zeidler , Quantum Field Theory I: Basics in Mathematics and Physics: A Bridge between Mathematicians and Physicists 2nd printing 2009. ISBN-13: 978-3540347620. 11. **"Quantum Field Theory"**, *Author*: Mark Srednicki *Edition*: 1st (2007), *ISBN*: 978-0-521-86449-7 **12. "The Quantum Theory of Fields, Volume 1: Foundations"** *Author*: Steven Weinberg, *Edition*: 1st (2005), *ISBN*: 978-0-521-67053-1
Electronic Materials	13. **"Lectures on Quantum Field Theory"** by David Tong *Institution*: University of Cambridge 14. **"Lecture Notes on Quantum Field Theory"** by Kevin Zhou **15. "Quantum Field Theory I"** by Jan M. Pawlowski *Institution*: Heidelberg University
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	9. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 10. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 11. Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	12. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	13. Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys to gather students' perceptions of teaching methods, clarity of explanations, and engagement.
Effectiveness of students' assessment	Course Instructor	Compare assessments (quizzes, assignments, projects) with course learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	Track student engagement with electronic materials (e.g., downloads, page visits) and physical resources.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates on the applicability of course content and learning outcomes in research or professional practice.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)
Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	**JANUARY 2025**

Course Title:	**Nuclear Reactions and Structure**
Course Code:	*Enter Course Code.*
Program:	**Master of Science in Nuclear Physics**
Department:	**Physics**
College:	**Science**
Institution:	**Umm Al-Qura University**
Version:	**2nd version**
Last Revision Date:	**January 2025**

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: (3 hrs)					
3 hours					
2. Course type					
A.	☐ University	☐College	☒ Department	☒ Track	
B.	☐Required		☒ Elective		
3. Level/year at which this course is offered: (3rd semester/2nd year)					
4. Course General Description:					

This course introduces the fundamental concepts and experimental techniques of nuclear reactions and structure, focusing on conceptual understanding and practical applications. It covers nuclear reaction mechanisms, including direct, compound, and pre-equilibrium processes, with accessible introductions to theoretical frameworks like the optical model and DWBA.

Students will explore nuclear structure through models like the shell and collective models, along with rotational and vibrational spectra, linking these to applications in nuclear energy and environmental impact.

In the final weeks, elective topics may include heavy-ion reactions, nuclear astrophysics, or computational approaches to nuclear reactions, tailored to advanced or applied interests.

By the course's end, students will gain foundational knowledge to pursue further studies or careers in nuclear physics and related fields.

5. Pre-requirements for this course (if any)**:**

6. Pre-requirements for this course (if any)**:**

7. Course Main Objective(s):

1. Explain the classification, mechanisms, and significance of nuclear reactions, including reaction cross-sections and pre-equilibrium processes.

2. Examine nuclear properties and introduce models like the shell and collective models, linking them to real-world applications.
3. Familiarize students with tools like particle accelerators and detectors, focusing on their applications in energy and medical physics.
4. Highlight the role of nuclear reactions in energy production, astrophysics, and environmental implications.
5. Offer electives on specialized areas such as heavy-ion reactions, nuclear astrophysics, and computational modeling.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 6. Traditional classroom 7. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
8.	**Lectures**	45
9.	**Laboratory/Studio**	
10.	**Field**	
11.	**Tutorial**	
12.	**Others (specify)……**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of PLOs	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Demonstrate understanding of nuclear reaction mechanisms, models, and experimental techniques.	**K1-I**	Lectures with visual aids (animations, simulations).	Conceptual quizzes and exams.
1.2	Explain and apply quantum mechanical models (e.g., shell, collective) to interpret nuclear dynamics.	**K2-P**	In-class problem-solving and group discussions.	
1.3	Relate nuclear physics principles to energy, medical, and astrophysics applications.	**K3-M**	Guided literature reviews and independent research proposals.	
2.0	**Skills**			
2.1	Analyze experimental data and theoretical models to solve nuclear physics problems.	**S1-P**	In-class problem-solving and group discussions.	Problem-based assignments and case studies.
2.2	Conduct independent literature reviews, identify trends, and apply findings to innovative research.	**S2-M**		
3.0	**Values, autonomy, and responsibility**			
3.1	Appreciate societal and ethical implications of nuclear applications, fostering global awareness	**V1-P**		Oral presentations and reflective reports.

C. Course Content:

No	List of Topics	Contact Hours
1	**Introduction to Nuclear Reactions**: Overview of nuclear reactions; classification (elastic, inelastic, capture, fission, and fusion); importance in science and technology.	3
2	**Reaction Cross-Sections**: Definition and significance; how cross-sections are measured experimentally; their role in nuclear processes.	3
3	**Nuclear Reaction Mechanisms**: Mechanisms of nuclear reactions; direct and compound processes explained with real-world examples.	3
4	**Experimental Techniques in Nuclear Reactions**: Overview of tools and techniques, including particle accelerators and detectors, with simplified technical explanations.	3
5	**Introduction to Quantum Mechanical Models**: Overview of the optical model for elastic and inelastic scattering; introduction to the coupled-channel approach using conceptual frameworks.	3
6	**Direct Reactions and DWBA**: Principles of the distorted wave Born approximation (DWBA); introduction to direct reactions with qualitative examples.	3
7	**Compound Nucleus Formation and Decay**: Description of the compound nucleus model; resonance phenomena and their applications in understanding nuclear reactions.	3
8	**Pre-Equilibrium Reactions**: Introduction to pre-equilibrium processes; differences from direct and compound reactions; practical implications.	3
9	**Structural Properties of Nuclei (Part 1)**: The nuclear shell model, magic numbers, basic properties, and an introduction to collective models.	3
10	**Structural Properties of Nuclei (Part 2)**: Rotational and vibrational spectra; experimental methods for studying deformation; magnetic dipole and electric quadrupole moments.	3
11	**Applications of Nuclear Reactions**: Role of nuclear reactions in energy production (fission and fusion reactors); environmental implications and prospects for nuclear energy.	3
12	**Elective Topic 1: Advanced Topics in Nuclear Reactions (Part 1)**: Heavy-ion reactions, fusion dynamics, and understanding nuclear matter at high energies.	3

13	**Elective Topic 2: Advanced Topics in Nuclear Reactions (Part 2)**: Applications in nuclear astrophysics, including the r-process and s-process in stellar nucleosynthesis.	3
14	**Elective Topic 3: Computational Approaches and Emerging Trends**: Introduction to computational methods in nuclear reaction modeling; discussion of cutting-edge research.	3
15	**Course Review and Case Studies**: Summary of key concepts; analysis of case studies in nuclear reactions and structure, linking theoretical and experimental insights to practical applications.	3
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
13.	Exercises & Home works	All weeks	10%
14.	Quizes	4th & 9th weeks	10%
15.	Midterm	8th week	30%
4.	Final Exam	18th week	50%

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	1. **Modern Nuclear Physics: From Fundamentals to Frontiers** a. **Authors**: Alexandre Obertelli, Hiroyuki Sagawa b. **Edition**: 1st Edition c. **Year**: 2022 d. **Publisher**: Springer e. **ISBN**: 978-9811622885 (Print), 978-9811622892 (eBook) f. **Description**: A comprehensive guide to nuclear physics covering basic quantum mechanics, nuclear structure, and advanced topics, along with applications in current research. 2. **Introduction to Nuclear Science** a. **Author**: Jeff C. Bryan b. **Edition**: 4th Edition c. **Year**: 2023 d. **Publisher**: CRC Press (Taylor & Francis Group)

	e. **ISBN**: 978-1032301808 f. **Description**: Focuses on nuclear stability, structure, decay, and nuclear reactions, with updates on nuclear power and medicine applications. 3. **Introduction to Nuclear Reactions** a. **Authors**: Carlos Bertulani, Pawel Danielewicz b. **Edition**: 2nd Edition c. **Year**: 2021 d. **Publisher**: Taylor & Francis Group e. **ISBN**: 978-0367355478 (Print), 978-0429331060 (eBook) **Description**: Combines theoretical approaches to nuclear reactions with applications in experimental data analysis.
Supportive References	4. **Advances in Nuclear Physics: Structure and Reactions** a. **Editors**: S. Kailas, Suresh Kumar b. **Edition**: 1st Edition c. **Year**: 2020 d. **Publisher**: Springer e. **ISBN**: 978-9811590610 (Print), 978-9811590627 (eBook) f. **Description**: Discusses recent developments in nuclear physics, focusing on reaction mechanisms and intermediate energy collisions. 5. **Handbook of Nuclear Physics** a. **Editors**: Isao Tanihata, Hiroshi Toki, Toshitaka Kajino b. **Edition**: 1st Edition c. **Year**: 2022 d. **Publisher**: Springer Nature e. **ISBN**: 978-9811588204 (Print), 978-9811588211 (eBook) f. **Description**: An extensive reference work covering nuclear structure, reactions, and contemporary developments in nuclear physics.
Electronic Materials	6. **MIT OpenCourseWare: "Introduction to Nuclear and Particle Physics"** a. **Platform**: MIT OpenCourseWare b. **Year**: Updated regularly (latest version 2020) c. **Link**: MIT OCW Nuclear and Particle Physics d. **Description**: Free access to lecture notes, problem sets, and videos covering nuclear and particle physics fundamentals.

	7. **edX: Nuclear Physics Courses** a. **Platform**: edX b. **Year**: Updated regularly c. **Link**: edX Nuclear Physics Courses d. **Description**: Online courses from leading institutions, focusing on nuclear energy, safety, and advanced physics topics. 8. **IAEA Online Learning Resources** a. **Platform**: International Atomic Energy Agency (IAEA) b. **Year**: Updated regularly c. **Link**: IAEA Learning d. **Description**: Provides diverse resources in nuclear energy, safety, and applications, with interactive modules and lectures.
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	9. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 10. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 11. Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	1. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	1. Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys to gather students' perceptions of teaching methods, clarity of explanations, and engagement.
Effectiveness of students' assessment	Course Instructor	Compare assessments (quizzes, assignments, projects) with course learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	Track student engagement with electronic materials (e.g., downloads, page visits) and physical resources.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates on the applicability of course content and learning outcomes in research or professional practice.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	**JNAUARY 2025**

Course Title:	**Nuclear Radiations and Detectors**
Course Code:	*Enter Course Code.*
Program:	Master of Science in Nuclear Physics
Department:	**Physics**
College:	**Science**
Institution:	**Umm Al-Qura University**
Version:	*Course Specification Version Number*
Last Revision Date:	**January 2025**

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: ( )					
3 hours					
2. Course type					
A.	☐ University	☐College	☒ Department	☒ Track	
B.	☐Required		☒ Elective		
3. Level/year at which this course is offered: (3rd semester /2nd year)					
4. Course General Description:					

This course introduces the principles, interactions, and detection of nuclear radiation, emphasizing conceptual understanding and practical applications with minimal mathematical complexity. Students will study the interactions of particles with matter, radioactive decay, and the design of radiation detectors such as gas-filled, scintillation, and semiconductor detectors.

Key topics include particle interactions like Compton scattering, photoelectric effect, and pair production, with applications in radiation safety, medical imaging, and high-energy physics.

In the final weeks, elective topics may include:

2. Neutron Detection Techniques: Applications in reactors and shielding.
3. Dosimetry and Radiation Protection: Basics for medical and industrial contexts.
4. Advanced Detector Technologies: Pixel detectors in cutting-edge research.

By the end of the course, students will be equipped for further studies or careers in medical physics, radiation safety, or research.

5. Pre-requirements for this course (if any):

6. Pre-requirements for this course (if any):

7. Course Main Objective(s):

5. Explain the mechanisms of alpha, beta, and gamma decay and the interactions of particles with matter in an accessible way.
6. Cover the principles, design, and applications of gas-filled, scintillation, and semiconductor detectors.
7. Discuss applications of nuclear radiation in nuclear medicine, radiometric dating, environmental safety, and material analysis.
8. Offer elective topics, such as neutron detection, dosimetry, or advanced detectors, tailored to student interests and lecturer expertise.
9. Equip students for advanced studies or careers in nuclear physics, medical physics, or radiation safety while fostering critical thinking through practical examples.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 10. Traditional classroom 11. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
12.	**Lectures**	45
13.	**Laboratory/Studio**	
14.	**Field**	
15.	**Tutorial**	
16.	**Others (specify)……**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Explain the interactions of nuclear radiations (alpha, beta, gamma) with matter and their significance.	K1-P	Lectures with visual aids (animations and diagrams).	- Quizzes, exams, and concept-based questions.
1.2	Describe the principles, design, and operation of radiation detection technologies.	K2-P	Interactive lectures. - Case studies showcasing detector applications.	Problem-solving assignments.
1.3	Understand the experimental techniques and methodologies used in nuclear reactions and detector operations.	K3-P	Hands-on demonstrations and lab-based tutorials. - Discussions on applications.	Lab reports and oral presentations.
2.0	**Skills**			
2.1	Apply nuclear reaction models to calculate energy, momentum, and cross-sections in simplified systems.	S1-M	- Problem-solving exercises and group discussions.	-Homework and numerical problem-solving assignments.
2.2	Analyze experimental data from detectors to identify nuclear radiation properties.	S3-M	- Guided analysis of experimental datasets.	- Data analysis tasks and written reports.
2.3	Operate and troubleshoot basic radiation detectors for specific nuclear physics experiments.	S4-P	- Lab sessions with hands-on experience.	- Practical tests and project reports.
3.0	**Values, autonomy, and responsibility**			
3.1	Demonstrate ethical practices in handling radiation experiments and ensuring safety protocols.	V3-M	Safety-focused workshops and role-play scenarios.	- Evaluation of adherence to lab safety practices.

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
3.2	Collaborate effectively in team projects to design and interpret experiments involving nuclear reactions.	V2-M	Group activities and collaborative problem-solving tasks.	Peer assessment and group project evaluations.
...				

C. Course Content:

No	List of Topics	Contact Hours
1	**Introduction to Radiation and Detectors**: Importance of studying radiation; overview of interactions of charged and neutral particles with matter; basic types of radiation detectors (gas-filled detectors, scintillation detectors, and semiconductor detectors).	3
2	**Passage of Charged Particles Through Matter (Basics)**: Types of interactions (ionization and excitation); stopping power and range; energy loss mechanisms for electrons and heavy particles; introduction to delta rays and their effects.	3
3	**Passage of Charged Particles Through Matter (Applications)**: Concepts of multiple scattering, mean scattering angle, and energy straggling; practical examples in particle detection and material analysis.	3
4	**Compton Effect**: Photon interaction basics; Compton scattering process (wavelength shift, angular relations); practical applications in shielding and imaging technologies.	3
5	**Photoelectric Effect and Pair Production**: Mechanisms of photon absorption, electron emission, and pair production; threshold energy concepts; practical examples in high-energy physics and X-ray imaging.	3
6	**Radiation Attenuation and Cross-Sections**: Linear and mass attenuation coefficients; energy dependence of cross-sections; applications in radiation shielding and dosimetry.	3
7	**Radioactive Decay Law**: Exponential decay law; concepts of half-life and mean life; activity determination; applications in radiometric dating and nuclear medicine.	3

8	**Alpha Decay**: Mechanism of alpha decay; understanding the Geiger-Nuttall law; introduction to quantum tunneling; applications in smoke detectors, radiotherapy, and nuclear dating.	3
9	**Beta Decay**: Types of beta decay (β^-, β^+, and electron capture); energy distribution in beta decay (Fermi's theory); basic introduction to double beta decay; practical applications in tracer studies and neutrino physics.	3
10	**Gamma Decay**: Mechanisms of gamma-ray de-excitation; qualitative understanding of multipole radiation; applications in gamma-ray spectroscopy and medical imaging (e.g., PET scans).	3
11	**Gas-Filled Detectors**: Principles of operation of Geiger-Müller counters and proportional counters; ionization and charge collection mechanisms; applications in radiation safety monitoring and dosimetry.	3
12	**Scintillation Detectors and Semiconductor Detectors**: Light emission mechanisms in scintillation materials; signal processing in semiconductor detectors; practical applications in high-energy physics and medical imaging.	3
13	**Elective Topic 1: Neutron Detection Techniques**: Methods for detecting neutrons using gas and scintillation detectors; applications in nuclear reactors and radiation shielding.	3
14	**Elective Topic 2: Dosimetry and Radiation Protection**: Basics of radiation dosimetry; types of dosimeters; principles of radiation protection; practical applications in medical and industrial settings.	3
15	**Elective Topic 3: Advanced Detector Technologies**: Introduction to advanced detector systems, including pixel and microstrip detectors; their applications in cutting-edge physics experiments and medical imaging.	3
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
17.	Exercises & Homework	Each chapter	10%
18.	Quizzes	Each chapter	10%
19.	Mid-term exam	8^{th} week	30%
4	Final exam	End of the term	50%

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	1. **"Radiation and Detectors: Introduction to the Physics of Radiation and Detection Devices"**, Lucio Cerrito, 1st (2017) *ISBN*: 978-3-319-53181-6 2. **"Measurement and Detection of Radiation"** Nicholas Tsoulfanidis and Sheldon Landsberger, 5th (2021) *ISBN*: 978-1-4822-1549-8
Supportive References	12. **"Radiation Detection: Concepts, Methods, and Devices"**, Douglas McGregor and Kenneth Shultis, 1st (2018) *ISBN*: 978-1-4398-1939-5 **13. "Detectors for Particle Radiation"**, Konrad Kleinknecht *Edition*: 2nd (1998) *ISBN*: 978-0-521-64854-7
Electronic Materials	14. **"Fundamentals of Radiation Detection & Measurement"** Amptek 15. **"Basics of Nuclear Physics and of Radiation Detection and Measurement"** *Author*: Jukka Lehto *Version*: 1.61 (February 2017) 16. **"Radiation Detection and Detectors"** *Publisher*: OpenStax
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	17. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 18. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 19. Simulation Rooms: For visualizing quantum phenomena using computational tools.

Items	Resources
Technology equipment (Projector, smart board, software)	20. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	21. Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys to gather students' perceptions of teaching methods, clarity of explanations, and engagement.
Effectiveness of students' assessment	Course Instructor	Compare assessments (quizzes, assignments, projects) with course learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	Track student engagement with electronic materials and physical resources.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates on the applicability of course content and learning outcomes in research or professional practice.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)
Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	

REFERENCE NO.	
DATE	JANUARY 2025

Course Title:	**Advanced Nuclear Physics**
Course Code:	*Enter Course Code.*
Program:	**Master of Science in Nuclear Physics**
Department:	**Physics**
College:	**Science**
Institution:	Umm Al-Qura university
Version:	2nd
Last Revision Date:	**January 2025**

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: 3 hrs

2. Course type

A.	☐University	☐College	☒ Department	☒ Track	
B.	☐Required		☒ Elective		

3. Level/year at which this course is offered: (2^{nd} year- third semester)

4. Course General Description:

This course provides an in-depth exploration of advanced nuclear and high-energy physics with a focus on computational applications. It is structured to integrate programming fundamentals, the use of modern tools like the PYTHIA8 event generator, and the application of these skills to solve complex problems in nuclear and particle physics. The course begins with foundational programming instruction (C++ or Python), followed by an introduction to key concepts in high-energy physics (HEP) and event simulation using PYTHIA8. It then progresses to advanced topics in nuclear physics, including nuclear structure, decay, and reactions, utilizing computational methods to analyze experimental data. Students will apply their learning in a comprehensive final project, synthesizing theoretical concepts and practical skills to address real-world challenges in nuclear and particle physics.

5. Pre-requirements for this course (if any)**:**

6. Pre-requirements for this course (if any)**:**

7. Course Main Objective(s):

1. Develop proficiency in Python or C++ for data analysis, debugging, and solving physics-related problems using computational tools.
2. Build foundational knowledge of the Standard Model, nuclear structure, decay processes, and Monte Carlo methods for event generation and simulations.
3. Train students in using PYTHIA8 for simulating and analyzing particle interactions, including decays and collisions.

4. Enable students to process and analyze large datasets, perform statistical analysis, and generate visual interpretations of experimental results.
5. Apply theoretical principles to practical scenarios, including energy production and medical imaging, through final projects and innovative use of computational methods.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 8. Traditional classroom 9. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
10.	**Lectures**	45
11.	**Laboratory/Studio**	
12.	**Field**	
13.	**Tutorial**	
14.	**Others (specify)……**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	Knowledge and understanding			

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.1	Explain nuclear structure, decay, and reactions, including fission and fusion.	K1-P	Lectures and real-world examples. Practical examples and discussions. Hands-on tutorials.	Quizzes and problem-solving tasks. Written reports. Project-based assessments.
1.2	Describe Monte Carlo methods in nuclear simulations.	K2-P		
1.3	Analyze the role of PYTHIA8 in modeling physical processes.	K3-M		
…				
2.0	**Skills**			
2.1	Develop Python or C++ programs for simulations.	S3-P	Coding workshops. Guided tutorials. Data analysis sessions.	Coding assignments. Simulation reports. Problem-solving tasks.
2.2	Apply PYTHIA8 to simulate nuclear events.	S4-M		
2.3	Perform statistical analysis of nuclear datasets.	S3-P		
…				
3.0	**Values, autonomy, and responsibility**			
3.1	Uphold ethical principles in research.	V3-P	Case-based discussions. Team assignments.	Participation in ethical discussions.
3.2	Contribute effectively to group projects.	V2-M		Peer feedback and group assessments.
…				

C. Course Content:

No	List of Topics	Contact Hours
	Module 1: Programming Essentials (Weeks 1–3) **Objective: Lay the foundation in programming skills for data analysis and simulations.**	

15.	**Introduction to Programming for Physics**: The importance of programming in nuclear and high-energy physics (examples: data analysis, simulations). **Setting up the programming environment**: Python or C++ installation, IDE setup. **Basics of Programming**: Syntax, variables, data types, and operators.Simple "Hello World" programs and basic mathematical computations. **Practical Exercise**: Write a program to calculate kinetic energy using user-input values for mass and velocity.	3
16.	**Control Structures**: Conditional statements (if, else, switch) and loops (for, while). Arrays and lists for handling data sets. **Introduction to Libraries: Python**: NumPy and Matplotlib for numerical computations and plotting. C++: Standard Template Library (STL) basics. **Practical Exercise**: Plot a simple nuclear decay curve (e.g., exponential decay).	3
17.	**File Handling and Statistics**: Reading and writing data files (CSV, text). Basic statistical operations: mean, standard deviation, and histograms. **Error Handling and Debugging**: Techniques for identifying and fixing errors in programs. **Practical Exercise**: Write a program to read particle collision data and calculate average collision energy.	3
	Module 2: Introduction to High Energy Physics and PYTHIA8 (Weeks 4–6) **Objective:** Introduce foundational HEP concepts and familiarize students with PYTHIA8	
18.	**Introduction to HEP**: Overview of fundamental particles and forces (quarks, leptons, bosons). The Standard Model of particle physics: structure and limitations. Key experiments (LHC, Fermilab). **Introduction to Event Generators:** Monte Carlo methods and their role in simulating physical events. **Practical Exercise:** Explore example data sets from an HEP experiment	3
19.	**Getting Started with PYTHIA8:** Installation and setup of PYTHIA8. Understanding the structure of a PYTHIA8 program. **Simulating Simple Events**: Generating events for electron-positron annihilation. Analyzing basic event outputs (particle IDs, energies). **Practical Exercise**: Generate and analyze events for a single process (e.g., Higgs boson decay).	3
20.	**Advanced PYTHIA8 Usage:** Configuring physics processes (e.g., hard scattering, parton showers). Simulating decay chains and cross-section calculations. **Practical Exercise**: Simulate proton-proton collisions and plot distributions of final-state particles	3
	Module 3: Nuclear Physics Applications (Weeks 7–8) **Objective:** Connect nuclear physics principles to experimental and computational analysis.	
21.	**Nuclear Structure and Decay**: Nuclear shell model: single-particle states, magic numbers. Decay mechanisms: alpha, beta, and gamma	3

	decay. Monte Carlo Simulations in Nuclear Physics: **Applying Monte Carlo methods to simulate radioactive decay. Practical Exercise**: Write a program to simulate a radioactive decay chain.	
22.	**Nuclear Reactions:** Fission and fusion processes: energy release and reaction dynamics. Reaction cross-sections and their calculation. **Simulating Nuclear Reactions**: Using PYTHIA8 to model simple nuclear reactions. Practical Exercise: Simulate neutron capture or proton-induced fission.	**6**
	Module 4: Applications and Final Project (Weeks 9–11) **Objective:** Integrate knowledge in a comprehensive project	
23.	**Applications of Nuclear and Particle Physics**: Nuclear power generation, medical imaging, and radiation therapy. Emerging technologies (e.g., muon tomography, neutrino detectors). **Project Brainstorming**: Students propose topics for final projects using PYTHIA8 or nuclear simulations.	**6**
24.	**Project Development:** Students work on implementing simulations or analyzing data with instructor guidance**.**	**6**
25.	**Project Presentations and Wrap-Up:** Students present their simulations or analysis findings. Course wrap-up and future directions in HEP and nuclear physics	**6**

Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
6.	**Quizzes:** Short quizzes to assess understanding of key concepts in HEP, nuclear physics, and programming basics.	**Weeks 4, 7, 10**	**15%**
7.	**Programming Assignments**: Individual tasks requiring students to write Python/C++ programs for solving physics-related problems	**Weeks 3, 5, 6**	**20%**
8.	**Practical Lab Reports**: Reports analyzing PYTHIA8 simulations or Monte Carlo modeling of	**Weeks 6, 8, 9**	**20%**

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
	nuclear and particle physics phenomena.		
9.	**Group Project**: Collaborative project where students simulate a physical process or analyze data, culminating in a written report.	**Weeks 9–11**	**15%**
10.	**Final Project**: Comprehensive individual project using PYTHIA8 or other computational methods, including a presentation and report.	**Week 15**	**25%**
11.	**Class Participation and Discussions**: Evaluation of engagement in discussions, ethical debates, and problem-solving sessions.	**Ongoing**	**5%**
…			

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	• **Introductory Nuclear Physics,** *Author*: Samuel S. M. Wong, *Edition*: 2nd Edition (1998), *Publisher*: Wiley, *ISBN*: 978-0471239734 *Description*: This comprehensive text offers a unified treatment of modern nuclear physics, suitable for senior undergraduate and first-year graduate courses. • **Introduction to Elementary Particles**, *Author*: David J. Griffiths, *Edition*: 2nd Edition (2008), *Publisher*: Wiley-VCH*ISBN*: 978-3527406012 • **Introduction to Computational Physics**, *Author*: Franz J. Vesely *Edition*: 2nd Edition (2008), *Publisher*: Springer, *ISBN*: 978-3540686950

	• **A Brief Introduction to PYTHIA 8.2**, *Authors*: Torbjörn Sjöstrand, Stephen Mrenna, and Peter Skands, *Publication Year*: 2015, *Publisher*: Computer Physics Communications, *DOI*: 10.1016/j.cpc.2015.01.024
Supportive References	12. **Introductory Nuclear Physics** 1. *Author*: Kenneth S. Krane 2. *Edition*: 3rd Edition (1987) 3. *Publisher*: Wiley 4. *ISBN*: 978-0471805533 5. *Description*: This comprehensive text provides an introduction to basic nuclear physics, including nuclear decays, reactions, and structure, while covering essential areas of basic research and practical applications. Amazon 13. **Modern Elementary Particle Physics: Explaining and Extending the Standard Model** 1. *Author*: Gordon L. Kane 2. *Edition*: 2nd Edition (2017) 3. *Publisher*: Cambridge University Press 4. *ISBN*: 978-1107165083 5. *Description*: An updated introduction to the foundations of modern particle physics, covering the Standard Model and recent developments in the field. Amazon **Online Lecture Notes:** 1. **MIT OpenCourseWare: Introduction to Nuclear and Particle Physics (8.701)** 1. *Institution*: Massachusetts Institute of Technology (MIT) 2. *Access*: MIT OCW - 8.701 3. *Description*: Comprehensive lecture notes and course materials covering fundamental concepts in nuclear and particle physics. 2. **Stanford University: Particle Physics Course Notes** 1. *Institution*: Stanford University 2. *Access*: Stanford Particle Physics

	3. *Description*: Detailed lecture notes and resources on particle physics topics, including the Standard Model and experimental methods.
Electronic Materials	**Datasets:** 1.Publicly available datasets from the CERN Open Data Portal. (https://opendata.cern.ch/) For hands-on practice with HEP and nuclear physics data. 2. Workshops and Tutorials: PYTHIA8 Tutorials (from conferences and workshops): Available through the official PYTHIA8 website or YouTube channels. **Simulated Experiments:** **1.**Example simulation setups provided by PYTHIA8 documentation and ROOT tutorials. **2**. Community Forums: Stack Overflow (for coding queries): (https://stackoverflow.com) **3**. High Energy Physics Stack Exchange: (https://physics.stackexchange.com)
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	16. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 17. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 18. Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	19. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	20. Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys to gather students' perceptions of teaching methods, clarity of explanations, and engagement.
Effectiveness of students' assessment	Course Instructor	Compare assessments (quizzes, assignments, projects) with course learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	Track student engagement with electronic materials (e.g., downloads, page visits) and physical resources.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates on the applicability of course content and learning outcomes in research or professional practice.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	