Course Specification

(Postgraduate Programs)

Course Title:	**Classical Mechanics**
Course Code:	*Enter Course Code.*
Program:	**Master of Science in 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				

2. Course type				
A.	☐ University	☐ College	☒ Department	☐ Track
B.	☒ Required		☐ Elective	

3. Level/year at which this course is offered: (1st year- first semester)

4. Course General Description:

This course provides an advanced exploration of the principles and applications of classical mechanics, emphasizing analytical methods and their role in modern physics. Designed for postgraduate students, the course begins with a survey of foundational concepts such as the mechanics of particles and systems, constraints, and the Lagrangian formulation.

The course delves into variational principles, exploring Hamilton's principle and its derivation of Lagrange's equations, alongside conservation theorems and symmetry properties. Students will study the central force problem, including the Kepler problem, scattering in central fields, and the three-body problem, highlighting the connection between classical mechanics and celestial dynamics.

Rigid body motion is addressed through kinematics and dynamics, with topics such as the inertia tensor, Euler equations, and torque-free motion. Oscillatory systems, including small oscillations, normal modes, and forced vibrations, are analyzed, extending to nonlinear systems like the damped driven pendulum and Josephson junction.

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

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

7. Course Main Objective(s):

Course Main Objectives:

1. Develop a Deep Understanding of Fundamental Principles:
   - Explain and apply the core concepts of classical mechanics, including the mechanics of particles, systems of particles, constraints, and variational principles.
   - Demonstrate proficiency in the Lagrangian and Hamiltonian formulations of mechanics.
2. Analyze Complex Physical Systems:

- Solve problems involving central forces, including the Kepler problem and scattering phenomena, using analytical and computational techniques.
- Understand the dynamics of rigid body motion, including the role of the inertia tensor and Euler equations.

3. Apply Conservation Laws and Symmetry Principles:
    - Derive and utilize conservation theorems associated with energy, momentum, and angular momentum.
    - Interpret the implications of symmetry properties for physical systems.
4. Explore Oscillatory and Nonlinear Systems:
    - Analyze small oscillations, normal modes, and forced vibrations in linear and nonlinear systems.
    - Extend classical mechanics concepts to modern applications, such as the Josephson junction and dissipative systems.
5. Bridge Classical and Modern Physics:
    - Recognize the relevance of classical mechanics in the context of modern physics, such as celestial mechanics, statistical mechanics, and quantum systems.
6. Develop Mathematical and Analytical Skills:
    - Utilize advanced mathematical tools, such as variational calculus, matrix methods, and eigenvalue problems, in solving mechanics-related problems.
    - Apply theoretical frameworks to formulate and solve real-world problems in physics and engineering.
7. Foster Research and Problem-Solving Competencies:
    - Engage in independent learning through advanced topics and problem-solving exercises.
    - Prepare for advanced research by applying classical mechanics concepts to complex, interdisciplinary problems.

These objectives align with the course's emphasis on developing theoretical understanding, analytical skills, and practical problem-solving abilities in classical mechanics.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	90%
2	E-learning		
3	Hybrid • Traditional classroom • E-learning		
4	Distance learning	15	10%

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	Understand the fundamental principles of mechanics.	**K1-P**	Lectures, reading assignments, and demonstrations.	Quizzes, Homework Assignments
1.2	Learn advanced analytical methods like Lagrange's and Hamilton's formulations.	**K2-I**	Interactive lectures and guest lectures on theoretical applications.	Problem sets and theoretical exams.
1.3	Master the mathematical techniques for modeling physical phenomena.	**K3-I**	Workshops, tutorials, and supplementary online materials.	Written assignments involving mathematical modeling and theory application.
2.0	**Skills**			
2.1	Analyze and solve problems involving the motion of particles and rigid bodies.	**S1-P**	use of simulation software, and peer teaching sessions.	practical exams, and peer assessments.
2.2	Develop effective communication of complex physical concepts.	**S2-I**	Group projects, presentations, and discussion forums.	Presentations, group project reports, and participation in

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
				discussions.
3.0	**Values, autonomy, and responsibility**			
3.1	Demonstrate intellectual integrity by critically evaluating the theoretical assumptions and applications of statistical mechanics.	**V1-P**	Lectures, Group Discussions	Written Exams, Research Papers, Peer Review Assignments
3.2	Uphold professionalism by applying principles of statistical mechanics to solve problems ethically and efficiently, respecting data accuracy and scientific truth.	**V2-I**	Research Projects	Professionalism Assessment
...				

C. Course Content:

No	List of Topics	Contact Hours
1.	**:Survey of the Elementary Principles** 1. Mechanics of a Particle 2. Mechanics of System of Particles 3. Constraints 4. D'Alembert's Principle and Lagrange's Equations 5. Velocity-dependent Potentials and the dissipation Function 6. Simple Applications of the Lagrangian Formulation	6
2.	**Variational Principles and Lagrange's Equations:** 1. Hamilton's Principle 2. Some Techniques of the Calculus of Variation 3. Derivation of Lagrange's Equations from Hamilton's	6

	Principle 4. Advantage of a Variational Principle Formulation 5. Conservations Theorems and Symmetry Properties 6. Energy Function and the Conservation of Energy	
3.	**The Central Force Problem:** 1. Reduction to the Equivalent One-Body Problem 2. The Equation of Motion and First Integrals 3. The equivalent One- Dimensional Problem, and Classification of Orbits 4. The Virial Theorm 5. The Differential Equation for the Orbits, and Integrable Power-Law Potentials 6. Conditions for Closed Orbits 7. The Kepler Problem: Inverse-Square Law of Force 8. The Motion in Time in the Kepler Problem 9. The Laplace-Runge-Lenz Vector 10. Scattering in a Central Force Field 11. Transformation of the Scattering Problem to Laboratory Coordinates 12. The Three-Body Problem	9
4.	**The Kinematics of Rigid Body Motion** 1. The independent Coordiantes of a Rigid Body 2. Orthogonal Transfromations 3. Formal Properties of the Transformation Matrix 4. The Euler Angles 5. The Cayley-Kelin Parametere and Related Quantities 6. Euler's Theorem on the Motion of a Rigid Body 7. Finite Rotaions 8. Infinitesimal Rotions 9. Rate of Change of a Vector 10. The Coriolis Effect	8
5.	**The Rigid Body Equation of Motion** Angular Moemntum and Kinetic Energy of Motion about a Point .1 Tensors .2 The Inertia Tensor and the Moment of Inertia .3 The Eigenvalues of the Inertia Tensor and the Principal Axis .4 Transformation Solving Rigid Body Problems and Euler Equations of Motion .5 Torque-free Motion of a Rigid Body .6	8
6.	**Oscillations** Formulation of the Problem .1	8

	The Eigenvalue Equation and the Principle Axis .2 Transformations Frequencies of free Vibrations and Normal Coordinates .3 Free Vibrations of a Linear Triatomic Molecules .4 Forced Vibrations and the effect of Dissipatives Forces .5 Beyond Small Oscillations: The Damped Driven Pendulum and .6 .the Josephon Junction	
Total		45

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	**Quizzes**	**Weeks 2, 4, 8,10,14**	**10%**
2.	Homework	**All Weeks**	**10%**
3.	Midterm Exam	**8th week**	**30%**
4.	Final Exam	**Week 18**	**50%**
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	1. **"Classical Mechanics"** by Herbert Goldstein, Charles P. Poole Jr., and John L. Safko (3rd Edition, 2001) **ISBN-13**: 978-0201657029 2. "Modern Classical Mechanics" by T. M. Helliwell and V. V. Sahakian (2020) ISBN: 978-1108834971 3. "Classical Mechanics and Relativity" by Harald J. W. Müller-Kirsten (2nd Edition, 2024) ISBN: 978-9811287114
Supportive References	• **"Classical Mechanics"** by John R. Taylor (2005) **ISBN-13**: 978-1891389221 • **"Mechanics"** by L. D. Landau and E. M. Lifshitz (3rd Edition, 1976) **ISBN-13**: 978-0750628969 • **"Introduction to Classical Mechanics: With Problems and Solutions"** by David Morin (2008) **ISBN**: 978-0521876223 • **"Analytical Mechanics"** by Louis N. Hand and Janet D. Finch (1998) **ISBN**: 978-0521573276

Electronic Materials	1- Classical Mechanics at MIT OCW 2- Classical Mechanics III at MIT OCW
Other Learning Materials	1- **Stanford Online** - Offers advanced courses in mechanics that might include topics in classical dynamics and modern analytical methods in physics. Stanford's approach to teaching often involves a mix of theoretical exploration and practical applications. 2- **Coursera**: There are several courses available on Coursera that deal with classical mechanics and related subjects from universities around the world. These courses often include video lectures, quizzes, and assignments for a thorough understanding. 3- **edX**: Similar to Coursera, edX offers courses from universities globally, including detailed courses on both the fundamentals and advanced topics in physics. Look for courses specifically targeting Lagrangian and Hamiltonian mechanics for a deep dive into the analytical techniques used in classical mechanics.

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities	(Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)
Technology equipment	(Projector, smart board, software)
Other equipment (Depending on the nature of the specialty)	(Depending on the nature of the specialty)

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
Effectiveness of students' assessment	Course Instructor	Compare assessments with course learning outcomes (CLOs).
Quality of learning resources	Course Instructor	Track student engagement with electronic materials .
The extent to which CLOs have	External Academic Reviewer	Collect feedback from

Assessment Areas/Issues	Assessor	Assessment Methods
been achieved		graduates
Other		

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

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	

Course Specification

(Postgraduate Programs)

Course Title:	**Electrodynamics**
Course Code:	*Enter Course Code.*
Program:	**Master of Science in 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					
2. Course type					
A.	☐ University	☐ College	☒ Department	☐ Track	
B.	☒ Required			☐ Elective	
3. Level/year at which this course is offered: (1st year- first semester)					

4. Course General Description:

This course provides a comprehensive exploration of the theoretical and practical aspects of electrodynamics, with a focus on advanced electrostatics, boundary-value problems, multipole expansions, magnetostatics, and quasi-static fields. Designed for postgraduate students, the course emphasizes analytical methods, numerical techniques, and their applications in solving complex electromagnetic problems.

The course begins with foundational concepts such as Coulomb's law, Gauss's law, and the scalar potential, progressing to Poisson's and Laplace's equations and their applications in boundary-value problems. Techniques like the method of images, separation of variables, and Green functions are explored in detail to solve electrostatic configurations in various geometries.

Students will study the behavior of dielectrics, including molecular polarizability and boundary conditions, and delve into magnetostatics, covering vector potentials, Ampere's law, and magnetic energy. Quasi-static fields and magnetic diffusion are introduced to address dynamic scenarios in conducting media.

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

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

7. Course Main Objective(s):

Course Main Objectives:

1. Develop a Deep Understanding of Electrodynamics Principles:
    - Explain the foundational principles of electrostatics, magnetostatics, and quasi-static fields.
    - Understand the derivation and application of key equations such as Poisson's and Laplace's equations, Green functions, and Maxwell's equations in static and dynamic scenarios.

2. Master Analytical and Numerical Techniques:
   - Apply methods like the method of images, separation of variables, and eigenfunction expansions to solve boundary-value problems.
   - Utilize numerical techniques, such as finite element analysis, to model and analyze complex electromagnetic configurations.
3. Analyze and Solve Boundary-Value Problems:
   - Solve boundary-value problems in various geometries using advanced mathematical tools, including spherical and cylindrical coordinates, Legendre polynomials, and Bessel functions.
   - Analyze mixed boundary conditions and their implications for fields and potentials.
4. Understand and Apply Concepts of Multipole Expansions and Dielectrics:
   - Develop multipole expansions for charge and potential distributions.
   - Explain the behavior of dielectrics, including molecular polarizability, electric susceptibility, and boundary conditions in dielectric media.
5. Explore Magnetostatics and Energy Principles:
   - Analyze magnetic fields generated by localized and distributed currents using vector potentials and Ampere's law.
   - Understand energy storage in magnetic fields, self-inductance, mutual inductance, and magnetic diffusion processes.
6. Integrate Electrodynamics into Real-World Applications:
   - Apply theoretical concepts to practical problems in engineering and physics, such as eddy currents, charge distributions, and electromagnetic energy storage.
   - Use computational tools to simulate and interpret electrodynamic systems in research and industry.
7. Develop Research and Problem-Solving Skills:
   - Formulate and solve complex electrodynamic problems, demonstrating proficiency in analytical and computational approaches.
   - Engage in discussions of advanced topics and contemporary research, preparing for further study or professional practice in electromagnetics.

These objectives aim to provide students with a robust theoretical foundation and the practical skills needed to tackle advanced problems in electrodynamics, bridging the gap between academic study and real-world applications.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	90%
2	E-learning		
3	Hybrid • Traditional classroom • E-learning		
4	Distance learning	15	10%

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	Demonstrate a deep understanding of fundamental principles of electrostatics, magnetostatics, and quasi-static fields.	**K1-P**	Lectures with detailed explanations. - Interactive discussions.	- Written exams. - Assignments.
1.2	Analyze boundary-value problems in different coordinate systems using Laplace's equation and associated mathematical tools.	**K2-I**	- Problem-solving sessions. - Step-by-step derivations.	- Problem sets. - Midterm exams
1.3	Explain the concepts of Green's functions and multipole expansions in solving electrodynamic problems.	**K3-I**	Theortical Lectures-Group Discussion	involving mathematical modeling.
2.0	**Skills**			

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
2.1	Apply mathematical techniques (e.g., separation of variables, Green's functions) to solve advanced electrostatic and magnetostatic problems.	**S1-P**	- Hands-on problem-solving. - In-class exercises	- Assignments. - Exam problems.
2.2	Utilize computational tools such as Finite Element Analysis (FEA) to simulate and analyze electrostatic and magnetostatic systems.	**S2-I**	- Practical computational sessions. -Software demonstrations	-Simulation projects. - Reports.
3.0	**Values, autonomy, and responsibility**			
3.1	Demonstrate responsibility and ethical practices in solving physical problems and presenting results.	**V1-P**	- Emphasis on academic integrity. - Group work.	- Group project evaluations.
3.2	Develop teamwork and communication skills when solving complex electrodynamic problems collaboratively.	**V2-I**	- Collaborative learning sessions. - Group projects.	- Peer assessments. - Group reports

C. Course Content:

No	List of Topics	Contact Hours
1.	**Introduction to Electrostatics** Coulomb's law .1 Electric Field .2 Gauss's law .3 Diffrential form of Gauss's law .4 Scalr Potential .5 Surface disturbution of Chrages and dipoles .6 Poisson's and Laplaces's equations .7 Green's theorem .8 Uniqueness theorem .9 Formal soloution of the boundary –value problem .10 Electrostatic potential energy .11	**6**

2.	**Boundary- Value Problems in Electrostatics: I** 1. Method of Images 2. Point charge in the Presence of Grounded Conducting Sphere 3. Point Charge in the Presence of a Charged, Insulated, Conducting Sphere 4. Point Charge Near a Conducting Sphere at Fixed Potential 5. Conducting Sphere in a Uniform Electric Field by Method of Images 6. Green Function for the Sphere, General Solution for the Potential 7. Conducting Sphere with Hemispheres at Diffrenet Potentials 8. Orthogonal Functions and Expansions 9. Sepration of Variables; Laplace Equation in Rectangular Coordinates 10. A Two- Dimensional Potential Problems; Summatio of Fourier Series. 11. Fields and Charge Densities in Two- Dimensional Corners and Along Edges. 12. Introduction to Finite Element Analysis for Electrostatics.	**11**
3.	**Boundary- Value Problems in Electrostatics: II** 1. Laplace Equation in Spherical Coordinates 2. Legendre Equatuion and Legendre Polynomials 3. Boundary-Value Problems with Azimuthal Symmetry 4. Behavior of Fields in a Canonical Hole or Near a Shape Point 5. Assicated Legendre Funtions and Shperical Harmonics 6. Addition Theorrem for Shperical Harmonics 7. Laplace Equation in Cylindrical Coordinates; Bessel Functions 8. Boundary-Value Problems in Cylindrical Coordinates 9. Expansion of Green Functions in Spherical Coordinates 10. Solution of Ptentials Problems with the Spherical Green Function Expansion 11. Expansion of Green Function in Cylindrical Coordinates 12. Eigenfunction Expansion for Green Function 13. Mixed Boundary Conditions, Conducting Plane with a Circular Hole.	**12**
4.	**Multipole, Electrostatics of Macroscopic Media, Dielectric** 1. Multiple Expansion 2. Multiple Expansion of the Energy of a Charge Distribution in an External Field 3. Elementry Treatment of Electrostatic with Ponderable Media 4. Boundary-Value Problems with Dilectrics 5. Molecualr Polarizability and Electric Susceptibility 6. Models of Electric Polarizability 7. Electrostatic Energy in Dielectric Media	**6**

5.	**Magnetostatics, Faraday's Law, Quasi- Static Fields** Introduction and Difenitions .1 Biot abd Savart Law .2 Differential Equation of Magnetostatics and Ampere's Law .3 Vector Potentials .4 Vector Potentials and Magnetic Induction for a Circular Current Loop .5 Magnetic Fields of Localized Current Distrubution, Magnetic Moment .6 Force and Torque on and Energy of a Localized Current Distrubution .7 in an External Magnetic Induction Macroscopic Equatuions, Boundary Conditions on **B** and **H** .8 Method of Solving Boundary-Value Problems in Magnetostatics .9 Faraday's Law of Induction .10 Energy in the Magnetic Field .11 Energy and Self- and Mutual Inductance .12 Quasi- Static Fields in Conductors, Eddy Currents; Magnetic .13 .Diffusion	**10**
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	**Quizzes**	**Weeks 2, 4, 8,10,14**	**10%**
2.	Homework	**All weeks**	**10%**
3.	Midterm Exam	**7th week**	**30%**
4.	Final Exam	**Week 18**	**50%**
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	1- Jackson, J. D. (1998). *Classical Electrodynamics* (3rd Edition). Wiley, **ISBN-13**: 978-0471309321. 2- Griffiths, D. J. (2013). *Introduction to Electrodynamics* (4th Edition). Pearson Education, **ISBN-13**: 978-0321856562.
Supportive References	1. Zangwill, A. (2013). *Modern Electrodynamics*. Cambridge University Press, **ISBN-13**: 978-0521896979. 2. Landau, L. D., & Lifshitz, E. M. (1980). *The Classical Theory of*

	Fields (Volume 2). Pergamon Press, **ISBN-13**: 978-0750627689. 3. Wolfgang K. H. Panofsky and Melba Phillips (2nd Edition, 2005), *Classical Electricity and Magnetism* , **ISBN-13**: 978-0486439242. 4. Schwinger, J., Milton, K. A., Tsai, W., & DeRaad, L. L. (1998). *Classical Electrodynamics*. Westview Press, **ISBN-13**: 978-0738200568 5. Sadiku, M. N. O. (2014). *Elements of Electromagnetics* (6th Edition). Oxford University Press, **ISBN-13**: 978-0199321384
Electronic Materials	Free online materials on **Classical Electromagnetism** (Graduate-Level). Includes lecture notes, assignments, and video lectures. Link: [MIT OCW - Electromagnetism II].
Other Learning Materials	1- **Stanford Online** - Offers advanced courses in mechanics that might include topics in classical dynamics and modern analytical methods in physics. Stanford's approach to teaching often involves a mix of theoretical exploration and practical applications. 2- **Coursera**: There are several courses available on Coursera that deal with classical mechanics and related subjects from universities around the world. These courses often include video lectures, quizzes, and assignments for a thorough understanding. 3- **edX**: Similar to Coursera, edX offers courses from universities globally, including detailed courses on both the fundamentals and advanced topics in physics. Look for courses specifically targeting Lagrangian and Hamiltonian mechanics for a deep dive into the analytical techniques used in classical mechanics.

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities	(Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)
Technology equipment	(Projector, smart board, software)
Other equipment (Depending on the nature of the specialty)	(Depending on the nature of the specialty)

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.
Effectiveness of students' assessment	Course Instructor	Compare assessments with course learning outcomes (CLOs)
Quality of learning resources	Course Instructor	Track student engagement with electronic materials.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates .
Other		

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

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	

Course Specification

(Postgraduate Programs)

Course Title:	Quantum mechanics I
Course Code:	
Program:	Master of Science in 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: (3hours)

2. Course type

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

3. Level/year at which this course is offered: (first level/first year)

4. Course general Description:

This course provides a foundational understanding of quantum mechanics, tailored for students with varying levels of mathematical preparation. It explores the principles and postulates of quantum mechanics, emphasizing conceptual clarity and practical applications relevant to modern physics.

The course begins with an introduction to the historical development of quantum mechanics, wave-particle duality, and the uncertainty principle. Core topics include wave functions, operators, matrix mechanics, the Schrödinger equation, and the role of symmetries in quantum systems. Students will develop an understanding of angular momentum, spin dynamics, and their applications to atomic and solid-state physics.

In the final weeks, the lecturer will select elective topics aligned with the students' academic tracks, such as:

1. Condensed Matter Applications: Bose-Einstein condensation, superconductivity, and Fermi-Dirac statistics.
2. Nuclear and Medical Physics Applications: Quantum tunneling in alpha decay and applications in medical imaging, such as PET scans.
3. Environmental Physics Applications: Quantum mechanics in photovoltaics and nanostructures for renewable energy systems.

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

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

7. Course Main Objective(s):

1. Introduce the Fundamentals of Quantum Mechanics:
   - Provide a historical context and foundation for quantum mechanics, including key principles such as wave-particle duality and the uncertainty principle.
   - Develop an understanding of wave functions, operators, and the mathematical

framework of quantum systems.

2. Explore Core Theoretical Concepts:
   - Introduce matrix mechanics and the Schrödinger equation as tools for describing quantum systems.
   - Discuss symmetries, conservation laws, and their implications in quantum mechanics.
   - Examine the concepts of angular momentum and spin dynamics and their applications in physics.
3. Foster Practical Applications of Quantum Mechanics:
   - Highlight the relevance of quantum mechanics to atomic structure, solid-state physics, nuclear physics, and renewable energy systems.
   - Provide practical examples and problem-solving techniques to connect theory with real-world phenomena.
4. Adapt the Course to Students' Interests and Future Goals:
   - Offer elective topics aligned with academic tracks in condensed matter physics, nuclear and medical physics, and environmental physics.
   - Enable students to explore specialized areas such as superconductivity, quantum tunneling, or photovoltaics, tailored to their future career paths.
5. Prepare Students for Advanced Studies and Applications:
   - Build a strong conceptual foundation for further studies in quantum mechanics and related disciplines.
   - Develop critical thinking and problem-solving skills through examples and elective topics relevant to modern physics research and applications.

These objectives ensure students gain a solid understanding of quantum mechanics, with content and applications tailored to their mathematical background and academic interests.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid • Traditional classroom • 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 CLOs aligned with program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Understand the mathematical framework of quantum mechanics, including operators, matrices, and the concepts of measurement and uncertainty.	**K1-P**	**1. Lectures. 2. Discussions. 3. Slides and computer simulation software may be used by the teachers to clarify concepts. 4. Problems solving.**	**1- Homework assignments. 2- Group Project assignment. 3- Question –answer session in class. 4- Exams: quizzes, Mid-term, and final exams**
1.2	Recognize the Schrödinger and Heisenberg pictures, evolution operators, and the implications of symmetries in physics.	**K2-P**		
1.3	Apply quantum theory to atomic and solid-state systems, including rotational invariance and angular momentum.	**K3-M**		
2.0	**Skills**			
2.1	Solve the Schrödinger equation for time evolution and calculate the time dependence of expectation values.	**S1-M**	**1. Lectures. 2. Discussions. 3. Problem solving. 4. Encourage the student to look for the information in different references. 5. Define duties for each chapter**	**1- Homework assignments. 2- Group Project assignment. 3- Question –answer session in class. 4- Exams: quizzes, Mid-term, and final exams**
2.2	Establish and analyze the Heisenberg equation of motion and the implications of translational invariances	**S2-M**		
2.3	Apply angular momentum addition rules and solve advanced problems in quantum systems, such as superconductivity and superfluidity.	**S3-P**		
3.0	**Values, autonomy, and responsibility**			
3.1	Participate effectively in		**1. Groupe assignments 2. Clarify deadlines for**	**1. Evaluate the efforts of each student in preparing**

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
	multidisciplinary and/or interdisciplinary teams	V1-P	delivery of assignments, reports, and exams.	the report. 2. Evaluate the work in teams. 3. Evaluation of student's presentations.

C. Course Content:

No	List of Topics	Contact Hours
1	**Introduction to Quantum Mechanics**: Historical background; wave-particle duality with real-world examples (e.g., photoelectric effect); uncertainty principle; overview of quantum mechanics.	3
2	**Wave Functions and Operators (Part 1)**: Introduction to wave functions and their physical meaning; Dirac notation basics; Hermitian and unitary operators with examples in measurement.	3
3	**Wave Functions and Operators (Part 2)**: Observables and measurements in quantum systems; postulates of quantum mechanics; eigenvalues, eigenvectors, and projection operators.	3
4	**Elements of Matrix Mechanics (Part 1)**: Basis and representation; introduction to matrices and their properties; matrix representation of operators in simple quantum systems.	3
5	**Elements of Matrix Mechanics (Part 2)**: Eigenvalues and eigenvectors; connection to quantum states and measurements; practical applications in two-level quantum systems.	3
6	**Time Evolution and the Schrödinger Equation (Part 1)**: Time-evolution operator; time-dependent Schrödinger equation; physical meaning of energy eigenstates.	3
7	**Time Evolution and the Schrödinger Equation (Part 2)**: Time dependence of expectation values; distinction between the Schrödinger and Heisenberg pictures; examples of the Heisenberg equation of motion.	3
8	**Symmetries in Quantum Mechanics (Part 1)**: Mathematical background for symmetries; translational invariance and its implications; time-translational invariance and conservation laws.	3
9	**Symmetries in Quantum Mechanics (Part 2)**: Time-reversal symmetry; parity invariance and physical consequences in atomic and nuclear systems.	3
10	**Rotational Invariance and Angular Momentum (Part 1)**: Rotational invariance in quantum systems; eigenvalue problems for orbital angular momentum; examples in hydrogen atom physics.	3

11	**Rotational Invariance and Angular Momentum (Part 2)**: Spin dynamics; addition of angular momenta; qualitative discussion of Clebsch-Gordan coefficients and their significance.	3
12	**Applications to Atomic Physics**: Introduction to spin-orbit coupling, fine structure of the hydrogen atom; Pauli exclusion principle; bosons and fermions in simple systems.	3
13	**Elective Topic 1: Condensed Matter Applications**: Symmetrization rules for Helium; basics of quantum models for superconductivity; Bose-Einstein condensation; Fermi-Dirac statistics.	3
14	**Elective Topic 2: Nuclear and Medical Physics Applications**: Quantum tunneling in alpha decay; application of quantum principles to radioactive decay in medical imaging (e.g., PET scans).	3
15	**Elective Topic 3: Environmental Physics Applications**: Quantum mechanics in photovoltaics; introduction to quantum confinement effects in nanostructures used for renewable energy applications.	3
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	**Exercises & Homework**	**Each chapter**	**10%**
2.	**Quizzes**	**Each chapter**	**10%**
3.	**Mid-term exam**	**8th 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.** "Modern Quantum Mechanics" by J.J. Sakurai and Jim Napolitano (3rd Edition, 2020) ISBN: 978-1108473224 **2.** "Principles of Quantum Mechanics" by R. Shankar (2nd Edition, 1994) ISBN: 978-0306447907
Supportive References	1. Quantum Mechanics: Concepts and Applications" by Nouredine Zettili (2nd Edition, 2009) ISBN: 978-0470026793 2. "Quantum Mechanics: A Modern and Concise Introductory Course" by Daniel Bes (2nd Edition, 2020) ISBN: 978-3030442961

	3. "Advanced Quantum Mechanics: Materials and Photons" by Rainer Dick (3rd Edition, 2020) ISBN: 978-3030382120
Electronic Materials	• MIT OpenCourseWare: Quantum Physics I ◦ An undergraduate course introducing the basic features of quantum mechanics, including lecture notes and assignments. ◦ https://ocw.mit.edu/courses/8-04-quantum-physics-i-spring-2016/ • Stanford Online: Quantum Mechanics for Scientists and Engineers ◦ A course designed to teach quantum mechanics to those with a college-level understanding of physical science or engineering. ◦ https://online.stanford.edu/courses/soe-yeeqmse01-quantum-mechanics-scientists-and-engineers • Coursera: Foundations of Quantum Mechanics ◦ Covers fundamental concepts and topics of quantum mechanics, including basic concepts and 1D potential problems. ◦ https://www.coursera.org/learn/foundations-quantum-mechanics/
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

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

Items	Resources
	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
Effectiveness of students assessment	Course Instructor	Compare assessments with course learning outcomes (CLOs).
Quality of learning resources	Course Instructor	Track student engagement with electronic materials>
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates.
Other		

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

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	

Course Specification

(Postgraduate Programs)

Course Title:	Theoretical Tools for Physics
Course Code:	
Program:	Master of Science in 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 hours)				
2. Course type				
A.	☐ University	☐ College	☒ Department	☐ Track
B.	☒ Required		☐ Elective	
3. Level/year at which this course is offered: (1st Year/First Term)				

4. Course General Description:

This course provides postgraduate students with a comprehensive understanding of the advanced mathematical and theoretical tools essential for modern physics. It is structured to progressively build a strong foundation in variational calculus, curvilinear coordinates, tensor analysis, functional analysis, integral equations, and group theory, while connecting these mathematical concepts to their applications in physics.

The course begins with foundational topics such as variational calculus and curvilinear coordinates, equipping students with the mathematical language required for advanced physical theories. It then explores tensor analysis in both Cartesian and curvilinear systems, functional analysis with applications to quantum mechanics, and integral equations with practical solution methods. Group theory, focusing on Lie groups and their applications to quantum mechanics and particle physics, completes the core topics.

In the final weeks of the course, students will study one elective topic, chosen by the lecturer, to explore a specialized area of theoretical physics in greater depth. Elective options include:

1. Tensors in Special Relativity: Application of tensors in Minkowski space, Lorentz transformations, and relativistic physics.
2. Perturbation Methods: Techniques for solving complex systems using dimensional analysis and asymptotic expansions.

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

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

7. Course Main Objective(s):

1. Understand and Apply Variational Calculus and Tensor Analysis
   - Derive and solve variational problems using the Euler-Lagrange equation, Beltrami density, and constraints.
   - Analyze and apply tensor calculus in Cartesian and curvilinear coordinates, including vector operators in physical systems.
2. Master Mathematical Tools for Advanced Physics
   - Utilize curvilinear coordinate systems to solve complex physical problems, such as gradient, divergence, curl, and Laplacian operations.
   - Solve integral equations using closed-form solutions, Neumann series, Fredholm theory, and Hilbert-Schmidt theory.
3. Explore Group Theory and Functional Analysis
   - Understand group theory basics, Lie groups, and their applications in symmetry operations for quantum mechanics and particle physics.
   - Analyze self-adjoint operators, Hilbert spaces, and spectral theorems with applications in quantum systems.
4. Develop Analytical and Problem-Solving Skills
   - Formulate and solve complex mathematical models related to classical mechanics, quantum mechanics, and general relativity.
   - Demonstrate critical thinking in selecting appropriate theoretical tools for specific physical problems.
5. Engage with Specialized Topics in Advanced Physics
   - Explore one elective topic, chosen by the lecturer, to gain in-depth knowledge in a specialized area of theoretical physics.
     - Elective Options: Tensors in Special Relativity or Perturbation Methods.
6. Prepare for Research and Lifelong Learning
   - Build a strong theoretical foundation for advanced research in physics and interdisciplinary fields.
   - Cultivate an appreciation for the evolving nature of theoretical tools and their applications to contemporary physics challenges.

These objectives ensure that students acquire both the theoretical knowledge and practical skills needed for advanced studies and research in 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 • Traditional classroom • 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	Explain the principles of variational calculus, curvilinear coordinates, and tensor analysis as applied to physics.	K1-P	Interactive lectures with problem-solving examples.	Written exams and quizzes.
1.2	Describe the fundamental concepts of functional analysis, integral equations, and group theory and their applications in physics.	K2-P	Case-based discussions on real-world applications.	Research-based assignments.
1.3	Understand the role of mathematical structures, such as Hilbert spaces and Lie groups, in quantum mechanics and particle physics.	K3-P	Concept-driven lectures and collaborative exercises.	Midterm and final examinations.
...				
2.0	**Skills**			
2.1	Apply tensor analysis and curvilinear coordinate systems to solve problems in continuum mechanics and relativity.	S1-P	Hands-on problem-solving workshops.	Analytical assignments.
2.2	Develop mathematical models for physical systems using integral equations and group theory.	S2-P	Group projects and guided mentorship sessions.	Group presentations and reports.
2.3	Analyze complex physical phenomena using advanced mathematical techniques, including perturbation methods and spectral analysis.	S3-P	Research-focused tasks and practical exercises.	Research projects and evaluations.
2.4				

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
...				
3.0	**Values, autonomy, and responsibility**			
3.1	Appreciate the importance of theoretical tools in advancing modern physics and addressing interdisciplinary challenges.	V1-P	Reflective discussions on the societal impact of theoretical physics.	Reflective essays.
3.2	Demonstrate ethical responsibility in applying advanced mathematical tools to solve real-world problems.	V2-M	Case studies on ethical applications in physics.	Case study analysis.

C. Course Content:

No	List of Topics	Contact Hours
1.	**Introduction to Theoretical Tools**: Overview of mathematical tools used in physics, linear algebra essentials (matrices, eigenvalues, eigenvectors), and differential equations.	3
2.	**Introduction to Variational Calculus (Part 1)**: Variational problems, Euler-Lagrange equation, and simple applications to mechanics (e.g., geodesics).	3
3.	**Variational Calculus (Part 2)**: Beltrami density, constraints, and applications to Lagrangian and Hamiltonian dynamics.	3
4.	**Introduction to Curvilinear Coordinates (Part 1)**: Scale factors, basis vectors, and general curvilinear coordinates.	3
5.	**Introduction to Curvilinear Coordinates (Part 2)**: Vector operators (grad, div, curl, Laplacian) in curvilinear coordinates and physical applications.	3
6.	**Tensor Analysis (Part 1)**: Suffix notation for vectors and tensors, Cartesian tensors—definitions, transformations, and applications in stress and strain analysis.	3
7.	**Tensor Analysis (Part 2)**: Tensors in curvilinear coordinates—basis vectors, metric tensor, transformation laws, and applications in continuum mechanics.	3
8.	**Functional Analysis (Part 1)**: Hilbert spaces and their properties, linear operators, and physical applications in quantum mechanics.	3
9.	**Functional Analysis (Part 2)**: Self-adjoint operators, spectral theorem, functional calculus, and applications in quantum mechanics.	3
10.	**Integral Equations (Part 1)**: Deriving integral equations from differential equations, types of integral equations (Volterra and Fredholm).	3
11.	**Integral Equations (Part 2)**: Operator notations, existence of solutions, Neumann series, Fredholm theory, and Hilbert-Schmidt theory.	3
12.	**Group Theory (Part 1)**: Basics of group theory, representation theory, and Lie groups (including SU(2) and SU(3) groups).	3
13.	**Group Theory (Part 2)**: Applications of group theory in quantum mechanics	3

	and particle physics (e.g., symmetry operations and conservation laws).	
14.	**Elective Topic 1: Tensors in Special Relativity**: Tensors in Minkowski space, Lorentz transformations, and the energy-momentum tensor in relativistic physics.	3
15.	**Elective Topic 2: Perturbation Methods**: Dimensional analysis, asymptotic expansions, and perturbation techniques (regular and singular).	3

Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	Problem Sets and Assignments	All week	10%
2.	Research Project and Presentation	5th week	10%
3.	Midterm Exam	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	• **Mathematical Methods for Physicists: A Comprehensive Guide**, George B. Arfken, Hans J. Weber, Frank E. Harris, Edition: 7th (2012) Publisher: Academic Press, ISBN-13: 978-0123846549 • **Mathematical Methods for Physics and Engineering: A Comprehensive Guide** Authors: K.F. Riley, M.P. Hobson, S.J. Bence Edition: 3rd (2006) Publisher: Cambridge University Press ISBN-13: 978-0521679718
Supportive References	• **Mathematical Methods in the Physical Sciences** Author: Mary L. Boas, Edition: 3rd (2006) Publisher: John Wiley & Sons, ISBN-13: 978-0471198260 • **Functional Analysis for Probability and Stochastic Processes: An Introduction**, Author: Adam Bobrowski Edition: 1st (2005) Publisher: Cambridge University Press ISBN-13: 978-0521831666 • **Perturbation Methods**, Author: Ali H. Nayfeh, Edition: 1st (2000) Publisher: John Wiley & Sons, ISBN-13: 978-0471345800

Electronic Materials	• **MIT OpenCourseWare: Mathematical Methods for PhysicsLink**: MIT OCW: Mathematical Methods for Physics **Description**: Provides lecture notes, assignments, and videos on mathematical methods for physicists, including variational calculus, functional analysis, and tensor calculus. • **Khan Academy: Multivariable Calculus and Linear Algebra Link**: Khan Academy **Description**: Free, self-paced learning modules on topics like gradient, divergence, curl, and Laplacian in curvilinear coordinates, as well as linear algebra fundamentals.
Other Learning Materials	Simulation software such as Matlab, Maple, etc.

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	• Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. • Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. • Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	• Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	• 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	Students	Student Feedback, Student Performance Metrics.
	Instructors (Self-assessment)	Instructor Self-Assessment,

Assessment Areas/Issues	Assessor	Assessment Methods
		Student Performance Metrics.
	Peers (Colleagues)	Peer Review.
	Academic and Industry Experts	Compilation of Teaching Materials.
Effectiveness of students' assessment	Instructors	Alignment with Learning Objectives, Review of Assessment Design, Tracking of Student Performance
	Students	Student Feedback on Assessments, Analysis of Assessment Results.
	Peers (Colleagues)	Peer Review and Collaboration.
	External Reviewers (Academic and Industry Experts)	External Benchmarking and Accreditation.
Quality of learning resources	Instructors	Instructor Review and Reflection, Alignment with Course Objectives.
	Students	Student Feedback on Learning Resources.
	Peers (Colleagues)	Peer Review.
	Academic and Industry Experts	External Expert Review, Comparative Analysis.
The extent to which CLOs have been achieved	Instructors	Direct Assessment Methods: Exams and Quizzes, Assignments and Projects. Indirect Assessment Methods: Surveys and Questionnaires, Self-Assessments.
	Peers (Colleagues)	Peer Review and Feedback.
	External Reviewers (Academic and Industry Experts)	Alumni and Employer Feedback, Benchmarking and External Review
Other		

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

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	

Course Specification

(Postgraduate Programs)

Course Title:	Statistical Physics
Course Code:	*Enter Course Code.*
Program:	Master of Science in 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: (1^{st} year- Second semester)					
4. Course General Description:					

This course on Statistical Mechanics provides a comprehensive exploration of the principles and applications of statistical methods to understand the physical properties of macroscopic systems from a microscopic perspective. Students will delve into the essential theories of thermodynamics, revisiting foundational concepts such as entropy, energy, and equilibrium, and extending these ideas to statistical interpretations.The course covers a broad range of topics, starting with a review of thermodynamics, progressing through the classical and quantum statistical mechanics frameworks, and exploring the statistical ensembles that describe different physical systems. Key ensembles like the microcanonical, canonical, and grand canonical are studied in depth, alongside statistical approaches to both equilibrium and nonequilibrium phenomena.Through a mixture of lectures, problem-solving sessions, and practical simulations, students will learn to apply statistical mechanics to a variety of physical situations, such as gas laws, phase transitions, and quantum systems. The course emphasizes analytical skills, encouraging students to derive and manipulate thermodynamic functions and distributions such as the Boltzmann, Fermi-Dirac, and Bose-Einstein statistics. Real-world applications are integrated throughout the curriculum to demonstrate the relevance of statistical mechanics in areas such as material science, nanotechnology, and biophysics. This course also places a strong emphasis on ethical scientific practice and professional development, preparing students for advanced studies or careers in physics, engineering, and beyond.

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

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

7. Course Main Objective(s):

1. **Foundational Understanding**:
   - To provide a solid foundation in the principles of thermodynamics and statistical mechanics, emphasizing their theoretical bases and practical implications.

- To develop a deep understanding of the laws of thermodynamics, including the zeroth, first, second, and third laws, and their relevance to physical systems.

2. **Statistical Approaches**:
   - To introduce the fundamental postulates of classical and quantum statistical mechanics, teaching students how macroscopic properties arise from the behavior of microscopic constituents.
   - To explore various statistical ensembles (microcanonical, canonical, grand canonical) and their applications in describing the properties of different physical systems.

3. **Analytical Skills**:
   - To enhance students' abilities to solve complex problems using statistical mechanics concepts, particularly through the derivation of thermodynamic quantities and the analysis of energy and particle distributions.
   - To apply mathematical and computational methods to solve statistical mechanics problems, fostering analytical and critical thinking skills.

4. **Practical Applications**:
   - To demonstrate the applications of statistical mechanics in real-world contexts such as phase transitions, heat engines, and refrigeration cycles.
   - To engage students in practical exercises and simulations that mimic real-life applications of the concepts learned, enhancing their understanding and retention.

5. **Research and Innovation**:
   - To encourage curiosity and inquiry into advanced topics and contemporary research areas within statistical mechanics, such as quantum statistics, Bose-Einstein condensation, and applications in new materials and nanotechnology.
   - To prepare students for further study and research in physics and related disciplines by providing a thorough grounding in the statistical approaches to energy and matter.

6. **Ethical and Professional Development**:
   - To instill a sense of professional responsibility and ethical conduct in scientific research and applications, emphasizing the importance of accurate data representation and the implications of scientific work on society.
   - To develop communication skills necessary for scientific discourse and presentation, ensuring students can articulate complex ideas effectively and professionally.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	90%
2	E-learning		
3	Hybrid		

No	Mode of Instruction	Contact Hours	Percentage
	• Traditional classroom • E-learning		
4	Distance learning	15	10%

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	Understand foundational concepts of thermodynamics and statistical mechanics, including the laws of thermodynamics and their statistical basis.	**K1-P**	Lectures, Interactive Demonstrations	Quizzes, Homework Assignments
1.2	Explain and apply Boltzmann, Maxwell-Boltzmann, and partition functions for monoatomic and diatomic gases.	**K2-P**	Problem Solving Sessions	Exams, Practical Assignments
1.3	Explore the implications and practical applications of canonical and grand canonical ensembles in thermodynamic systems.	**K3-I**	Lectures, Demonstrations	Exams, Homework Assignments

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
2.0	**Skills**			
2.1	Derive thermodynamic quantities (e.g., entropy, energy, equilibrium constants) from statistical principles and apply them to real-world systems.	**S1-P**	Interactive Demonstrations	Homework Assignments, Quizzes
2.2	Use thermodynamic potentials and equations of state to analyze equilibrium and spontaneous processes in physical and chemical systems.	**S2-I**	Lectures, Problem Solving	Written Exams, Practical Tests
2.3	Quantify and analyze energy fluctuations and relate entropy to microstates for practical and theoretical problem-solving.	**S3-P**	Lectures	Exams
3.0	**Values, autonomy, and responsibility**			
3.1	Demonstrate intellectual integrity by critically evaluating theoretical assumptions and respecting data accuracy in statistical mechanics applications.	**V1-I**	Lectures, Group Discussions	Written Exams, Research Papers, Peer Review Assignments
3.2	Uphold professionalism by solving problems ethically and efficiently using statistical mechanics principles.	**V2-I**	Research Projects	Professionalism Assessment

C. Course Content:

No	List of Topics	Contact Hours
1.	**:Review in thermodynamics** Preliminaries 1-1 The first law of thermodynamic 1-2 The second law of thermodynamic 1-3 Entropy 1-4 Thermodynamic potentials 1-5	**3**

	Response functios 1-6 Classical ideal gas 1-7 1-8 The Third law of thermodynamic 1-9 Applications of Thermodynamics	
2.	**Classical Statistical Mechanics** 2-1 The postulated of classical sstatistical mechanics 2-2 Microcanonical ensemble 2-3 Derivation of thermodynamic 2-4 Equilibrium theorm 2-5 Gibbs Paradox	**6**
3.	**Canonical Ensemble** 3-1 Notaion of statistical mechanis 3-1 Contact between statistical mechanics and thermodynamic 3-1 The entropy in tem of the number of microstate 3-1 Thermodynamic connection 3-4 Ensemble and canonical ensemble 3-5 Canonical emsemble from statsitcal mechanics over of view 3-6 Derivations and Applications of the Canonical Ensembl 3-6-1 Method the most probable distribution 3-6-2 Probabilty calculation 3-6-3 Derivation the mechanical properites in canonical ensemble 3-6-4 Derivation the inverse temperature 3-7 Thermodynamic Laws from a Statistical Perspective	**6**
4.	**Grand canonical ensemble** 4-1 Method the most probable distribution 4-2 Probabilty calculation 4-3 Derivation the mechanical properites in grand canonical ensemble 4-4 Derivation the relationbetween chemical potential and inverse temperature. 4-5 Behavior and Implications of the Grand Canonical Ensemble 4-6 Equivalance of the canonical ensemble and the grand canonical ensemble	**6**
5.	**Fluctuations** Energy fluctuation in canonical ensemble 5-1 Particle Number Fluctuations in the Grand Canonical Ensemble 5-2	**3**
6.	**.Boltzmann, Fermi-Dirac and Bose-Einstein Statistics** **6-1 The Special Case of Boltzmann Statistics**	**6**

	6-1-1 Assumptions and Derivation 6-1-2 Maxwell-Boltzmann Velocity Distribution **6-2 Fermi-Dirac and Bose-Einstein Statistics** 6-2-1 Fermi-Dirac Statistics 6-2-1 Bose-Einstein Statistics 6-2-3 Bose-Einstein Condensation **6-3 Comparison of the Three Statistics** 6-3-1 Graphical and mathematical comparisons 6-3-2 Physical intuition	
7.	**Ideal Monoatomic gas** The translational partition function 7-1 The electronic and Nuclear partition functions 7-2 7-3 Thermodynamic functions	3
8.	**Ideal Diatomic gas** The vibrational partition function 8-1 The rotational partition function of a heteronuclear diatomic 8-2 molecule The Symmetry requirement of the total wavefunction of a 8-3 homonuclear diatomic molecule The rotational partion function of a homonuclear diatomic 8-4 .molecule 8-5 Thermodynamic Function	6
9.	**Classical Statistical mechanics** the classical partition function 9-1 Phase space and Liouville Equation 9-2 9-3 Equipartition energy	3
10.	**Chemical Equilibrium** The Equilibrium constant in terms of partition functions 10-1 Examples of calculation of equilibrium constant 10-2	3
Total		45

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	**Quizzes**	**Weeks 2, 4, 8,10,14**	**10%**
2.	Homework	**All weeks**	**10%**
3.	Midterm Exam	**7th week**	**30%**
4.	Final Exam	**Week 18**	**50%**
5.			

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
...			

*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	• **"Statistical Mechanics"** by Donald A. McQuarrie (2000) **ISBN-13**: 978-1891389153 • **"Statistical Mechanics"** by Kerson Huang (2nd Edition, 1987) **ISBN-13**: 978-0471815181 • **"Equilibrium Statistical Mechanics"** by Bernard J. H. Jackson (2000) **ISBN-13**: 978-0137470983 • **"Statistical Mechanics"** by R. K. Pathria and Paul D. Beale (3rd Edition, 2011) **ISBN-13**: 978-0123821881 • **"Statistical Mechanics: An Introductory Graduate Course"** by A. J. Berlinsky and A. B. Harris (2019) **ISBN**: 978-3-030-28186-1 • **"Statistical Physics"** by Nicolas Sator, Nicolas Pavloff, and Lénaïc Couëdel (2022) **ISBN**: 978-1032113450
Supportive References	• **"Statistical Physics: Volume 5"** by L. D. Landau and E. M. Lifshitz (3rd Edition, 1980) **ISBN-13**: 978-0750628969 • **"Fundamentals of Statistical and Thermal Physics"** by Frederick Reif (1965) **ISBN-13**: 978-1577666127 • **"Theoretical Physics 8: Statistical Physics"** by Wolfgang Nolting (2018) **ISBN**: 978-3-319-73826-0 • **"A Modern Course in Statistical Physics"** by Linda E. Reichl (3rd Revised and Updated Edition) **ISBN**: 978-3527407828
Electronic Materials	1- **Statistical Mechanics II: Statistical Mechanics of Fields** MIT OCW Statistical Mechanics II 2- **Stanford Online** Stanford Online Statistical Mechanics 3- **Statistical Thermodynamics: Molecules to Machines**: Coursera Statistical Thermodynamics
Other Learning Materials	Research Journals: • **Physical Review B**: Specializes in condensed matter and

	materials physics, offering research papers that apply statistical mechanics to electronic materials. • **Journal of Statistical Mechanics: Theory and Experiment**: Publishes papers on the application of statistical mechanics to different materials, including electronic systems.

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities	(Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)
Technology equipment	(Projector, smart board, software)
Other equipment (Depending on the nature of the specialty)	(Depending on the nature of the specialty)

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
Effectiveness of students' assessment	Course Instructor	Compare assessments with course learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	Track student engagement with electronic materials
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates
Other		

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

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	

هيئة تقويم التعليم والتدريب
Education & Training Evaluation Commission

اعتماد
NCAAA

2024
TPG-153

Course Specification
(Postgraduate Programs)

Course Title:	**Quantum mechanics II**
Course Code:	
Program:	**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: (3hours)					
2. Course type					
A.	☐ University	☐ College	☒ Department	☐ Track	
B.	☒ Required		☐ Elective		
3. Level/year at which this course is offered: (2nd level/first year)					

4. Course general Description:

This course builds upon the foundational principles of quantum mechanics introduced in Quantum Mechanics I, offering a deeper exploration of advanced topics while remaining accessible to students with varying mathematical backgrounds. The curriculum emphasizes both theoretical concepts and practical applications, tailored to the diverse academic tracks of condensed matter physics, nuclear physics, environmental physics, and medical physics.

Students will learn about approximation methods, including perturbation theory, the variational method, and the WKB approximation, with applications to atomic and molecular systems. The course also introduces quantum mechanics of identical particles, quantum scattering theory, and the fundamentals of relativistic quantum mechanics, including the Dirac equation and relativistic corrections.

In the final weeks, the lecturer will select elective topics tailored to the students' tracks, such as:

1. Quantum Computing (Condensed Matter Track): Qubits, quantum gates, and applications in cryptography and quantum computing.
2. Quantum Medical Imaging (Medical Physics Track): Quantum principles in MRI, CT, and PET imaging modalities, including photon detection and annihilation processes.
3. Renewable-Environmental and Nuclear Physics Applications (Environmental and Nuclear Tracks): Quantum tunneling in nuclear fusion, renewable energy applications, and nuclear reactions for sustainability.

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

Quantum Mechanics I

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

7. Course Main Objective(s):

1. Deepen Understanding of Advanced Quantum Mechanics Concepts:
    - Expand on approximation methods, including perturbation theory, the variational method, and the WKB approximation, to solve complex quantum systems.
    - Develop knowledge of quantum mechanics of identical particles and quantum scattering theory.
2. Introduce Relativistic Quantum Mechanics:
    - Provide an introduction to the Klein-Gordon and Dirac equations and their significance in describing relativistic quantum systems.
    - Explore relativistic corrections and applications to atomic and molecular physics.
3. Connect Theory to Practical Applications:
    - Demonstrate the role of advanced quantum mechanics in condensed matter, nuclear, environmental, and medical physics.
    - Discuss real-world applications, including quantum computing, medical imaging, and renewable energy technologies.
4. Foster Critical Thinking and Problem-Solving Skills:
    - Provide problem-solving techniques to apply quantum mechanics to atomic systems, molecular spectra, and scattering processes.
    - Encourage students to analyze and interpret quantum systems using approximation methods and computational approaches.
5. Adapt Content to Students' Academic Tracks:
    - Offer elective topics tailored to specific tracks, such as quantum computing for condensed matter physics, quantum medical imaging for medical physics, and quantum tunneling for nuclear and environmental physics.
    - Enable students to explore specialized areas relevant to their academic and career interests.
6. Prepare Students for Advanced Studies and Research:
    - Equip students with the theoretical and conceptual tools necessary for pursuing advanced research in quantum mechanics and its applications.
    - Build a foundation for interdisciplinary exploration in physics, engineering, and applied sciences.

These objectives ensure that students gain a robust understanding of advanced quantum mechanics while connecting theory to practical applications in their chosen fields of study.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid • Traditional classroom • 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 CLOs aligned with program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Understand advanced approximation methods, including perturbation theory, variational methods, and the WKB approximation.	K1-P	Interactive lectures with real-world examples. Problem-solving sessions with group discussions. Conceptual demonstrations and visual aids.	Written exams. Problem sets. Concept-based quizzes.
1.2	Explain the principles of permutation symmetry and the behavior of identical particles, including bosons and fermions.	K2-P		
1.3	Describe the key concepts of quantum scattering, relativistic quantum mechanics, and their physical applications.	K3-M		
2.0	**Skills**			
2.1	Apply quantum mechanical methods to analyze atomic, molecular, and solid-state systems.	S1-M	Guided exercises and computational workshops.	Analytical problem-solving tasks.
2.2	Solve problems involving quantum scattering and collision dynamics, using concepts like the scattering matrix and cross-sections.	S2-P	Step-by-step problem-solving in class.	Homework assignments.
2.3	Perform basic analysis of advanced topics like quantum computing or quantum medical imaging.	S3-P	Project-based learning and presentations.	Research projects.
3.0	**Values, autonomy, and responsibility**			
3.1	Appreciate the interdisciplinary applications of quantum mechanics	V1-P	Discussions on real-world	Reflection essays.

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
	in fields like computing and medical imaging.		quantum advancements.	
3.2	Demonstrate professional responsibility in analyzing and interpreting quantum phenomena.	V2-I	Mentoring sessions on research integrity.	Supervisor evaluations.

C. Course Content:

No	List of Topics	Contact Hours
1	**Review of Approximation Methods in Quantum Mechanics**: Overview of time-independent perturbation theory; non-degenerate and degenerate cases; practical applications in atomic and molecular systems.	3
2	**Time-Independent Perturbation Theory Applications**: Calculating energy corrections for simple systems; practical problems on hydrogen and helium atoms; molecular spectra examples.	3
3	**Time-Dependent Perturbation Theory**: Transition probabilities; introduction to Fermi's golden rule; applications to light absorption, emission, and electromagnetic interactions.	3
4	**Variational Method**: Basics of trial wavefunctions; calculating ground-state energy of helium; applications to molecular systems; practical examples for problem-solving.	3
5	**WKB Approximation**: Semi-classical quantization; tunneling phenomena in quantum systems; applications to molecular vibrations and bound states.	3
6	**Identical Particles in Quantum Mechanics**: Symmetry and the spin-statistics theorem; bosons and fermions; examples in atomic systems (e.g., Helium atom); introduction to Bose-Einstein condensates.	3
7	**Applications of Identical Particles in Condensed Matter**: Free electron gas; basic band structure; introduction to Fermi surfaces and their role in solid-state physics.	3
8	**Quantum Scattering: One-Dimensional Scattering**: Scattering amplitude and cross-section; Born approximation basics; low-energy collision examples.	3
9	**Quantum Scattering: Partial Wave Analysis**: Partial wave analysis techniques; concept of scattering matrices; applications in nuclear and particle physics collisions.	3
10	**Introduction to Relativistic Quantum Mechanics**: Lorentz transformations; Klein-Gordon equation; interaction with electromagnetic potentials; relativistic corrections to quantum systems.	3
11	**Relativistic Quantum Mechanics: Dirac Equation**: Derivation and interpretation; connection to spin and magnetic momentum; fine structure of hydrogen.	3
12	**Relativistic Applications**: Applications to high-energy physics; relativistic effects in atomic and molecular systems; introductory concepts in quantum electrodynamics.	3
13	**Elective Topic 1: Quantum Computing (Condensed Matter)**: Introduction to qubits and quantum gates; basics of quantum entanglement; practical	3

	applications in quantum cryptography and computing.	
14	**Elective Topic 2: Quantum Medical Imaging (Medical Physics)**: Application of quantum principles in imaging modalities; quantum mechanics of MRI, CT, and PET; annihilation processes in PET scans.	3
15	**Elective Topic 3: Environmental and Nuclear Physics Applications**: Quantum tunneling in fusion and environmental processes; applications to nuclear reactions and sustainable energy technologies.	3
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	Exercises & Homework	Each chapter	10%
2.	Quizzes	Each chapter	10%
3.	Mid-term exam	8th 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. Modern Quantum Mechanics (3rd edition, 2020) by Jun John Sakurai and Jim Napolitano ISBN: 978-1108422413. 2. Introduction to Quantum Mechanics" by David J. Griffiths and Darrell F. Schroeter, Edition: 3rd (2018) ISBN: 978-1107189638 3. Principles of Quantum Mechanics, (2nd Edition 2014) by R. Shankar, Springer edition ISBN: 978-0306447907 4. Introductory quantum mechanics (4th edition 2002) by R. L. Liboff, Pearson Education ISBN: 978-0805387148 5. Quantum Mechanics: A Modern Introduction (1st edition, 1996) by Kenneth S. Krane ISBN 978-0-471-80515-2 6. "Quantum Computation and Quantum Information" by Michael A. Nielsen and Isaac L. Chuang, Edition: 10th Anniversary Edition (2011) ISBN: 978-1107002173 7. "Quantum Mechanics of Molecular Imaging" by Marcus Elbert and David Parker, Edition: 1st (2021) ISBN: 978-3030754259
Supportive References	• **Quantum Mechanics: A Modern and Concise Introductory Course" by Daniel Bes, Edition**: 1st (2004) **ISBN**: 978-3540203659.

	• **"Quantum Mechanics: Concepts and Applications" by Nouredine Zettili, Edition**: 2nd (2009) **ISBN**: 978-0470026793. • **"A Textbook on Modern Quantum Mechanics" by A. C. Sharma, Edition**: 1st (2021) **ISBN**: 978-0367693600
Electronic Materials	• **MIT OpenCourseWare: Quantum Physics I**: **Link**: MIT OCW Quantum Physics I. • **Lecture Notes on Quantum Mechanics by David Tong (University of Cambridge) Link**: Cambridge Lecture Notes • **"Advanced Quantum Mechanics: Materials and Photons" by Rainer Dick, Edition**: 3rd (2020) **ISBN**: 978-3030578695 **Link**: SpringerLink
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	• Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. • Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. • Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	• Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	• 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
Effectiveness of students	Course Instructor	Compare assessments with course learning outcomes

Assessment Areas/Issues	Assessor	Assessment Methods
assessment		(CLOs).
Quality of learning resources	Course Instructor	Track student engagement with electronic materials.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates.
Other		

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

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	

Course Specification

(Postgraduate Programs)

Course Title:	Physics Simulations and Modelling
Course Code:	
Program:	Master of 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 Identificationn:

1. Credit hours: (3hours)

2. Course type

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

3. Level/year at which this course is offered: (Second level/first year)

4. Course general Description:

This course provides a comprehensive introduction to the principles and techniques of physics simulation and modeling, tailored for students with varying levels of mathematical and programming expertise. It emphasizes practical applications in computational physics, covering foundational programming skills, numerical methods, and visualization techniques to simulate and analyze physical systems.

The course begins with an introduction to programming for physicists, including Python or MATLAB, followed by essential numerical methods such as solving ordinary and partial differential equations, Fourier methods, curve fitting, and Monte Carlo techniques. Students will learn how to simulate dynamic systems, visualize results, and interpret data effectively.

In the final weeks, the course includes elective topics tailored to students' academic tracks:

1. Condensed Matter Physics Simulations: Modeling crystal lattices, phonons, and thermal properties.
2. Nuclear and Medical Physics Simulations: Simulating radioactive decay and particle transport in radiation therapy and imaging.
3. Renewable and Environmental Physics Simulations: Modeling energy systems such as wind turbines and solar panels to evaluate efficiency and environmental impact.

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

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

7. Course Main Objective(s):

1. Develop Foundational Programming and Computational Skills:
   - Introduce essential programming techniques using Python or MATLAB for physics simulations.
   - Build proficiency in numerical methods, including solving ordinary and partial differential equations, Fourier analysis, and Monte Carlo techniques.

2. Teach Simulation Techniques for Physical Systems:
    - Provide students with the tools to simulate and analyze various physical phenomena, such as wave motion, heat diffusion, and random processes.
    - Enable students to visualize and interpret simulation results through effective graphing and animation techniques.
3. Apply Simulations to Physics Research and Applications:
    - Demonstrate how simulations are used to model real-world systems in condensed matter physics, nuclear physics, renewable energy, and medical physics.
    - Encourage students to connect theoretical knowledge with practical computational applications.
4. Encourage Problem-Solving and Analytical Thinking:
    - Guide students through problem-solving exercises to deepen their understanding of physical concepts through computational modeling.
    - Develop students' ability to interpret results and critically evaluate the limitations of computational methods.
5. Tailor the Course to Students' Academic Tracks:
    - Offer elective topics in the final weeks, enabling students to explore simulations specific to their areas of interest, such as lattice modeling for condensed matter physics, radiation transport for medical physics, or renewable energy system modeling.
6. Prepare Students for Advanced Studies and Research:
    - Equip students with the computational tools and knowledge necessary for advanced research in physics and interdisciplinary fields.
    - Build a strong foundation for professional applications of simulation techniques in science and engineering.

These objectives ensure that students acquire practical computational skills and understand their relevance to real-world physics problems, tailored to their academic and career interests.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid • Traditional classroom • 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 CLOs aligned with program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Understand programming concepts in Python/MATLAB, including debugging and applying numerical methods.	**K1-P**	**1. Lectures. 2. Discussions 3. Problems solving**	**1. Homework assignments. 2. Group Project assignment. 3. Exams: quizzes, Mid-term and final exams**
1.2	Develop the ability to write programs for basic numerical methods and display results in graphical or tabular formats.	**K2-M**		
1.3	Recognize the importance of precision and clarity in conveying technical information	**K3-P**		
2.0	**Skills**			
2.1	Apply numerical methods and simulation techniques to solve real-world physical problems.	**S1-M**	**1. Lectures. 2. Discussions. 3. Problems solving.**	**1- Homework assignments. 2- Group Project assignment. 3- Question –answer session in class.**
2.2	Analyze and evaluate the suitability of numerical methods for different scientific problems.	**S2-I**		
2.3	Implement and develop computational tools to model, analyze, and predict the behavior of physical systems.	**S3-M**		
3.0	**Values, autonomy, and responsibility**			
3.1	Demonstrate responsibility for self-learning and staying updated with advancements in physics and computational tools.	**V1-P**	**Encourage them how to attend lectures regularly by assigning marks for attendance.**	**1. Evaluate the scientific values of solutions. 2. Evaluate the work in team**
3.2	Work effectively both independently and collaboratively in teams to solve problems.	**V2-P**		

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods

C. Course Content:

No	List of Topics	Contact Hours
1	**Introduction to Programming for Physicists**: Overview of Python/MATLAB for simulation; basics of variable assignments; input/output statements and their use in simple physics calculations.	3
2	**Functions and Program Control**: Built-in and user-defined functions; control structures ("if", "while"); use of modules/packages for scientific calculations.	3
3	**Arrays and Loops**: Introduction to arrays and their manipulation; arithmetic operations on arrays; "for" loops for iterative computations; basic structure of physics simulation programs.	3
4	**Graphics and Visualization (Part 1)**: Creating 2D graphs to represent data; scatter plots and density plots; basic visualization of simulation results.	3
5	**Graphics and Visualization (Part 2)**: Introduction to 3D graphing techniques; creating basic animations to visualize dynamic systems such as oscillators or particle motion.	3
6	**Curve Fitting and Interpolation (Part 1)**: Linear and non-linear curve fitting methods; applying curve fitting to experimental or simulated data.	3
7	**Curve Fitting and Interpolation (Part 2)**: Polynomial and spline interpolation; practical examples such as fitting temperature profiles or material deformation data.	3
8	**Fourier Methods (Part 1)**: Fundamentals of Fourier series and discrete Fourier series; discrete Fourier transform (DFT) and its applications in analyzing periodic signals.	3
9	**Fourier Methods (Part 2)**: Power spectrum analysis; bandwidth and filtering techniques; Fast Fourier Transform (FFT) for solving time-series data in physics.	3
10	**Ordinary Differential Equations (ODEs)**: Solving first- and second-order ODEs using numerical methods; applications to simple systems like pendulums, oscillators, and diffusion processes.	3
11	**Partial Differential Equations (PDEs)**: Solving boundary value problems using relaxation and Gauss-Seidel methods; applications in heat conduction and wave equations.	3
12	**Random Processes and Monte Carlo Methods**: Generating random numbers for simulations; Monte Carlo integration; applying Monte Carlo methods to problems like random walks or statistical mechanics.	3
13	**Elective Topic 1: Condensed Matter Physics Simulations**: Simulating crystal lattices; modeling thermal vibrations and phonon dynamics; Monte Carlo simulations for lattice defects.	3
14	**Elective Topic 2: Nuclear and Medical Physics Simulations**: Modeling radioactive decay and interaction of radiation with matter; Monte Carlo simulations for particle transport in medical imaging.	3

15	**Elective Topic 3: Renewable and Environmental Physics Simulations**: Simulating renewable energy systems such as wind or solar power; modeling energy efficiency and environmental impact using PDEs and ODEs.	3
	Total	**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	Exercises & Homework	Each chapter	10%
2.	Quizzes	Each chapter	10%
3.	Mid-term exam	8th 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. Numerical Methods in Science and Engineering: Theories with MATLAB, Mathematica, Fortran, C and Python Programs, By P. Dechaumphai and N. Wansophark, ALPHA SCIENCE INTERNATIONAL LTD, (2020) ISBN: 978-1842656495. 2. Computational Physics by M. Newman, 1st edition (2012) ISBN: 978-1480145511 3. Numerical methods for engineering and scientists by A. Gilat & V. Subramaniam, 3rd edition (2014) ISBN: 978-1118554937 4. "Computational Physics" by Mark Newman (2nd Edition, 2013) ISBN: 978-1480145511 5. "Numerical Recipes: The Art of Scientific Computing" by William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery (3rd Edition, 2007) ISBN: 978-0521880688 6. "A Student's Guide to Python for Physical Modeling" by Jesse M. Kinder and Philip Nelson (2nd Edition, 2021) ISBN: 978-0691223654
Supportive References	• "An Introduction to Computational Physics" by Tao Pang (2nd Edition, 2006) ISBN: 978-0521825696 • "Matlab: A Practical Introduction to Programming and Problem

	Solving" by Stormy Attaway (5th Edition, 2022) ISBN: 978-0128154793 • "Computational Modeling and Visualization of Physical Systems with Python" by Jay Wang (1st Edition, 2022) ISBN: 978-3030850810

Electronic Materials	• **SciPy and NumPy Documentation**
	  • **Relevance**: Extensive documentation and tutorials for Python libraries used in numerical methods, Fourier transforms, and curve fitting.
	  • https://scipy.org/
	• **MATLAB Online**
	  • **Relevance**: Online platform for MATLAB programming and numerical simulation.
	  • https://matlab.mathworks.com/
	• **Project Jupyter (Jupyter Notebooks)**
	  • **Relevance**: Interactive Python notebooks for teaching programming, simulations, and visualization.
	  • https://jupyter.org/

Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

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

Items	Resources

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
Effectiveness of students assessment	Course Instructor	Compare assessments with course learning outcomes (CLOs).
Quality of learning resources	Course Instructor	Track student engagement with electronic materials.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates.
Other		

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

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	

هيئة تقويم التعليم والتدريب
Education & Training Evaluation Commission
اعتماد
NCAA

2024
TPG-153

Course Specification

(Postgraduate Programs)

Course Title:	Research Methodology and ethics
Course Code:	
Program:	Master of Science in Physics
Department:	Physics
College:	Science
Institution:	Umm Al-Qura University
Version:	2nd
Last Revision Date:	18/01/2025

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: Second semester /1st year

4. Course General Description:

This course provides students with a comprehensive introduction to research methods and ethics as applied in the field of higher education. It is designed to equip students with the foundational knowledge required for postgraduate research, including an understanding of research methodologies, challenges, and the organization of research projects. Students will learn how to identify, select, process, and analyze information relevant to their chosen topics.

The course covers the entire research process, including the formulation of a problem statement, the selection of appropriate research methodologies, literature review, data collection (both experimental and theoretical), data analysis, and presentation of findings. In addition, students will explore the process of summarizing results, making recommendations, drawing conclusions, and compiling references.

An important aspect of the course is its focus on ethical considerations in research. Students will be introduced to research ethics, including issues related to plagiarism, authorship, confidentiality, and the ethical treatment of research participants. Emphasis will also be placed on the responsible conduct of research, including adherence to ethical guidelines and the importance of maintaining integrity throughout the research process.

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

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

7. Course Main Objective(s):

1. Understand Research Fundamentals:
   Equip students with a solid understanding of the key concepts, methodologies, and challenges in postgraduate research.
2. Develop Research Skills:

Enable students to identify, select, and apply appropriate research methods to address specific academic or scientific problems.

3. Master the Research Process:
   Familiarize students with the stages of research, including problem formulation, literature review, data collection, analysis, and presentation of findings.
4. Apply Ethical Principles:
   Instill a strong understanding of research ethics, including avoiding plagiarism, ensuring confidentiality, maintaining integrity, and adhering to ethical guidelines in academic research.
5. Enhance Analytical and Critical Thinking:
   Develop students' ability to critically analyze research data, interpret results, and formulate evidence-based conclusions.
6. Practice Research Communication:
   Improve students' skills in writing research proposals, conducting small-scale research projects, and producing well-structured academic reports.
7. Integrate Theory and Practice:
   Provide students with hands-on experience in applying theoretical knowledge to real-world research scenarios.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100
2	E-learning		
3	Hybrid • Traditional classroom • 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	Explain the principles of research methodology, including research design and data analysis.	K1-I	Interactive lectures and discussions.	Written exams and quizzes.
1.2	Identify ethical considerations and practices in conducting scientific research.	K2-P	Case-based teaching and examples of ethical dilemmas.	Case studies and reflective essays.
1.3	Understand the structure and components of scientific reports and presentations.	K3-M	Conceptual lectures and hands-on report writing exercises.	Written assignments and reports.
2.0	**Skills**			
2.1	Conduct a comprehensive literature review and identify research gaps effectively.	S1-I	Guided research tasks and library/database training.	Research assignments and reviews.
2.2	Develop and present well-structured oral and poster presentations for research findings.	S2-P	Practice sessions with peer feedback.	Oral presentations and poster evaluations.
2.3	Apply appropriate tools for data analysis and interpretation in research.	S3-M	Workshops on data analysis techniques.	Practical assignments and case studies.
3.0	**Values, autonomy, and responsibility**			
3.1	Appreciate the importance of ethics in research and the broader impact of scientific work.	V1-P	Reflective discussions and ethical case studies.	Ethics-based essays and reports.
3.2	Demonstrate responsibility in conducting research, including proper	V2-M	Interactive workshops on plagiarism detection and referencing.	Turnitin reports and evaluations.

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
	citation and avoiding plagiarism.			
3.3	Commit to lifelong learning by continuously updating knowledge of research practices and methodologies.	V3-M	Seminars on emerging research trends.	Supervisor feedback and reviews.

C. Course Content:

No	List of Topics	Contact Hours
1.	**Introduction to Research Methodology**: Purpose, significance, motivation, and objectives of research. Types of research and defining research objects.	3
2.	**The Process of Scientific Research**: Steps in the research process, scientific explanation, and demarcation criteria.	3
3.	**Efficient Reading of Scientific Papers**: Strategies for reading critically, writing a paper summary, and presenting a paper.	3
4.	**Ethical Aspects of Research Work (Part 1)**: Research ethics considerations, primary and secondary sources, reviews, treatises, and patents.	3
5.	**Ethical Aspects of Research Work (Part 2)**: Searching for existing literature using web resources and databases.	3
6.	**Literature Review and Problem Definition**: Importance of literature reviews, identifying gap areas, and conducting a comprehensive literature review.	3
7.	**Research Design and Methods (Part 1)**: Designing a research plan, features of a good design, and tools of data collection.	3
8.	**Research Design and Methods (Part 2)**: Research methods, experimental methods, and analyzing and interpreting data.	3
9.	**Reporting and Thesis Writing (Part 1)**: Purpose and framework of a research report, structure and components of scientific reports, and types of reports.	3
10.	**Reporting and Thesis Writing (Part 2)**: Layout, illustrations, tables, bibliography, referencing, footnotes, and avoiding plagiarism.	3
11.	**Citation and Acknowledgments**: Understanding proper citation methods, acknowledgment practices, and plagiarism detection tools.	3
12.	**Research Presentation (Part 1)**: Purpose and types of research presentations. Elements of an effective research presentation.	3
13.	**Research Presentation (Part 2)**: Structuring research presentations, creating impactful visuals, and oral and poster presentation techniques.	3
14.	**Do's and Don'ts of Research Presentations**: Common mistakes, effective delivery techniques, and tailoring presentations to specific audiences.	3
15.	**Create and Present a Research Project**: Students prepare and deliver a complete oral presentation and poster based on their research topic.	3

Total	45

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	Present a journal article	2nd week	15%
2.	Write a Litaerure review of a selected topic in interest	6th week	30%
3.	Write a research Proposal	8th week	15%
4.	Present a selected topic by a poster presentation	10th week	15%
5.	Oral Presenttaion of a selected topic	18th week	25%

*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. **"Research Methodology: The Aims, Practices, and Ethics of Science"** Peter Pruzan (2016) *ISBN*: 978-3-319-27166-8 2. **"The Oxford Textbook of Clinical Research Ethics"** *Editors*: Ezekiel J. Emanuel, Christine Grady, Robert A. Crouch, Reidar K. Lie, Franklin G. Miller, David Wendler (2008) *ISBN*: 978-0-19-516865-5
Supportive References	1. **Research Ethics: A Philosophical Guide to the Responsible Conduct of Research"** Gary Comstock (2013) *ISBN*: 978-1-107-01066-8 **2. "The Palgrave Handbook of Research Methods and Ethics in Neurodiversity Studies"** Hanna Bertilsdotter Rosqvist, David Jackson-Perry (2024) *ISBN*: 978-3-031-66127-3
Electronic Materials	1. **"Research Ethics"** *Platform*: OpenWHO 2. **"Research Methodologies"** *Institution*: Queen Mary University of London *Platform*: Coursera 3. **"Research Methods in Psychology - 4th American Edition"** Paul C. Price, Rajiv Jhangiani, I-Chant A.

	Chiang (2017) *ISBN*: 978-1-77420-009-4
Other Learning Materials	1. Camputer-based programs/CD, professional standards or regulations and software. • Online Journals and Articles 2. John W. Creswell , J. David Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, SAGE Publications, Inc; Fifth Edition (2018) ISBN-13: 978-1506386706 3. Ron Iphofen, Martin Tolich Handbook of Qualitative Research. Sage, (2018) ISBN13: 978-1473970977

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	• Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. • Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. • Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	• Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	• 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
Effectiveness of students' assessment	Course Instructor	Compare assessments with course learning outcomes (CLOs).
Quality of learning resources	Course Instructor	Track student engagement with electronic materials.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates .
Other		

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

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	

هيئة تقويم التعليم والتدريب
Education & Training Evaluation Commission
اعتماد
NCAAA
2024
TPG-153

Course Specification

(Postgraduate Programs)

Course Title:	**Master's Capstone Research Project**
Course Code:	*Enter Course Code.*
Program:	**Master of Science in 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: (6)				
2. Course type				
A.	☐ University	☐ College	☒ Department	☒ Track
B.	☒ Required		☐ Elective	
3. Level/year at which this course is offered: (2nd year-Fourth semester)				

4. Course General Description:

The **Master's Capstone Research Project** is the culminating experience of the Master’s in Physics program, designed to allow students to demonstrate their ability to conduct independent, advanced research in their chosen specialization. Over the course of the second semester in the second year, students will integrate knowledge and skills acquired during their studies to investigate a specific research problem within one of the four specialization tracks: Condensed Matter Physics, Nuclear and High Energy Physics, Renewable Energy and Environment, or Medical Physics.

The project emphasizes critical thinking, methodological rigor, and the application of theoretical and practical tools. Under faculty supervision, students will propose, design, and execute a research project that contributes to their field of study. The capstone culminates in a comprehensive written report and an oral presentation to faculty and peers. This experience prepares students for careers in research, industry, or academia, fostering professionalism, ethical responsibility, and effective scientific communication.

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

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

7. Course Main Objective(s):

The **Master's Capstone Research Project** aims to achieve the following objectives:

1. **Integrate Knowledge Across Disciplines**:
Enable students to synthesize theoretical concepts, technical skills, and practical tools learned throughout the Master's program to address a significant research problem in their chosen specialization.

2. **Develop Research Skills**:

Foster the ability to independently design and execute a research project, including formulating hypotheses, conducting experiments or simulations, and analyzing data.

3. **Enhance Problem-Solving Abilities**:
Encourage critical thinking and creativity in approaching complex research challenges and developing innovative solutions.

4. **Promote Technical Proficiency**:
Strengthen students' expertise in advanced methodologies, computational tools, and experimental techniques specific to their specialization track.

5. **Advance Communication Skills**:
Cultivate the ability to effectively communicate scientific findings through a well-structured written report and a clear, professional oral presentation.

6. **Encourage Collaboration and Mentorship**:
Facilitate productive interactions with faculty supervisors and, where applicable, collaborative work with peers or research teams.

7. **Instill Ethical Responsibility**:
Ensure adherence to research ethics, including data integrity, proper citation practices, and respect for safety and environmental standards.

8. **Prepare for Future Endeavors**:
Equip students with the research experience and scientific acumen necessary for pursuing careers in academia, industry, or advanced research programs.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	90 hrs	100
2	E-learning		
3	Hybrid • Traditional classroom • E-learning		
4	Distance learning		

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

No	Activity	Contact Hours
1.	**Lectures**	90 hrs
2.	**Laboratory/Studio**	
3.	**Field**	
4.	**Tutorial**	
5.	**Others (specify)……**	
	Total	90 hrs

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	Demonstrate a comprehensive understanding of advanced concepts, theories, and methodologies in their chosen specialization track: Condensed Matter Physics, Nuclear and High Energy Physics, Renewable Energy and Environment, or Medical Physics.	**K1-M**	Faculty supervisors provide one-on-one guidance to help students understand advanced concepts, theories, and methodologies specific to their research track.	Continuous assessment through regular meetings with the supervisor to review the student's comprehension and progress.
1.2	Identify and critically analyze existing research literature to define research gaps and formulate significant research questions.	**K2-M**		
1.3	Understand the principles of research design, including experimental, theoretical, and computational approaches applicable to their specialization.	**K3-M**		
2.0	**Skills**			
2.1	Develop and execute an independent research project, including hypothesis formulation, methodological planning, and implementation.	**S1-M**	Students independently execute their research project	Comprehensive evaluation of the student's ability to
2.2	Use specialized tools and techniques effectively, such as simulation software (e.g., PYTHIA8, ROOT, MATLAB), laboratory equipment, or	**S2-M**		

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
	medical imaging systems.		under faculty guidance, developing practical skills in real-world problem-solving.	document and interpret research findings.
2.3	Analyze complex datasets, draw meaningful conclusions, and compare results with existing studies in the field.	**S3-M**		
3.0	**Values, autonomy, and responsibility**			
3.1	Uphold the highest standards of research ethics, including integrity, reproducibility, and proper citation practices.	**V1-M**	Interactive sessions highlighting real-world examples of ethical dilemmas in research, focusing on data integrity, authorship, and environmental/societal responsibilities.	Supervisors assess the student's adherence to ethical principles and professional conduct throughout the project.
3.2	Demonstrate responsibility in the conduct of research, ensuring respect for safety protocols, environmental considerations, and societal impact.	**V2-M**		
...				

C. Course Content:

No	List of Topics	Contact Hours
1-3	**Weeks 1–3: Research Proposal Development** **Objective:** Equip students with the skills to define research problems, formulate objectives, and prepare a robust research plan. **Week 1:** -Introduction to the capstone project structure, expectations, and deliverables. -Guidelines on selecting research topics and aligning them with specialization tracks. -Interactive session: Brainstorming research questions within each track. **Week 2:** -Writing a research proposal: Key components (introduction, objectives, methodology, timeline).	**18**

	-Review of relevant literature: Techniques for effective searching and referencing using databases like Scopus and Web of Science. -Practical Activity: Draft an initial research question and outline. **Week 3:** -Proposal refinement: Feedback sessions with supervisors. -Ethical considerations in research, including plagiarism, data integrity, and safety protocols. -Submission of the research proposal for approval.	
4-6	**Weeks 4–6: Literature Review and Methodology Design** **Objective:** Develop a comprehensive understanding of the research background and design effective methodologies. **Week 4:** -Conducting an in-depth literature review using advanced tools (e.g., Mendeley, EndNote). -Identifying gaps in current research and defining the project's scope. -Group Discussion: Sharing literature findings with peers for feedback. **Week 5:** -Methodology design: Experimental, computational, or theoretical approaches. Tools and techniques specific to tracks: -Condensed Matter Physics: Material synthesis and characterization tools. -Nuclear and High Energy Physics: PYTHIA8, ROOT, or experimental setups. -Renewable Energy and Environment: Simulation tools like MATLAB, COMSOL. -Medical Physics: Imaging techniques, radiation simulation software. **Week 6:** **-**Detailed planning: Creating a step-by-step research workflow. -Practical Activity: Mock execution of a small portion of the methodology for feedback	**18**
7-10	**Weeks 7–10: Research Execution** **Objective:** Conduct research and analyze preliminary results**.** **Week 7:** -Implementing the research plan: Data collection, experiments, or simulations. -Emphasis on accuracy and reproducibility in research processes. -Supervisor meeting: Weekly check-in to discuss progress and challenges. **Week 8:** **-**Data analysis techniques: Statistical analysis, error estimation, and visualization. -Practical Workshop:	**24**

	-Condensed Matter Physics: Analyzing material properties. -Nuclear and High Energy Physics: Event analysis using ROOT/PYTHIA8. -Renewable Energy: Energy efficiency modeling. -Medical Physics: Analyzing imaging data. **Week 9:** -Refining experimental or computational approaches based on preliminary results. -Peer Discussion: Present initial findings and gather feedback. **Week 10:** -Troubleshooting research issues with supervisors. -Preparing for mid-term progress reporting: Structuring the results and discussion sections.	
11-13	**Weeks 11–13: Data Analysis and Report Writing** **Objective**: Finalize research analysis and draft the capstone report. **Week 11:** **-**Comprehensive data analysis: Interpret results in the context of the research question. -Comparative analysis with existing studies: Highlight novel contributions. **-Workshop**: Using tools for visualization (e.g., Matplotlib, OriginLab). **Week 12:** **-**Structuring the capstone report: Guidelines for academic writing. -Writing the introduction, methodology, and preliminary results sections. -Supervisor feedback session: Reviewing drafts and refining content. **Week 13:** **-**Writing the discussion, conclusion, and references sections. -Peer Review: Exchange reports with classmates for feedback.	**18**
14-15	**Weeks 14–15: Final Presentation and Submission** **Objective:** Present research findings and submit the final report. **Week 14:** **-**Final revisions of the report based on supervisor and peer feedback. -Workshop: Creating effective presentation slides (focus on visuals and key messages). **-Week 15:** **-**Oral presentations to faculty and peers. -Submission of the final capstone report. -Reflection session: Discussing challenges, lessons learned, and future applications of the research.	**12**
Total		**90**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	**Research Proposal:** Assess research planning, topic relevance, and methodological design	**Week 3**	**20%**
2.	**Mid-Term Report:** Evaluate progress, understanding of research, and refinement of methodology.	**Week 7**	**15%**
3.	**Practical Deliverables:** Assess practical skills in data collection, analysis, and application of tools.	**Weeks 6-10**	**20%**
4.	**Final Report:** Evaluate the quality, clarity, and depth of the written research work.	**Week 14**	**30%**
5.	**Oral Presentation:** Assess communication skills, ability to defend research findings, and engagement with the audience.	**Week 15**	**15%**
...			

*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	N.A
Supportive References	N.A
Electronic Materials	N.A
Other Learning Materials	N.A

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	N.A
Technology equipment (Projector, smart board, software)	N.A
Other equipment (Depending on the nature of the specialty)	N.A

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	