هيئة تقويم التعليم والتدريب
Education & Training Evaluation Commission

اعتماد
NCAAA

2024
TPG-153

# Course Specification
## (Postgraduate Programs)

| | |
|---|---|
| **Course Title:** | Quantum Mechanics |
| **Course Code:** | PHYS603 |
| **Program:** | Master of Science in Physics |
| **Department:** | Physical Sciences |
| **College:** | Science |
| **Institution:** | Jazan University |
| **Version:** | |
| **Last Revision Date:** | 20/4/2024 |

## Table of Contents

# A. General information about the course:

## 1. Course Identification:

**1. Credit hours: ( 3 )**

**2. Course type**

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

**3. Level/year at which this course is offered: (**Level 2 /year 1)

**4. Course general Description:**

**This course is designed to establish the foundation of quantum mechanics starting with the axioms of quantum mechanics in finite and infinite dimensional vector spaces and their applicability to physics examples such as spin, position and momentum. The course then develops the use of unitary transformation and its essential role in deriving the commutation relations of various physical quantities. The course also addresses the quantum dynamics and provides the essential techniques to solve various physical systems. The theory of angular momentum is extensively studied in view of rotational symmetry, orbital angular momentum, Schrodinger's equation for central potentials, addition of angular momenta and tensor operators.**

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

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

**7. Course Main Objective(s):**

**The main objectives of this course are focused on the following:**

1. Design vector spaces related to the physical quantities of interest in both Dirac representation and matrix representation.
2. Perform essential calculations such as expectation values, commutation relations and uncertainty relations.
3. Discuss the role of symmetry and unitary transformation in physics in general and in quantum mechanics in particular such as in deriving the commutation relation and comparing them to their classical analogues when existed, the time evolution of a quantum system.

4. Solve the eigenvalue problems for various quantum mechanical systems such as a particle in a box, the harmonic oscillator and the hydrogen atom, addition of angular momenta problems.
5. Distinguish between Schrödinger and Heisenberg pictures while studying the dynamics of quantum systems.
6. Perform commutation relations for angular momenta operators including spin.

## 2. Teaching Mode: (mark all that apply)

| No | Mode of Instruction | Contact Hours | Percentage |
|---|---|---|---|
| 1 | Traditional classroom | 45 | 100 |
| 2 | E-learning | | |
| 3 | Hybrid<br>• Traditional classroom<br>• E-learning | | |
| 4 | Distance learning | | |

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

| No | Activity | Contact Hours |
|---|---|---|
| 1. | **Lectures** | 45 |
| 2. | **Laboratory/Studio** | 0 |
| 3. | **Field** | 0 |
| 4. | **Tutorial** | 0 |
| 5. | **Others (specify)……** | 0 |
| | **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: Upon completing the course students will be able to** | | | |
| 1.1 | Write down the matrix representation of a given state or observable, the | PLO1.1 | Lectures and discussion | Homework assignments, |

| Code | Course Learning Outcomes | Code of CLOs aligned with program | Teaching Strategies | Assessment Methods |
|---|---|---|---|---|
| | uncertainty relation for a pair of physical quantities such as spins, position, momentum, energy and time, the quantum interpretation for probability and measurements and the equation of motion for a quantum state that evolves with time. | | | Midterm exams and final exam. |
| 1.2 | Describe the necessity for complex vector spaces and Hermitian operators in quantum mechanics, the conservation of some quantum quantities under unitary transformation, the difference between the Heisenberg picture and the Schrödinger picture. | **PLO1.1** | Lectures and discussion | Homework assignments, Midterm exams and final exam. |
| ... | | | | |
| **2.0** | **Skills: Upon completing the course students will be able to** | | | |
| 2.1 | Estimate the eigenvalues and the eigenstates for various quantum systems, the expectation values of various quantum mechanical observables including but limited to spins, angular momenta, position, momentum and energy. | **PLO2.1** | Lectures and discussion | Homework assignments, Midterm exams and final exam. |
| 2.2 | Show that the uncertainty relations hold for various pairs of quantum observables including but not limited to spins, angular momenta, position and momentum and that a particular quantum observable or quantity is a constant of motion. | **PLO2.1** | Lectures and discussion | Homework assignments, Midterm exams and final exam. |

| Code | Course Learning Outcomes | Code of CLOs aligned with program | Teaching Strategies | Assessment Methods |
|---|---|---|---|---|
| 2.3 | Prove that a given observable is unitary, Hermitian or otherwise, a particular quantity is a constant of motion and given more than one observable, there exist a set of simultaneous eigenstates and if they have same spectra. | **PLO2.1** | Lectures | Homework<br>Take Home Exams |
| 2.4 | Explain why some quantum quantities are constant of motion, how a quantum state evolves under some unitary transformation, weather a given state is an eigenstate of a given observables and why a set of eigenstates is discrete or continuous. | **PLO2.1** | Lectures | Homework<br>Take Home Exams |
| 2.5 | Demonstrate how to solve eigenvalue problems and plot the corresponding wavefunctions using programming techniques. | **PLO2.3** | Hands on Tutorials | Submitted reports. |
| **3.0** | **Values, autonomy, and responsibility: Upon completing the course students will be able to** | | | |
| 3.1 | Demonstrate abilities in individual assigned tasks as well as in working as a team with others. | **PLO3.3** | Active learning, In class discussion | Submitted reports and direct evaluation. |
| 3.2 | | | | |
| ... | | | | |

## C. Course Content:

| No | List of Topics | Contact Hours |
|---|---|---|
| 1. | • The Stern-Gerlach Experiment.<br>• Kets, Bras, and Operators. | 4.5 |

| | | |
|---|---|---|
| | • Base Kets and Matrix Representations. | |
| 2. | • Measurements, Observables, Uncertainty Relations.<br>• Change of Basis. | 4.5 |
| 3. | • Position, Momentum, and Translation.<br>• Wave Functions in Position and Momentum Space. | 4.5 |
| 4. | • Time Evolution and the Schrodinger Equation. | 4.5 |
| 5. | • The Schrodinger Versus the Heisenberg Picture. | 4.5 |
| 6. | • Simple Harmonic Oscillator.<br>• Schrödinger Wave Equation. | 4.5 |
| 7. | Elementary Solution to the Schrodinger equation: Various Examples. | 4.5 |
| 8. | • Rotations and Angular Momentum Commutation Relations.<br>• Spin 1/2 Systems in Finite Rotation. | 4.5 |
| 9. | • SO(3), SU(2) and Euler Rotations.<br>• Density Operators and Pure Versus Mixed Ensembles. | 3 |
| 10. | • Eigenvalues and Eigenstates of Angular Momentum.<br>• Orbital Angular Momentum. | 3 |
| 11. | • Schrodinger's Equation for Central Potentials.<br>• Addition of Angular Momenta.<br>• Tensor Operators. | 3 |
| Total | | 45 |

## D. Students Assessment Activities:

| No | Assessment Activities * | Assessment timing (in week no) | Percentage of Total Assessment Score |
|---|---|---|---|
| 1. | Homework | 2 | 4 |
| 2. | Homework | 4 | 4 |
| 3. | Homework | 6 | 4 |
| 4. | First Midterm Exam | 6 | 10 |
| 5. | Submitted Report | 7 | 5 |
| 6. | Homework | 8 | 4 |
| 7. | Homework | 10 | 4 |
| 8. | Submitted Report | 11 | 5 |
| 9. | Second Midterm Exam | 12 | 10 |
| 10 | Final Exam | 16 | 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** | J. J. Sakurai and Jim J. Napolitano, Modern Quantum Mechanics, (3rd edition, Cambridge University Press, 2021). |
| **Supportive References** | • Leslie E Ballentine, Quantum Mechanics: a Modern Development, (2nd edition, World Scientific, 2014).<br>Ramamurti Shankar, Principles of Quantum Mechanics, (2nd edition, Kluwer Academic, 1994). |
| **Electronic Materials** | |
| **Other Learning Materials** | |

## 2. Educational and Research Facilities and Equipment Required:

| Items | Resources |
|---|---|
| **facilities**<br>(Classrooms, laboratories, exhibition rooms, simulation rooms, etc.) | Classrooms |
| **Technology equipment**<br>(Projector, smart board, software) | Smart boards |
| **Other equipment**<br>(Depending on the nature of the specialty) | None |

# F. Assessment of Course Quality:

| Assessment Areas/Issues | Assessor | Assessment Methods |
|---|---|---|
| **Effectiveness of teaching** | Students, Peer and program leader | Indirect (CES)- Indirect peer evaluation |
| **Effectiveness of students assessment** | Students, Peer and program leader | Indirect (CES)- Indirect peer evaluation |
| **Quality of learning resources** | Students, Faculty members | Indirect |
| **The extent to which CLOs have been achieved** | Instructor | Direct/ Indirect |
| **Other** | | |

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

## G. Specification Approval Data:

| | |
|---|---|
| COUNCIL /COMMITTEE | **Department Council** |
| REFERENCE NO. | **Psci2415** |
| DATE | **1/10/2024** |