The University of Jordan

الجامعة الاردنية

Form: **Course Syllabus**	**Form Number**	EXC-01-02-02A
	Issue Number and Date	2/3/24/2022/2963 05/12/2022
	Number and Date of Revision or Modification	
	Deans Council Approval Decision Number	2/3/24/2023
	The Date of the Deans Council Approval Decision	23/01/2023
	Number of Pages	06

1.	**Course Title**	Advanced Quantum Mechanics I
2.	**Course Number**	0302754
3.	**Credit Hours (Theory, Practical)**	(3,0)
	Contact Hours (Theory, Practical)	(3,0)
4.	**Prerequisites/ Corequisites**	
5.	**Program Title**	M.Sc. in Physics
6.	**Program Code**	
7.	**School/ Center**	Science
8.	**Department**	Physics
9.	**Course Level**	Master degree
10.	**Year of Study and Semester (s)**	2025, Spring
11.	**Other Department(s) Involved in Teaching the Course**	
12.	**Main Learning Language**	
13.	**Learning Types**	☒Face to face learning ☐Blended ☐Fully online
14.	**Online Platforms(s)**	☐Moodle ☐Microsoft Teams
15.	**Issuing Date**	25/6/2025
16.	**Revision Date**	25/6/2025

17. Course Coordinator:

Name: Mohd Hussein — Contact hours: : Sunday, Tuesday 13.30-14.30

Office number: 08 — Phone number: 22023

Email: m.hussein@ju.edu.jo

18. Other Instructors:

Name:
Office number:
Phone number:
Email:
Contact hours:
Name:
Office number:
Phone number:
Email:
Contact hours:

19. Course Description:

This course is intended for the first year graduate students who have studied Quantum Mechanics (QM) at the undergraduate senior level. It provides a modern introduction to nonrelativistic QM. The focus is on the formalism and little emphasis is left on applications. The latter is addressed in detail in the second part of the course; namely Advanced QM II (954).

20. Program Intended Learning Outcomes: (To be used in designing the matrix linking the intended learning outcomes of the course with the intended learning outcomes of the program)

1. To be able to identify, formulate, and solve broadly defined technical or scientific problems by applying knowledge of mathematics and science and/or technical topics to areas relevant to the discipline.
2. To be able to formulate or design a scientific system, process, procedure or program to contribute achieving scientific desired needs.
3. To be able to develop and conduct experiments or test hypotheses, analyze and interpret data and use scientific judgment to draw conclusions.
4. To be able to communicate his/her scientific contributions effectively with a range of audiences.
5. To be able to recognize and demonstrate social, ethical and professional responsibilities and the impact of technical and/or scientific solutions in global economic, environmental, and societal contexts.

6. To be able to function effectively independently and on teams for establishing goals, plan tasks, meet deadlines, and analyze risk and uncertainty.

21. Course Intended Learning Outcomes: (Upon completion of the course, the student will be able to achieve the following intended learning outcomes)

1) Use Stern-Gerlach (SG) Experiment to rationalize some peculiarities of QM.

2) Define Hermitian operators and urge the students to browse some literature regarding Non-Hermitian Quantum Mechanics.

3) Study the outer product, projection operator, and the matrix representation of an operator.

4) Analyze sequential SG experiments using the projection operator.

5) Learn about the compatible and incompatible observables, and the commutation relations.

6) Prove the general uncertainty relation.

7) Master the similarity and unitary transformation.

8) Define the infinitesimal translation operator and its generator.

9) Define the time evolution operator and derive Schrodinger equation.

10) Derive Heisenberg equation of motion.

11) Study the density operator and time evolution of ensembles.

12) Study Harmonic oscillator using Dirac's approach: Schwinger oscillators, Quantization of the electromagnetic fields, and Coherent states.

13) Define the infinitesimal rotation operator and its generator.

14) Analyze the precession of a spin-1/2 particle in a magnetic field using the time evolution operator and the rotation operator.

Course ILOs	The learning levels to be achieved					
	Remembering	Understanding	Applying	Analysing	evaluating	Creating
1		✓	✓	✓		
2		✓	✓	✓		
3		✓	✓	✓		
4		✓	✓	✓		
5		✓	✓	✓		

6		✓	✓	✓		
7		✓	✓	✓		
8		✓	✓	✓		
9		✓	✓	✓		
10		✓	✓	✓		
11		✓	✓	✓		
12		✓	✓	✓		
13		✓	✓	✓		
14		✓	✓	✓		

22. The matrix linking the intended learning outcomes of the course with the intended learning outcomes of the program:

Program ILOs / Course ILOs	ILO (1)	ILO (2)	ILO (3)	ILO (4)	ILO (5)
1	✓	✓		✓	
2	✓	✓		✓	
3	✓	✓		✓	
4	✓	✓		✓	
5	✓	✓		✓	
6	✓	✓		✓	
7	✓	✓		✓	
8	✓	✓		✓	
9	✓	✓		✓	
10	✓	✓		✓	
11	✓	✓		✓	
12	✓	✓		✓	

13	✓	✓		✓	
14	✓	✓		✓	

23. Topic Outline and Schedule:

Week	Lecture	Topic	ILO/s Linked to the Topic	Learning Types (Face to Face/ Blended/ Fully Online)	Platform Used	Synchronous / Asynchronous Lecturing	Evaluation Methods	Learning Resources
1	1.1	Use Stern-Gerlach (SG) Experiment to rationalize some peculiarities of QM.	1					
	1.2							
	1.3							
2	2.1	Define Hermitian operators and urge the students to browse some literature regarding Non-Hermitian Quantum Mechanics.	2					
	2.2							
	2.3							
3	3.1	Study the outer product, projection operator, and the matrix representation of an operator.	3					
	3.2							
	3.3							
4	4.1	Analyze sequential SG experiments using the projection operator.	4					
	4.2							
	4.3							
5	5.1	Learn about the compatible and incompatible observables, and the commutation relations.	5					
	5.2							
	5.3							
6	6.1	Prove the general uncertainty relation.	6					
	6.2							
	6.3							
7	7.1	Master the similarity and unitary transformation.	7					
	7.2							
	7.3							
8	8.1	Define the infinitesimal translation operator and its generator.	8					
	8.2							
	8.3							
9	9.1	Define the time evolution operator and derive Schrodinger equation.	9					
	9.2							

	9.3							
10	10.1		10					
	10.2							
	10.3	Derive Heisenberg equation of motion.						
11	11.1	Study the density operator and time evolution of ensembles.	11					
	11.2							
	11.3							
12	12.1	Study Harmonic oscillator using Dirac's approach: Schwinger oscillators, Quantization of the electromagnetic fields, and Coherent states.	12					
	12.2							
	12.3							
13	13.1	Study Harmonic oscillator using Dirac's approach: Schwinger oscillators, Quantization of the electromagnetic fields, and Coherent states.	12					
	13.2							
	13.3							
14	14.1	Define the infinitesimal rotation operator and its generator.	13					
	14.2							
	14.3							
15	15.1	Analyze the precession of a spin-1/2 particle in a magnetic field using the time evolution operator and the rotation operator.	14					
	15.2							
	15.3							

24. Evaluation Methods:

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment methods and requirements:

Evaluation Activity	Mark	Topic(s)	ILO/s Linked to the Evaluation activity	Period (Week)	Platform
First Exam	30		1,2,3,4,5,6,7,8	8	On campus
Second Exam	30		9,10,11,12,13	13	On campus
Final Exam	40		1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15	15	On campus

25. Course Requirements:

(e.g.: students should have a computer, internet connection, webcam, account on a specific software/platform…etc.): N/A

26. Course Policies:

A- Attendance policies: According to JU by-laws. B- Absences from exams and submitting assignments on time: According to JU by-laws. C- Health and safety procedures: N/A D- Honesty policy regarding cheating, plagiarism, misbehavior: According to JU by-laws. E- Grading policy: According to JU by-laws. F- Available university services that support achievement in the course: N/A

27. References:

A- Required book(s), assigned reading and audio-visuals:

Text: Modern QM, by J. Sakurai and J. Napolitano, 3rd edition, Cambridge University Press 2021, ISBN 978-1-108-47322-4.

B- Recommended books, materials, and media:

- References: Any advanced book comparable to Sakurai's book is suitable. Suggested titles include, but are not limited to, “QM” by Merzbacher, “Principles of QM” by Shankar, “QM with Basic Field Theory” by B. Desai, 2010, Cambridge University Press, “QM for Pedestrians 1: Fundamentals”, by J. Pade, 2014, Springer [Pade-1], “QM for Pedestrians 2: Applications and Extensions”, by J. Pade, 2014, Springer [Pade-2], and “Mastering QM: Essentials, Theory, and Applications”, by B. Zwiebach, 2022, The MIT Press. There are also three online courses (videos) recorded by Zwiebach in which he explained about 90% of the material of the book. Please explore YouTube to find the courses: MIT 8.04 Quantum Physics I, MIT 8.05 Quantum Physics II, and MIT 8.06 Quantum Physics III. I strongly endorse Gilbert Strang's book, Introduction to Linear Algebra, 6th edition 2023, Cambridge University Press, as an excellent resource for linear algebra.

- It is highly advantageous to review, at the very least, the superb books authored by prominent physicists, such as “The Principles of QM” by Dirac, “QM: Symbolism of Atomic Measurements” by Schwinger, “Lectures on QM” by Weinberg, “Advanced QM” by Dyson, and “QM” by Peebles.
- Self-reading titles: “Foundations of QM”, by T. Norsen, 2017, Springer [Norsen]. “Quantum Physics for Poets”, by L. Lederman and C. Hill, 2011, Prometheus Books [Lederman]. “How to Understand QM”, by J. Ralston, 2017, IOP [Ralston]. “Understanding QM”, by R. Omnes, 1999, Princeton University Press [Omnes]. “The Interpretation of QM”, by R. Omnes, 1994, Princeton Series in Physics. “Quantum: Einstein, Bohr and the Great Debate about the Nature of Reality”, by M. Kumar, 2009, Icon Books Ltd. “Quantum Physics: Illusion or Reality?” By A. Rae, 2004, Cambridge University Press. “Quantum Ontology: A Guide to the Metaphysics of QM”, by P. Lewis, 2016, Oxford University Press [Lewis].
- Further engaging titles worth exploring: “The Picture Book of QM”, by S. Brandt and H. Dahmen, 2012, Springer. “Non-Hermitian QM”, by N. Moiseyev, 2011, Cambridge University Press [Moiseyev]. “Computational QM”, by J. Izaac and J. Wang, 2018, Springer. “Quantum Computing for the Quantum Curious”, by C. Hughes et al., 2021, Springer. “Fractional QM”, by N. Laskin, 2018, World Scientific Publishing. “Introductory QM: A Traditional Approach Emphasizing Connections with Classical Physics”, by P. Berman, 2018, Springer. “QM: A Conceptual Approach”, by H. Hameka, 2004, John Wiley & Sons. “Discrete QM”, by H. Williams, 2015, Morgan & Claypool Publishers.

28. Additional information:

Name of the Instructor or the Course Coordinator:	Signature:	Date:
Mohd Hussein …………………………………………………	………….…………………	**25/6/2025……..……… …**
Name of the Head of Quality Assurance Committee/ Department …………………………………………………	Signature: ………….…………………	Date: ……..…………
Name of the Head of Department …………………………………………………	Signature: ………….…………………	Date: ……..…………

Name of the Head of Quality Assurance Committee/ School or Center	Signature:	Date:
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Name of the Dean or the Director	Signature:	Date:
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