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**	Quantum Mechanics -3
2.	**Course Number**	0302959
3.	**Credit Hours (Theory, Practical)**	(3,0)
	Contact Hours (Theory, Practical)	(3,0)
4.	**Prerequisites/ Corequisites**	None
5.	**Program Title**	PhD in Physics
6.	**Program Code**	9
7.	**School/ Center**	03
8.	**Department**	02
9.	**Course Level**	10
10.	**Year of Study and Semester (s)**	1,2
11.	**Other Department(s) Involved in Teaching the Course**	None
12.	**Main Learning Language**	English
13.	**Learning Types**	☒Face to face learning ☐Blended ☐Fully online
14.	**Online Platforms(s)**	☐Moodle ☒Microsoft Teams
15.	**Issuing Date**	
16.	**Revision Date**	2019

17. Course Coordinator:

Name: Prof. Mahmoud Jaghoub Contact hours: Sundays, Mondays, Thursdays 10 - 11

Office number: 308 Phone number: 22022

Email: mjaghoub@ju.edu.jo

18. Other Instructors:

Name: None Office number: Phone number: Email: Contact hours: Name: Office number: Phone number: Email: Contact hours:

19. Course Description:

Elastic and Inelastic Scattering Cross Section, Partial Wave Analysis, Resonance, Lippmann-Schwinger Equation; T-Matrix; Scattering of Identical Particles; Introduction to Relativistic Quantum Mechanics; Klien-Gordon Equation; Dirac Equation. Quantization of the Electromagnetic Field; Interaction of Electromagnetic Field with Charged Particles; Applications.

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)

SO1: to be able to demonstrate an advanced and comprehensive understanding of core physics concepts and specialized knowledge in a chosen field of research, contributing to the frontier of physics.

SO2: to be able to develop and execute independent, original research projects that address complex scientific problems, advancing theoretical and experimental physics.

SO3: to be able to apply advanced mathematical and computational techniques to analyze complex physical phenomena and critically evaluate scientific literature and experimental results.

SO4: to be able to effectively communicate complex physics concepts, research findings, and their significance through academic writing, presentations, and public outreach.

SO5: to be able to adhere to high ethical standards and professional responsibility in conducting research, including data integrity, ethical treatment of subjects, and the responsible use of resources.

SO6: to be able to demonstrate leadership and collaborative skills within multidisciplinary teams, contributing to the development of new scientific knowledge and promoting knowledge-sharing across disciplines.

SO7: to be able to cultivate the ability to adapt to new scientific advancements and continuously engage in professional development to contribute to innovation in the field of physics.

SO8: to be able to master experimental and computational techniques relevant to the research field, demonstrating competency in operating and developing specialized physics instrumentation and software.

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

1. Understand the concepts of elastic and inelastic scattering cross-sections and explain their significance in quantum scattering theory.
2. Perform partial wave analysis to analyze scattering processes and determine scattering amplitudes.
3. Describe the phenomenon of resonance in scattering processes and its implications for particle interactions.
4. Derive and apply the Lippmann-Schwinger equation to solve quantum scattering problems.
5. Use the T-matrix formalism to calculate scattering amplitudes and cross-sections.
6. Apply operator quantum mechanics to analyze scattering processes.
7. Analyze the scattering of identical particles and account for symmetry considerations in quantum mechanical systems.
8. Solve the Klein-Gordon equation and interpret its physical meaning in describing relativistic scalar particles.
9. Derive and interpret the Dirac equation, explaining its role in describing spin-½ particles and predicting phenomena such as antimatter.
10. Understand the quantization of the electromagnetic field and describe its significance in quantum field theory.
11. Analyze the interaction of electromagnetic fields with charged particles, including processes like absorption, emission, and scattering.
12. Apply the concepts learned to practical problems and research areas, such as quantum field theory, particle physics, or condensed matter systems.

Course ILOs	The learning levels to be achieved					
	Remembering	**Understanding**	**Applying**	**Analysing**	**evaluating**	**Creating**
1		**X**		**X**		
2			**X**	**X**	**X**	
3		**X**				
4			**X**	**X**		
5			X		X	X
6			X	X		
7				X		X
8				X		X
9					X	X
10		X				
11			X	X		
12			X		X	

٢٢. 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)	ILO (6)	ILO (7)	ILO(8)
1	X							
2			X					
3	X				X			
4			X					X
5	X		X					
6	X		X					
7	X		X					
8			X				X	
9	X		X					X
10		X		X				
11	X							X
12							X	X

2٣. 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 Lectures	Evaluation Methods	Learning Resources
1	1.1	Elastic scattering currents	1	Face to Face	MS Teams		Assignments Presentations Exams	
	1.2	Differential cross sections	1					
	1.3	Nonelastic cross sections (absorption)	1					
2	2.1	Total cross section	1					
	2.2	Optical theorem	1					
	2.3	Plane waves	2					
3	3.1	Distorted waves	2					
	3.2	Phase shifts	2					
	3.3	Incoming and outgoing waves	2					
4	4.1	Elastic waves with absorption	2					
	4.2	Partial waves amplitudes	2					
	4.3	Differential cross sections: s and p waves	2					
5	5.1	Total cross section	2					
	5.2	Solving Schrodinger’s equation	2					
	5.3	Scattering applications: The low energy limit	3					
6	6.1	Low-energy wave function	3					
	6.2	Relation to bound states	3					
	6.3	Resonances	3					
7	7.1	Breit-Wigner resonances	3					
	7.2	Definition of Green’s function	4					
	7.3	Lippmann-Schwinger equation	4					
8	8.1	Born Approximation	4					
	8.2	Integral expression for the scattering amplitude	4					

	8.3	Yukawa and Coulomb potentials	4					
9	9.1	T- and V-matrix elements	5					
	9.2	Lippmann-Schwinger equation for T	5					
	9.3	On the energy shell	5					
10	10.1	Of-shell T	5					
	10.2	Operator Schrodinger's equation	6					
	10.3	Operator Lippmann-Schwinger equations	6					
11	11.1	momentum space LS wave equation	6					
	11.2	Operator equation for the T-matrix	6					
	11.3	Relativistic Schrodinger equation	7					
12	12.1	Klein-Gordon equation	7					
	12.2	Probability and current	7					
	12.3	Interactions and the Klein-Gordon equation	7					
13	13.1	Positive- and negative-Energy degrees of freedom	7					
	13.2	Relation to Schrodinger's equation	7					
	13.3	Dirac Equation	8					
14	14.1	Properties of the α and β matrices	8					
	14.2	Electrons at rest	8					
	14.3	Requirements on Dirac equation	9					
15	15.1	Holes in the sea	10					
	15.2	Properties of plane wave spinors	10,11					
	15.3	Introduction to interaction of electromagnetic field with charged particles	11,12					

٢٤. 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
Assignments	20	All	All	At the end of each chapter	E-learning, MS Teams, Paper
Presentations	20	Chosen by the student and approved by the instructor	Depends on the chosen topic	Week 14	Face to Face
Mid-term written Exam	20	Material covered in the first 6 weeks	1, 2, 3, 4 and 5	Week 8	Face to Face
Final written Exam	40	All the material	1 to 12	Week 15	Face to Face
Assignments	20	All	All	At the end of each chapter	E-learning, MS Teams, Paper

٢٥. Course Requirements:

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

Computer with internet connection and installed MS teams.

٢٦. Course Policies:

A- Attendance policies: As per University regulations

B- Absences from exams and submitting assignments on time: As per University regulations

C- Health and safety procedures: As per University regulations

D- Honesty policy regarding cheating, plagiarism, misbehavior: As per University regulations

E- Grading policy: Assignments 20, Presentations 20, Mide-term exam 20, Final exam 40.

F- Available university services that support achievement in the course: Library, Computer labs, internet connction.

2٧. References:

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

- Quantum Mechanics II, A second course in quantum theory, second edition, R. Landau, John Wiley and Sons, Inc.

B- Recommended books, materials, and media:

- Modern Quantum Mechanics, J. J. Sakurai, Addison - Wesley Publishing Company.
- Advanced Quantum Mechanics, J. J. Sakurai, Addison - Wesley Publishing Company.
- Quantum Mechanics, L. I. Schiff, McGraw – Hill Book Company, Inc.

2٨. Additional information:

Name of the Instructor or the Course Coordinator: Prof. Mahmoud Jaghoub	Signature: ……..……	Date: ……..……
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:
……	……..……	……..……
Name of the Dean or the Director	Signature:	Date:
……	……..……	……..……