The University of Jordan

الجامعة الاردنية

Form: Course Syllabus		
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	Number of Pages	06

1.	**Course Title**	Elementary Particle Physics
2.	**Course Number**	0332966
3.	**Credit Hours (Theory, Practical)**	(3,0)
	Contact Hours (Theory, Practical)	(3,0)
4.	**Prerequisites/ Corequisites**	0332958
5.	**Program Title**	
6.	**Program Code**	Ph.D. in Physics
7.	**School/ Center**	Science
8.	**Department**	Physics
9.	**Course Level**	PhD
10.	**Year of Study and Semester (s)**	2016, Fall
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**	30/1/2017
16.	**Revision Date**	28/1/2025

17. Course Coordinator:

Name: Mohammad 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 primarily aims to investigate various topics in particle physics from a phenomenological perspective. The structure of the curriculum is designed to ensure a balanced emphasis on both fundamental understanding and the acquisition of highly advanced mathematical techniques. It is organized into four key sections: examining the fundamental processes in Quantum Electrodynamics (QED), investigating the essential processes in Quantum Chromodynamics (QCD), studying electroweak theory and Higgs mechanics, and ultimately testing the Standard Model (SM) predictions concerning the top quark, the W/Z bosons, and the Higgs boson.

The students are required to compose a critique (8-10 pages long) on a measurement or theoretical concept and deliver it effectively within a 30-minute time frame. The draft must focus on a subject within particle physics. It should be an authentic piece of work, with plagiarism being completely prohibited. The draft must incorporate essential equations, figures, and a comprehensive bibliography. The chosen topic needs to be sanctioned by the instructor before November 6, and the final draft must be submitted by December 11. Following this, students are required to share their final drafts with each other. The presentations are set to begin on December 25. The delivery should closely mirror the content of the written draft.

It is crucial to highlight that this course is specifically aimed at third-year graduate students who have successfully completed the quantum field theory course, PHY 0332958.

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 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.
2. To be able to develop and execute independent, original research projects that address complex scientific problems, advancing theoretical and experimental physics.
3. To be able to apply advanced mathematical and computational techniques to analyze complex physical phenomena and critically evaluate scientific literature and experimental results.
4. To be able to effectively communicate complex physics concepts, research findings, and their significance through academic writing, presentations, and public outreach.
5. 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.
6. 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.
7. 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.
8. 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. Underlying concepts: special relativity, non-relativistic quantum mechanics, Fermi's golden rule, differential cross section, symmetries in quantum mechanics, first- and second-order perturbation theory, and the elements of the SM.

2. Recall the basic properties of the Dirac equation: the covariant form of the Dirac equation, antiparticles, and spin and helicity states.

3. QED:

3.1 Feynman diagrams and virtual particles.
3.2 Feynman rules for QED.
3.3 Electron-positron annihilation.
3.4 Chirality.
3.5 Trace techniques and Casimir" trick.
3.6 Form factors and the relativistic electron-proton elastic scattering.
3.7 Deep inelastic electron-proton scattering and the quark-parton model.
3.8 The evolution of α.

4. QCD:

4.1 Ground state baryon wavefunctions.
4.2 SU(3) flavor symmetry.
4.3 The local gauge principle and the QCD interaction.
4.4 Color, gluons, and color confinement.
4.5 Running of α_s and asymptotic freedom.
4.6 QCD in electron-positron annihilation.
4.7 Color factors.
4.8 Hadron-hadron collisions and jet production.
4.9 The quark mass and the origin of the hadron mass.

5. The weak interactions:

5.1 Parity.
5.2 *V-A* structure of the weak interaction.
5.3 Chiral structure of the weak interaction.
5.4 The W-boson propagator.
5.5 Helicity in pion decay.
5.6 Lepton universality.
5.7 Neutrino scattering.
5.8 Neutrino oscillations.
5.9 Long-baseline neutrino experiments.
5.10 The CKM matrix.
5.11 The neutral kaon system.
5.12 CP violation in the SM.

6. The SM:

6.1 The weak interaction group.
6.2 Electroweak unification.
6.3 The need for the Higgs boson.
6.4 Local gauge invariance and the particle masses.
6.5 The Higgs mechanism.

7. Tests of the SM:

7.1 Properties of the W boson: W boson decay, W boson pair cross section, W boson mass and width.

7.2 Properties of the Z boson: Z boson mass and width, Z resonance and cross section, the electro-weak mixing angle.

7.3 Quantum loop corrections.

7.4 Properties of the top quark: top quark mass and width, top quark pair cross section, single top quark cross section, top quark electric charge, helicity of the W boson, top anti-top spin correlations, forward-backward charge asymmetry.

7.5 Properties of the Higgs boson: Higgs boson decay and the branching ratios, the discovery of the Higgs boson, Higgs boson mass.

8. The SM and beyond - open questions in particle physics:

What is dark matter? Does supersymmetry exist? Can the forces be unified? What is the nature of the Higgs boson? Are neutrinos Majorana particles? What does vacuum mean? What is the cause for the matter-antimatter asymmetry? Why does the SM contain too many free parameters? Why do the masses of the fermions differ by a factor of almost one million? Is the proton really stable? And more ambitious questions …!

9. Draft - Presentation

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

2٢. 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	✓	✓	✓	✓			✓	
2	✓	✓	✓	✓			✓	
3	✓	✓	✓	✓			✓	

4	✓	✓	✓	✓			✓	
5	✓	✓	✓	✓			✓	
6	✓	✓	✓	✓			✓	
7	✓	✓	✓	✓			✓	
8	✓	✓	✓	✓			✓	
9	✓	✓	✓	✓			✓	

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 Lecturing	Evaluation Methods	Learning Resources
1	1.1	Underlying concepts: special relativity, non-relativistic quantum mechanics, Fermi's golden rule, differential cross section, symmetries in quantum mechanics, first- and second-order perturbation theory, and the elements of the SM.	1					
	1.2							
	1.3							
2	2.1	Recall the basic properties of the Dirac equation: the covariant form of the Dirac equation, antiparticles, and spin and helicity states.	2					
	2.2							
	2.3							
3	3.1	QED	3					
	3.2							
	3.3							
4	4.1	QED	3					
	4.2							
	4.3							
5	5.1	QCD	4					
	5.2							
	5.3							
6	6.1	QCD	4					

	6.2								
	6.3								
7	7.1	QCD	4						
	7.2								
	7.3								
8	8.1	The weak interactions	5						
	8.2								
	8.3								
9	9.1	The weak interactions	5						
	9.2								
	9.3								
10	10.1	The weak interactions	5						
	10.2								
	10.3								
11	11.1	The SM	6						
	11.2								
	11.3								
12	12.1	The SM	6						
	12.2								
	12.3								
13	13.1	Tests of the SM	7						
	13.2								
	13.3								
14	14.1	-Tests of the SM -The SM and beyond - open questions in particle physics	7,8						
	14.2								
	14.3								
15	15.1	Draft - Presentation	9						
	15.2								
	15.3								

2٤. 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
Mid-term Exam	30		3,4,5	11	On campus
Draft - Presentation	30		1,2,3,4,5,6,7,8	15	On campus

Final Exam	40		1,2,3,4,5,6,7,8	15	On campus

2٥. Course Requirements:

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

N/A

2٦. 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

2٧. References:

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

Text:

1. Modern Particle Physics, by Mark Thomson, first published 2013, 3rd printing 2015, Cambridge University Press, ISBN: 9781107034266.
2. Quarks & Leptons, 1st edition, by Francis Halzen & Alan Martin, 1st edition 1984, John Wiley & Sons, ISBN: 0-471-88741-2.

B- Recommended books, materials, and media:

References: Suggested titles include, but are not limited to:

-Introduction to Elementary Particle Physics, by Alessandro Bettini, 2nd edition 2014, Cambridge University Press, ISBN: 978-1-107-05040-2.

-Modern Elementary Particle Physics, by G. Kane, 1st edition 1987, Addison-Wesley Publishing Company, ISBN: 0-201-11749-5.

-Introduction to High Energy Physics, by Donald Perkins, 4th edition 2000, Cambridge University Press, ISBN: 0 521 62196 8.
-Introduction to Elementary Particles, by David Griffiths, 2nd edition 2004, Wiley-VCH, ISBN: 978-0-471-60386-3.
-Particle Physics, by B. Martin & G. Shaw, 3rd edition 2009, John Wiley & Sons, ISBN: 978-0-470-03294-7.
-Review of Particle Physics, by Particle Data Group: One can read, print or order for free at http://pdg.lbl.gov

2٨. Additional information:

Name of the Instructor or the Course Coordinator: Mohammad Hussein	Signature:	Date: 28/1/2025
Name of the Head of Quality Assurance Committee/ Department	Signature:	Date:
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Name of the Head of Department	Signature:	Date:
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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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