LUMS
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Lahore University of Management Sciences

PHY 539 – Introduction to Quantum Field Theory

Spring 2024

To understand how to navigate course outlines, consult: How to Use a Course Outline (http://surl.li/gpvuw)

Instructor	Rizwan Khalid
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Office Hours	TBA. On most days, an email appointment will be appreciated.
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Secretary/TA	TBD
TA Office Hours	N/A
Course URL	On LMS
Support Services	LUMS offers a range of academic and other services to support students. These are mentioned below, and you are encouraged to use these in addition to in-class assistance from course staff. For a complete list of campus support services available for you click here (https://advising.lums.edu.pk/#supportservices)

Course Basics				
Credit Hours	3 (2-1)			
Lecture(s)	Nbr of Lec(s) Per Week	1	Duration	2 hrs
Workshop(s)	Nbr of Lec(s) Per Week	1	Duration	3 hrs

Course Distribution	
Core	
Elective	Intended for Physics Majors and graduate students in Physics.
Open for Student Category	All
Close for Student Category	

COURSE DESCRIPTION

This course deals with the quantum theory of the scalar field. In choosing the simplest of the field representations, we will be able to cover essentially the entire formalism of the quantum theory of fields. We will, in particular, discuss field quantization, scattering theory, renormalization, introduction to gauge theories, internal symmetries and spontaneous symmetry breaking. The course is partially evaluated via an immersive project which will take students to one of the many topics that we will not be able to cover during the class.

COURSE PREREQUISITE(S)

A sound grounding in Classical Mechanics (including at least a decent introduction to special relativity), Quantum Mechanics, and mathematical maturity (calculus + tensors + complex analysis) is needed to do well in this class. At LUMS, these topics are covered adequately in RED and MMP.

	Learning Outcomes (CLOs)	Cognitive Level
1	Compute correlation functions in scalar field theory	Analysis
2	Compute one loop divergent diagrams in scalar field theory	Analysis
3	Analyze simple models with internal symmetries (gauged or otherwise) as well as those with spontaneous symmetry breaking	Analysis
4	Compute processes in quantum electrodynamics	Analysis
5	Demonstrate effective writing and speaking skills via course project and presentation	Analysis

Grading break up: Component Details and weightages

Workshop Practice (15%): Weekly. We will get together for a 3-hour workshop style session every week. You will be asked to individually work on some derivations as part of this session. Think of these sittings as guided study sessions. An N-3 shall be implemented for this component which is intended only to cater to medical emergencies.

Assignments (15%): Weekly. Weekly assignments shall be handed out on the day of the workshop and are due before the following lecture. An N-2 shall be implemented.

Quizzes (10%): Most weeks. A short (5 min) recall quiz will be held at the beginning of most lectures. Please ensure you reach the lecture room

before the beginning of the class. If you have done the workshop practice and the assignment diligently, you will find the quizzes to be trivial. An N-3 shall be implemented.

Project: (30%). A comprehensive project will take care of a large chunk of your course grade. The project is designed to get you started in week 2 and work your way ground up. The project report will be due on 07 April at 5PM after which we shall have presentations in the following two weeks. This 30% is further broken down into the following components (detailed instructions will be given later):

- Project Report (12%): The largest chunk goes to the project report which must be typeset in my favorite style which is that of the Journal of High Energy Physics (JHEP).
- Presentation (6%): The actual presentation will be worth 6% of credit. Each member of the team will speak for ten or so minutes and grading is individual.
- Asking Questions (4%): The quality of the questions you ask says a lot about your absorption of the material. 4% of your grade will depend on the questions you ask.
- Answering Questions (8%): Finally, 8% of your grade will depend on questions that will be directed to you individually.

Final Exam (30%): A four-hour comprehensive final exam on date decided by the RO.

Grading Basis (Relative)
As per departmental policy.

Examination Detail	
Midterm Exam	**No** Separate: N/A Duration: N/A Preferred Date: N/A Exam Specifications: N/A
Final Exam	**Yes** Combine/Separate: N/A Duration: 4 hours Exam Specifications: Comprehensive final exam on date decided by the RO. Since the RO schedules only 3-hour slots, expect this to be the last exam on the day.

Campus supports & Key university policies

Campus Supports

Students are strongly encouraged to meet course instructors and TA's during office hours for assistance in course-content, understand the course's expectations from enrolled students, etc. Beyond the course, students are also encouraged to use a variety of other resources. (Instructors are also encouraged to refer students to these resources when needed.) These resources include Counseling and Psychological Services/CAPS (for mental health), LUMS Medical Center/LMC (for physical health), Office of Accessibility & Inclusion/ OAI (for long-term disabilities), advising staff dedicated to supporting and guiding students in each school, online resources (https://advising.lums.edu.pk/advising-resources), etc. To view all support services, their specific role as well as contact information click here (https://advising.lums.edu.pk/#supportservices).

Academic Honesty/Plagiarism

LUMS has zero tolerance for academic dishonesty. Students are responsible for upholding academic integrity. If unsure, refer to the student handbook and consult with instructors/teaching assistants. To check for plagiarism before essay submission, use similarity@lums.edu.pk. Consult the following resources: 1) Academic and Intellectual Integrity (http://surl.li/gpvwb), and 2) Understanding and Avoiding Plagiarism (http://surl.li/gpvwo).

LUMS Academic Accommodations/ Petitions policy

Long-term medical conditions are accommodated through the Office of Accessibility & Inclusion (OAI). Short-term emergencies that impact studies are either handled by the course instructor or Student Support Services (SSS). For more information, please see Missed Instrument or

Lahore University of Management Sciences

'Petition' FAQs for students and faculty (https://rb.gy/8sj1h)

LUMS Sexual Harassment Policy
LUMS and this class are a harassment-free zone. No behavior that makes someone uncomfortable or negatively impacts the class or individual's potential will be tolerated.

To report sexual harassment experienced or observed in class, please contact me. For further support or to file a complaint, contact OAI at oai@lums.edu.pk or harassment@lums.edu.pk. You may choose to file an informal or formal complaint to put an end to the offending behavior. You can also call their Anti-Harassment helpline at 042-35608877 for advice or concerns. *For more information: Harassment, Bullying & Other Interpersonal Misconduct: Presentation (http://surl.li/gpvwt)*

Course Overview			
Week#	Topics	Readings*	CLOs**
1-3	Introduction to Lie groups, Lie algebra of the Poincare group, elements of classical field theory	Ch 2, 3	1
3-4	Quantization of the free scalar field	Ch 3, 4	1
5	S Matrix and the LSZ formula	Ch 5	1
6-8	Perturbative expansion and the Feynman rules, U(1) gauge invariance and scalar electrodynamics	Ch 5	1
8-9	Renormalization and physical perturbation theory	Ch 5	2
10	Spontaneous symmetry breaking	Ch 11	3
11-12	The linear sigma model and its renormalization	Ch 11*	1, 2, 3
13	Cross sections and decay rates, resonances, Born approximation in the non-relativistic limit	Ch 6	1

***Readings are from Maggiore except for material in Weeks 11-12 which is from Peskin and Schroeder.**
**** CLOs 4 and 5 are developed in the project.**

Textbook(s)/Supplementary Readings	
1	**A Modern Introduction to Quantum Field Theory**, M Maggiore.
2	**An Introduction to Quantum Field Theory**, ME Peskin and DV Schroeder.
3	**The Quantum Theory of Fields Vol 1**, S Weinberg. (This `bible' is certainly not for the faint of heart. My personal favorite but reading it is very time consuming. The benefit is a very wholesome understanding of the underlying theory and its foundations.)

Course Policies	
Late Assignment	Late assignments shall not be accepted.
Missed Assignment	Missed assignments shall be catered to by the N-X policy.
Missed Final Exam	Please petition the OSA in case of a missed exam.