PHYS 622 (Fall 2019)
Quantum Field Theory
Tues & Thurs, 2:30-3:45 pm, GRB W211

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Course Description: An introduction to quantum field theory.

Learning Objectives:
By the end of the course, you (the student) should be able to do the following:

- Understand canonical quantization of spin-0, spin-1 and spin-1/2 fields
- Carry out simple calculations of scattering and decay, and become familiar with Feynman diagrams
- Understand the important role of symmetries, and symmetry breaking in field theory
- Have a basic understanding of renormalization, and some topological aspects in field theory

Prerequisites: A good base in electromagnetism, classical mechanics, special relativity and quantum mechanics is essential. I will assume familiarity with systems of ordinary/partial differential equations, multivariable calculus, Fourier analysis, complex analysis and linear algebra.

Class Website: All course materials including problem sets, links to relevant websites, supplementary material, class updates and announcements will be posted on the PHYS 622 Canvas page. It is your responsibility to check the course page regularly for the most recent information concerning the class.

Main Text(s): I will provide part hand-written, part typeset class notes. For additional resources, see below.

Additional Resources:

- *QFT 622 Notes* by Prof. Paul Stevenson. Paul taught this course for many years at Rice. His elegant notes will be available on our course webpage.
- *Quantum Field Theory for the Gifted Amateur* by Tom Lancaster and Stephen Blundell: This is a delightful, pedagogical and entertaining book will be a good companion for the course. The sections and chapters are short, with lots of insightful comments and useful examples. I highly recommend it, and will assign *optional* reading from here.

- *Lectures on Quantum Field Theory* by David Tong. A beautiful set of notes from a similar course from U. of Cambridge (http://www.damtp.cam.ac.uk/user/tong/qft.html)
- *An Introduction to Quantum Field Theory* by Michael Peskin and Daniel Schroeder: The standard modern text. Does not shy away from detailed calculations. For those interested in the particle physics applications of QFT, this is your book.
- *Quantum Field Theory in a Nutshell* by Anthony Zee: A book full of anecdotes and insights. A pleasure to read and excellent for getting the beauty and generality of the important ideas, but at times not sufficient for mastering details of calculations. Focuses more on functional methods early on.
- *Quantum Field Theory* by Mark Srednicki: Paul Stevenson's notes and this book have some overlap. If you want more details than the notes, this might be a good place. Appropriate comments on the prerequisites before each section make the book easy to navigate.
- *The Quantum Theory of Fields* by S. Weinberg: Not quite introductory, but it is rigorous and rewarding in the end.
- *Introduction to Quantum Effects in Gravity* by Sergei Winitzki and Viatcheslav Mukhanov: An introductory book for those interested in cosmology of the early universe, and QFT in time dependent classical backgrounds. Also has excellent introductory sections on classical fields, quantization etc.
- *Notes from Sidney Coleman's Physics 253a* by Sidney Coleman: From the master himself. (https://arxiv.org/abs/1110.5013)

Exams and Problem Sets:
Homework will be due (roughly) every week.
1 final exam

Grading Policies: Homeworks will be worth 70% of the grade and the final exam will be worth 30% of the grade. Late homeworks are annoying. For unexcused tardiness, there will be a 20% reduction/per day in credit (including weekends), with no credit 2 days after the homework is due. If illness or other circumstances beyond your control lead to a delay in submission, please contact me as soon as possible (preferably before the deadline). The final grade for the course will include some discretion based on class participation/interactions etc. Attendance is not mandatory, but highly recommended.

Collaboration and Help: For a better understanding of the material you are strongly encouraged to talk to other students, postdocs and faculty (including me!). For the problem sets, you should work on each problem independently first ($\geq$ 1 hr). When needed, get help about the general idea of how to do the problem but not the details of the entire calculation. If you collaborate/get help from others, they should be acknowledged in the problem sets along with details of what you collaborated/got help on. The write-up should always be done independently. Do not look up solutions online or from previous years. The Honor Code applies. You can review Rice's Honor Council documentation online at: honor.rice.edu/index.cfm

Special Needs: If you have a documented disability that requires special consideration for this class then please contact me as soon as possible to discuss your needs. Students with disabilities should also contact the Disability Support Services Office in the Ley Student Center (dss.rice.edu).

Tentative Course Outline:

Week	Content
Week 1	• What is QFT? + Review of Special Relativity and Mathematical Preliminaries, • Review of Classical and Quantum Mechanics
Week 2	• Scalar Fields • Free Fields
Week 3	• Causality+Charged Fields • Charges Fields
Week 4	• Interacting Fields, the S-matrix • Overview of Perturbation Theory
Week 5	• Decay + Introducing Feynman Diagrams • Scattering
Week 6	• Feynman Propagator, Cross Sections • The Vacuum and Connected, Amputated Diagrams
Week 7	• Renormalization 1 • Renormalization 2
Week 8	• **Symmetries**: Noether's Theorem • Spacetime Symmetries
Week 9	• Representations and Field Transformations • Spin 1/2 Fields
Week 10	• The Dirac Equation • Feynman Rules
Week 11	• Massive Spin 1 Fields • Massless Spin 1 Fields
Week 12	• Gauge Invariance and Quantum Electrodynamics • Spontaneous Symmetry Breaking
Week 13	• The Higgs Mechanism (+ Solitons) • Functional Methods
Week 14	• Functional Methods • Summary and Outlook

I might change aspects of this syllabus as the class progresses depending on the needs of the class.