University of Virginia
Department of Physics
PHYS 8630: Introduction to Field Theory (Fall 2021)

Instructor
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Office hours: Wednesday 2 − 5 pm (or by appointment). Zoom link here.

Course webpage: UVaCollab

Lectures
Monday, Wednesday and Friday 11:00am − 11:50am Physics Bldg 210, Aug 25 − Dec 6, 2021

Course description
Welcome students! PHYS8630 is a first course in the relativistic quantum theory of fields. The theory describes elementary particles in high energy, and the idea is applicable to collective or emergent particles in nuclear, atomic and condensed matter physics. The course covers the quantization of fields, Feynman diagrams, and introduces renormalization.

This course requires the background knowledge of quantum and classical mechanics. Statistical mechanics is not required but will definitely be helpful. You can refresh your memory by reading any standard text on solid state, such as *Modern Quantum Mechanics* by J. J. Sakurai, *Mathematical Methods of Classical Mechanics* by Vladimir I. Arnold, and *Statistical Mechanics* by R. K. Pathria.

Textbook
An Introduction to Quantum Field Theory (Student economy edition.)
Michael E. Peskin and Daniel V. Schroeder
CRC Press, ISBN: 9780429494178

You should be able to find the textbook (hardcopy or e-text) in the University bookstore and library. UVa library owns the e-Book and students can download on the Taylor & Francis website.

Tentative syllabus
Chapter 1 - 9 (maybe 10 as well if time allows). Topics include but not limited to

- Klein-Gordon and Dirac field quantization
- Interactions and Feynman diagrams, correlation functions and S-matrices
- Quantum electrodynamics
- Path integrals and functional quantization of fields
- Regularization and renormalization (if time allows).

Recommended texts (in the order of relevance to this course)

- Lewis H. Ryder, *Quantum Field Theory*
- Claude Itzykson and Jean-Bernard Zuber, Quantum Field Theory
- Steven Weinberg, The Quantum Theory of Fields: Volume 1, Foundations and The Quantum Theory of Fields, Volume 2: Modern Applications
  Library e-Book here and here.

- Jean Zinn-Justin, Quantum Field Theory and Critical Phenomena
  Library e-Book here.
- John C. Collins, Renormalization (An Introduction to Renormalization, the Renormalization Group and the Operator-Product Expansion)
  Library e-Book here.
- Reinhold A. Bertlmann, Anomalies in Quantum Field Theory
  Library e-Book here.
- A. Zee, Quantum Field Theory in a Nutshell

Recommended texts of quantum field theory in condensed matter physics (not in any particular order)

- Eduardo Fradkin, *Field Theories of Condensed Matter Physics*
  Library e-Book here.
- Alexei M. Tsvelik, *Quantum Field Theory in Condensed Matter Physics*
  Library e-Book here.
- Xiao-Gang Wen, *Quantum Field Theory of Many-body Systems: From the Origin of Sound to an Origin of Light and Electrons*
- John Cardy, *Scaling and Renormalization in Statistical Physics*
- Alexander L. Fetter and John Dirk Walecka, *Quantum Theory of Many-Particle Systems*
- R. Shankar, *Renormalization-group approach to interacting fermions*, Rev. Mod. Phys. **66**, 129 (1994)

Evaluation
Lecture participation 30%, homework 30%, midterm 30%, take-home final 10%

Lecture participation: The instruction of this course relies more heavily than other courses on students' preparation and independent reading of the textbook before the lectures. Only the key points and important calculations will be demonstrated in lectures. Students will be asked to perform short blackboard calculations or answer quizzes. Students will be assessed by participation points. There will be roughly 5 - 7 points available in each lecture, 1 point per question, and there are roughly 40 lectures. Student can earn participation points by either volunteering to answer a question or solving an assigned problem. Students are evaluated based on effort and do not necessarily need to give a correct answer to earn a point. Students earning a total of 20 points or more will receive the maximum score in lecture participation and obtain the full 30% towards the overall grade.

Homework: There will be 4 to 5 homework assignments, depending on the course progress. They will be given once every 2-3 weeks and posted on the Collab course site. Each one of them is due at the *beginning* of class on the due date. Soft copy submission by email is preferred but hard copy submission will also be accepted. Late HW will not be accepted under normal circumstances without permission. If you need more time on a particular HW, you will need to let the instructor know at least 2 days in advance with a good reason. Depending on the situation, a late submission may or may not be granted. A point penalty may be incurred. Late HW may be allowed only in special circumstances with proof, such as university closure due to extreme weather or earth quake, traffic accident, or serious illness. If you cannot attend class, you can submit a soft copy to my email or slide your HW under my office door *before* the deadline (i.e. beginning of class on the due date). You are encouraged to discuss the problems with your peers. For HW assignments, students must submit their own independent version.. If you collaborated with your peers or consulted any alternative resources, such as a reference textbook, a journal or online article, please acknowledge that in your HW submission to avoid plagiarism.

Midterm: The tentative date of the midterm exam is Nov 22, 2021, the Monday before the Thanksgiving break. The scope of the midterm will cover everything up to and including the lecture on Nov 12. The midterm exam is expected to cover part I (Ch.1-7) of the textbook. The exam will be conducted in the normal lecture room. It will be an open-book exam.

Take-home final: The tentative date of the take-home final exam is Dec 8, 2021. The exam will be uploaded on Collab before 7 am on Dec 8. The deadline of submission is before midnight on Dec 8. The exam will be shorter than a normal HW and it will normally take less than 3 hours to complete. Soft copy submission by email (jteo@virginia.edu) only. Students must submit their own exam and not discuss with others before the submission period ends. The exam will be open-book.

Lecture instruction and office hours during COVID Students must follow UVa policy Sec-045: COVID-19 Health & Safety Requirements. Below are some important highlights relevant to the course.

1. **Face Coverings** Masks are required for all people, both vaccinated and unvaccinated, in indoor UVA properties. This means students and the instructor must wear masks during lectures and office hours. A face mask should (i) cover both the mouth and the nose, (ii) fit snugly but comfortably against the side of the face, (iii) include multiple layers of fabric, and (iv) allow for breathing without restriction. The masking requirement is temporary and is subjected to change.
2. **Physical Distancing** The CDC still recommend distancing as one of the ways to protect yourself and others. Students should be as spread out as possible in the lecture room. Office hours via Zoom meeting is preferred.
3. **Quarantine and Isolation** Depending on whether you are fully vaccinated, showing COVID symptoms, or have been in close contact with someone who has COVID, you may need to quarantine or isolate. You can find the guidelines on quarantine and isolation on this UVa Student Health webpage or this pdf poster. You can also find similar guidelines from CDC. You should get familiar with these and follow the guidelines. Basically, if you are feeling sick, do not come to class. Your class participation points will be adjusted or compensated by extra credits.
4. **Lecture notes taking** I encourage everyone to take lecture notes. In the situation when someone miss a lecture, I may ask for scans of someone else lecture notes and upload them on Collab. Otherwise, in normal circumstances, lecture notes will not be available on Collab.