Syllabus, PHYS 786, Quantum Field Theory, Fall 2021

Time and Location
Wednesday, 4:30 pm-7:10 pm, Planet Hall 220

Instructor
Erhai Zhao, ezhao2@gmu.edu

Office hours
Wednesday, 2:00-3:00 pm or by appointment, Planetary Hall, Rm 207

Textbook
Quantum field theory for the gifted amateur, Tom Lancaster and Stephen Blundell, Oxford University Press. I will jump around and skip sections. Despite the phase 'amateur' in its title, it is a serious (and pedagogically excellent, in my opinion) textbook.

There are many excellent textbooks on QFT. A standard choice is Peskin and Schroeder, *An introduction to quantum field theory*. For those more interested in condensed matter physics: Abrikosov, Gorkov, Dzyaloshinski, *Method of quantum field theory in statistical physics* (a classic, but terse); Altland and Simons, *Condensed matter field theory* (modern, broad coverage); Mahan, *Many-particle physics* (a good reference); Negele and Orland, *Quantum many-particle systems* (path integral all the way).

Grades
Homework (50%) + Class Participation (50%).
We will have 5 homework sets. They will be posted on Blackboard with due date specified. Please try your best to tackle the assign problems — let me know if you need more time. It is a small class, so let us make it conversational and feel free to ask questions, I mean any kinds of questions!

Prerequisites
Standard Quantum Mechanics (for graduate students, Phys 684 or equivalent is desired) and basic Special Relativity (4-vectors, Lorentz transformations, electromagnetic tensor, raising and lowering indices etc.). Experience with Lagrangian, calculus of variations, and complex analysis will help -- we will review them when it is used for the first time.

Topics (tentative)
Preparatory chapters (e.g. chapter 1-4, 8-10, 21, 23) will be skipped, and we will not have time to cover advanced topics (Wilsonian renormalization group, Non-abelian gauge fields, Finite temperatures, Topological objects, superfluidity and superconductivity).

1. Review of Special Relativity and Classical E&M, covariance, notation, units.

2. Scalar fields, from slinky to Klein-Gordon Eq: Lagrangians, Hamiltonians, functional derivatives.
3. Canonical quantization of real and complex scalar fields. Particles from fields. Antiparticle. Symmetry, Noether's current.
4. Perturbation theory of interacting fields: interaction picture, S-matrix, Gellman-Low theorem, Green function/Propagator, Wick theorem.
5. Feynman diagrams for phi^4 theory: vacuum bubbles, connected diagrams, Link cluster theorem, Feynman rules, scattering amplitudes, superficial degree of divergence.
6. Canonical quantization of EM field, gauge choices, photon propagator.
7. Dirac field, gamma matrices, helicity, eigen spinors in chiral representation, quantization of Dirac field, positron.
8. QED: gauge fields and minimal coupling, Feynman rules.
9. QED: tree diagrams, scattering cross sections, trace and sum tricks.
10. QED: loop diagrams, self energies, vertex corrections, renormalization of e, m, g, integral tricks.
11. Field integrals, source, generating functionals, perturbation expansion and diagrams again.
12. Diagrams for interacting electron gas, Hartree Fock, RPA, self-energy, effective mass, screening, dielectric function.

Safety
We meet face to face. Please heed the university protocol specified below. Thank you.

All students taking courses with a face-to-face component are required to follow the university's public health and safety precautions and procedures outlined on the university Safe Return to Campus webpage (https://www2.gmu.edu/safe-return-campus). Similarly, all students in face-to-face and hybrid courses must also complete the Mason COVID Health Check daily, seven days a week. The COVID Health Check system uses a color code system and students will receive either a Green, Yellow, or Red email response. Only students who receive a "green" notification are permitted to attend courses with a face-to-face component. If you suspect that you are sick or have been directed to self-isolate, please quarantine or get testing. Faculty are allowed to ask you to show them that you have received a Green email and are thereby permitted to be in class.

Students are required to follow Mason's current policy about facemask-wearing. As of August 11, 2021, all community members are required to wear a facemask in all indoor settings, including classrooms. An appropriate facemask must cover your nose and mouth at all times in our classroom. If this policy changes, you will be informed; however, students who prefer to wear masks either temporarily or consistently will always be welcome in the classroom.