Instructor: Howard Haber
Office Hours: via zoom; arranged by e-mail appointment
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Course web page: `http://scipp.ucsc.edu/~haber/ph222/`

RECOMMENDED TEXTBOOKS:

An Introduction to Quantum Field Theory, by Michael Peskin and Daniel Schroeder
Quantum Field Theory and the Standard Model, by Matthew D. Schwartz
Quantum Field Theory (Second edition), by Lewis H. Ryder

Additional references of interest:

Introduction to Gauge Field Theory (Revised edition), by David Bailin and Alexander Love
Modern Quantum Field Theory, by Thomas Banks
From Classical to Quantum Fields, by Laurent Baulieu John Iliopoulos and Roland Sénéor
Quantum Field Theory: Lectures of Sidney Coleman, edited by Bryan Gin-ge Chen et al.
Lectures on Quantum Field Theory, by Ashok Das
The Conceptual Framework of Quantum Field Theory, by Anthony Duncan
Quantum Field Theory: From Basics to Modern Topics, by François Gelis
Particles and Quantum Fields, by Hagen Kleinert
Quantum Fields: From the Hubble to the Planck Scale, by Michael Kachelriess
Quantum Field Theory for the Gifted Amateur, by Tom Lancaster and Stephen J. Blundell
Quantum Field Theory: A Modern Perspective, by V. Parameswaran Nair
Introduction to Quantum Field Theory, by Horaţiu Năstase
Gauge Field Theories, by Stefan Pokorski
The Quantum Theory of Fields, Volumes 1, 2 and 3, by Steven Weinberg
Field Theory: A Modern Primer, by Pierre Ramond
Quantum Field Theory, by Mark Srednicki
Quantum Field Theory II, by Mikhail Shifman
Advanced Topics in Quantum Field Theory, by Mikhail Shifman
An Introduction to Quantum Field Theory, by George Sterman
Quantum Field Theory in a Nutshell by Anthony Zee
Quantum Field Theory, by Claude Itzykson and Jean-Bernard Zuber

Spring 2020 Course Outline

1. Brief review of generating functionals in quantum field theory
2. Introduction to Regularization and Renormalization
3. One-Loop Renormalization of Scalar Field Theory
4. Renormalization of Quantum Electrodynamics
5. Charge Conservation in QED (and the Ward Identities)
6. The Renormalization Group
7. Renormalization of Yang-Mills theory
8. Quantum Chromodynamics and Asymptotic Freedom
9. The Effective Action and the Effective Potential
10. Anomalies in Perturbation Theory

Course Requirements

The requirements of this course consist of four problem sets and a final project. There will be no midterm or final exam. A list of suggested topics for the final project is provided on the next page. Some of the topics require only additional readings in the recommended textbooks or one of the other textbooks cited in the list of additional references. Others will require some consultation with additional sources. Feel free to ask for additional references if needed.

The project may be presented either orally or in written form at the end of the academic quarter. Oral presentations, which will be given using zoom, are encouraged since they will benefit all members of the class. In choosing your project, you should plan on meeting the following deadlines:

Initial choice of topic for term project .... April 28
Short written proposal for term project .... May 5
Oral Presentations of the term projects .... To be arranged during June 8–11
Written version of term project .... June 11

All projects should include a one page bibliography (containing references pertinent to the project). For those projects presented orally, a digital copy of the powerpoint slides (or equivalent) are acceptable in lieu of a full written version.

Suggestions for the final project

For the final project, you may select from one of the topics listed below, or propose another project that is connected to quantum field theory. (Note that for each subject listed below, each subtopic constitutes a possible project.) I will be available during my virtual office hours for suggestions and consultation on your choice for the term project.

1. Effective field theory methods
   (a) Heavy quark effective field theory
   (b) Standard Model Effective Field Theory (SMEFT)
2. QCD
   (a) Deep inelastic scattering and the parton model
   (b) Operator product expansions in quantum field theory
3. Topological Objects in Field Theory
   (a) Classical lumps and their quantum descendants
   (b) Instantons and the θ-vacua
4. Infrared divergences and mass singularities
   (a) Sudakov form factors
   (b) The Kinoshita-Lee-Nauenberg theorem
5. Precision tests of the Standard Model
   (a) The one-loop prediction of the W mass
   (b) The S, T and U parameters
6. One-loop production and decays of the Higgs boson
   (a) The partial rate for $H \to \gamma\gamma$
   (b) Gluon-gluon fusion mechanism for Higgs boson production
7. Unification of gauge couplings and Yukawa couplings in grand unified theories
8. Finite-temperature field theory
   (a) Temperature-dependent effective potential and phase transitions