PHYSICS 8630
FALL 2014

Lecture: 11:00 - 11:50 a.m. MWF, Physics Building, Room 210
Instructor: Peter Arnold, Physics Building, Room 320
Office hours: drop by any time, or by appointment if that doesn't work.
Phone: 4-6813; e-mail: parnold@virginia.edu
Grader: John Wood, e-mail: jgw2kb@virginia.edu
TEXT: Peskin and Schroeder, *An Introduction to Quantum Field Theory*.

There is no single quantum field theory book that is good for every topics, even within a given subfield. So, for any given topic you want to know about, flip through the indexes of a lot of quantum field theory books (such as those on the reserve shelf for this course in the library) until you find one with a discussion of that topic that you like. But here are a few books I'll highlight.

An all-around book that isn't afraid to cover everything from Grand unified theories to gravity to condensed matter physics is

- Zee, *Quantum Field Theory in a Nutshell*.

For condensed matter physicists, try:

- Altland and Simons, *Condensed Matter Field Theory*
- Fetter and Walecka, *Quantum Theory of Many Particle Systems* (an old book)
- Fradkin, *Field Theory of Condensed Matter Systems*
- Tsvelik, *Quantum Field Theory in Condensed Matter Systems*

For a book that right at the beginning reviews the Quantum II topic of quantizing electromagnetic waves and absorption and emissions with atoms,

- Sakurai, *Advanced Quantum Mechanics* .

For AMO physicists interested in the Bose-Einstein condensates, try chapter 8 of

- Pethick and Smith, *Bose-Einstein Condensation in Dilute Gases*

Some of the many books that, like Peskin, focus more on relativistic field theory and particle physics:

- Ramond, *Field Theory: A Modern Primer*
- Weinberg, *The Quantum Theory of Fields*
- Brown, *Quantum Field Theory*
- Itzykson and Zuber, *Quantum Field Theory* (and old book, useful for reference but not to learn from)
- Bjorken and Drell, *Relativistic Quantum Mechanics* and *Relativistic Quantum Fields* (old famous books sometimes useful, but mostly supplanted by Peskin and Schroeder).

Finally, I'll mention for the sake of anyone who someday becomes a hard core condensed matter theorist, it's worth knowing about the tome

- Zinn-Justin, *Quantum Field Theory and Critical Phenomena* (useful for experts).

Grade weighting

65%	Homework
35%	Final exam

Exam Dates

Final exam: Friday, December 12, 9:00 a.m. – 12:00 noon.

Homework: Will always be due at the **start** of the class in which it is due. Late homework will be assessed a penalty, which will grow as time increases. (If you know you have some scheduling problem in advance, talk to me about it in advance.) Collaborating on working out methods of solution is actively encouraged! Copying another person's solution that you did not substantially participate in is unacceptable. In particular, do not look at anyone's solutions from last year. Since many problems will be the same, I would consider that a violation of the honor code.

Topics covered (subject to change):

- How to quantize a field theory and why
- The Klein-Gordon field (Peskin, ch. 2)
  - Brief history and motivation
  - Simplest relativistic theory but also describes acoustic phonons
  - Lagrangians $\leftrightarrow$ Hamiltonians for field theories
  - Quantization
  - Interpretations of excited states as particles
  - Aside: The cosmological constant problem
- Noether's Theorem for field theories
  - The stress and stress-energy tensors
- Non-relativistic field theories
  - Schrödinger-like field theory as non-relativistic limit of K-G eq.
  - Bosons vs. fermions
  - The tight-binding approximation (a link between condensed matter physics and discretized field theory)
- The complex Klein-Gordon equation and anti-particles
- The Dirac field (Peskin, ch. 3)
  - Review of the Dirac equation
  - A condensed matter application: graphene
  - Chirality
  - the Dirac Lagrangian and Hamiltonian

  - Quantization and anti-commutation relations
  - Conserved charges
- Perturbation theory and Feynman diagrams (Peskin, ch. 4)
  - Overview of where we're going
  - The Feynman propagator
  - Review of the interaction picture
  - Free theory Green functions and Wick's Theorem
  - Explicit result for free K-G theory Feynman propagator
  - Feynman rules for $\lambda\phi^4$ theory
  - Scattering matrix elements
  - Relation of Feynman diagrams to usual QM perturbation theory
  - Scattering cross sections
- Gross-Pitaevski equation for cold atomic gases
  - Non-relativistic Schrödinger field theory with interactions
  - Short-range approximation
  - scattering length
  - Gross-Pitaevski equation
- Quantum Electrodynamics (QED) (Peskin, section 4.8)
  - gauge invariance
  - Feynman rules with fermions and photons
  - Outline of calculations of scattering processes ($e^-e^- \to e^-e^-$, $e^+e^- \to \gamma\gamma$, etc.)
  - Feynman diagrams contributing to $g-2$ of electron
- Retarded propagators and the fluctuation-dissipation theorem
- The Path Integral (Peskin, ch. 9)
  - Brief review of path integral in QM
  - How to use it for time-ordered Green functions
  - Generalization to quantum field theory (QFT)
  - Relation of zero-temperature QFT to finite-temperature classical statistical mechanics
  - Feynman rules from the path integral
  - Fermionic path integrals