Physics 621—Relativistic Quantum Field Theory
Course Syllabus

Instructor	Steven Gottlieb, Distinguished Professor
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Open Door Policy	I don't want to constrain when you can see me, so you may see me at any mutually convenient time. You may just drop by my office, to see if I am in. Alternatively, feel free to call or email (sg@iub.edu) to see if I am around before dropping in. If I can't see you immediately, we can make an appointment.
Course	Physics 621, section 15755, meets TR 12:20 p.m.–2:15 p.m. in Swain West 220.
Prerequisites	You should have a sound knowledge of electrodynamics, classical mechanics and quantum mechanics at the graduate level. You should also be familiar with special relativity, but we will review breifly so we all use the same notation. Familiarity with the Dirac equation is not assumed.
Web page	There is a home page for the class that includes a link to the syllubus and where homeworks will be announced. The URL is: http://physics.indiana.edu/˜sg/p621.html.
Text	*Quantum Field Theory*, by Mark Srednicki is the **required** textbook. Errata can be found at http://www.physics.ucsb.edu/˜mark/qft.html. I previously used *An Introduction to Quantum Field Theory*, by Michael E. Peskin and Daniel V. Schroeder, or *Quantum Field Theory*, by Claude Itzykson and Jean-Bernard Zuber. The latter was found not to be sufficiently pedagogic. The former was fine, but I wanted a change to keep things interesting. There are copies of P&S and I&Z on reserve.
Description	I hope that you will find studying quantum field theory as fascinating as I do. If it were not such a fascination, I would not be an elementary particle physicist today. Quantum Field Theory has been under development since the early days of quantum mechanics, and even today is not a closed subject. Its main application, the theory of elementary particle physics is certainly a vibrant field and a thorough knowledge of field theory is important for those who wish to contribute to its future. Field theoretical and diagramatic techniques are also of great importance in the modern theory of critical phenomena and in many-body physics.

I believe that in the first semester of this course we can cover canonical quantization of free field theory, introduce interactions, develop the Feynman diagram expansion for perturbation theory, cover some of the important applications and perhaps introduce renormalization (maybe).

The expected enrollment in this course is quite small. I hope that we can proceed at a pace that everyone finds comfortable and that we can have lively class discussions.

Course Goals

1. To understand relativistic covariance and discrete symmetries.
2. To be able to carry out the canonical quantization program.
3. To gain familiarity with perturbation theory.
4. To have a thorough understanding of the Dirac equation and its solutions.
5. To be able to carry out tree-level calculations in QED.

Homework

There will probably be six homework assignments. Assignments will be posted with the due date during the course of the semester.

Class Schedule

There are a number of classes that will have to be rescheduled. I will set up a doodle poll so that I can find a mutually convenient time for the rescheduled classes.

Exams

There will be no final examination, as such an exercise seems inappropriate for this course.

Grading

Homework will be the sole factor in the determination of your grade.

Late Assignments

Homework handed in within 24 hours of time due will have 10% of the value of the assignment subtracted. Homework handed in between 24 and 48 hours late will have 20% of its value subtracted. Homework handed in later will be reduced in value by 50%.

Academic Honesty

One of the best ways to learn and to enjoy physics is by discussing it with colleagues. It is expected that you may wish to discuss the problems with others in the class. However, when you write up your homework assignments the work should be your own, not copied from someone else.

COURSE OUTLINE

1. Spin 0 (Secs. 1–12)
   - Lorentz covariance
   - Canonical quantization of scalar field
   - LSZ reduction formula
   - Path integrals
   - Feynman rules for scalar fields
   - Cross sections and decay rates
   - Discrete symmetries: C, P, T and continuous ones
2. Spin 1/2 (Secs. 33–48)
   - Representations of Lorentz group
   - Spinor fields
   - Canonical quantization of spinor fields
   - Path integrals for fermion fields
   - Feynman rules for Dirac fields
   - Spin sums and gamma matrices
3. Spin 1 (Secs. 54-59)
   - Coulomb gauge
   - Path integral for photons
   - Feynman rules for QED
   - Scattering in QED

BIBLIOGRAPHY

When last I checked (a while ago) there were about 230 books in the IU Library system on the subject of Quantum Field Theory. There are fewer titles, but that gives you some idea of the range of texts on the subject. Naturally, you would be pretty depressed if you thought that you had to read them all to understand field theory. Of course, you don't have to read them all, but I thought you should have a short list of some of the classics and some of the recent books that are very useful.

J. D. Bjorken and S. Drell, *Relativistic Quantum Mechanics*, and *Relativistic Quantum Field Theory.* These are the classic volumes of the mid-1960's that served as the standard texts until the late 1970's. First you learn to calculate in volume one, then you learn real field theory in volume 2.

N. N. Bogoliubov and D. V. Shirkov, *Introduction to the Theory of Quantized Fields.* This book was published in the late 1950's. It has an excellent treatment of basic QFT in the order we are going to start. The last three chapters treat functional integration, renormalization group and dispersion relations. The first two are still with us, but would probably be presented in a somewhat different way. The last topic was hot at the time, but fell into disuse as more modern field theoretic techniques came to the fore with the ascendancy of gauge theories.

C. Itzykson and J.-M. Zuber, *Quantum Field Theory.* It is rather encyclopedic, so it is not the shortest, most direct root to a basic understanding of QFT. A solid reference work for additional and deeper material.

M.E. Peskin and D.V. Schroeder, *Introduction to Quantum Field Theory.* An excellent book that I have used in the past for this course.

P. Ramond, *Field Theory—A Modern Primer.* This book launches quickly into symmetry considerations, construction of suitable Lagrangians and the path integration. It really is quite nice. (I sure wish I could find my copy). So, if you just can't wait to get to path integration, pick up this book and start reading it.

L. Ryder, *Quantum Field Theory.* Another book that presents field theory from the path integral viewpoint.

S. Weinberg, *The Quantum Theory of Fields*, by a Nobel Laureate noted for his earlier text on gravitation and cosmology as well as popular works. Three volumes. I don't really like the notational conventions, but there is a lot that you can learn from this book.

B. de Wit, and J. Smith, *Field theory in particle physics.* This book takes the pragmatic approach. After a brief introduction to mechanics, the approach is a diagramatic one. By chapter two the reader is introduced to propagators and Feynman rules. The calculations of cross sections and decays continue from there.

I. J. R. Aitchison and A. J. G. Hey, *Gauge Theories in Particle Physics.* Again, this book is designed to get you calculating cross sections as soon as possible.

T. D. Lee, *Particle Physics and Introduction to Field Theory.* After a quick introduction to field theory, this book discusses a wide variety of topics in elementary particle physics.

A. Zee, *Quantum Field Theory in a Nutshell.* A short introduction covering a number of topics of interest to the author, and hopefully the reader. I don't actually own this book, but I have known the author since he was an assistant professor and I was a graduate student.

You will find additional references in Srednicki's bibliography on page 636, the Peskin and Schroeder bibliography that starts on page 811, or in Itzykson and Zuber, page xxi. Please explore as your time and taste dictate.