

Physics 416, Advanced Topics in Physics

Spring 2009

Dr. Yost

Office:	216 Grimsley Hall	Textbook:	David Griffiths, <i>Introduction to Elementary Particles</i> , 2 nd , revised edition.
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Classes:	208 Grimsley Hall, MWF 10:00	Office Hours:	MTuF 13:30 - 14:30 or by appointment
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This course is an introduction to elementary particle physics. The emphasis will be on the concepts underlying a modern understanding of the physical structure of our universe at its most fundamental level. We will review the historical progress that led to the current Standard Model of elementary particle interactions and discuss the conceptual breakthrough of combining special relativity with quantum mechanics. We will be building on many topics you have studied in previous courses on mechanics, electrodynamics, and quantum mechanics. The mathematics used will include partial differential equations, Fourier analysis, and elementary group theory, which will be introduced as needed. The course will focus not on complex calculations, but on the conceptual structure underlying modern particle physics.

Grades

Grades will be based on four aspects of the course, with approximately equal weight:

- Midterm exam
- Final exam
- Presentation on a topic in particle physics
- Homework and participation

Exams

The midterm exam will cover material in about the first 5 weeks of the course, which should include (at minimum) chapters 1 – 4 in Griffiths. The final exam will focus primarily on the later parts of the course. Notes will be permitted during the exams, which will focus on homework-style problems (not necessarily from the homework, but requiring similar analysis).

Presentation

Each student will select a topic in elementary particle physics, in consultation with me, and present it in a written paper as well as in an oral presentation to the class near the end of the semester. The paper should be approximately 10 pages in length, and will be presented in a 20 minute talk before the class, to be followed by a question period. I will schedule meetings with each student before mid-terms to discuss your choice of topic. The topics should be at an appropriate level for this course. The outreach portions of web sites of national and international laboratories can be useful starting points, as can popular-level magazines and books, and magazines such as *Physics Today* or *Nature*.

Homework and Participation

A limited amount of homework will be assigned weekly to clarify the reading. It will be due one week after it is assigned. The purpose of the homework, in most cases, is to clarify the reading, and to be sure you have understood it. You should also find it useful to work through derivations in the text, and fill in any gaps, so you are certain of your understanding. This is true in any advanced physics course. You should come to class prepared to discuss the assigned readings, and to ask questions about any parts that require further clarification.

Schedule

As this is an advanced topics course, the schedule will be somewhat open. We will take time to clarify questions or discuss topics of interest that may come up in class. In particular, during the latter parts of the class, the selection of topics may depend on student interest. I expect to cover the first 4 chapters in Griffiths by mid-term, but we may go further. Thus, we will start in chapter 1 with a survey of the history of particle physics, and then look at the content of the Standard Model in chapter 2, motivating what we will explore in more detail throughout the remainder of the course. Chapter 3 is a review of special relativity, in particular as it applies to particle collisions. Chapter 4 explores the important role of symmetry in particle physics. We will then skip chapter 5, and learn about Feynman Diagrams in chapter 6. These form the basis for virtually all discussion of elementary particle processes, and will be an important

centerpiece of the course. We will go on to discuss quantum electrodynamics (QED) in chapter 7. QED forms the prototype for all of the interactions in the Standard Model. Beyond this, if time remains, we could select topics from the remainder of the text. Possibilities include gauge theory and electro-weak symmetry breaking, an introduction to the strong and weak nuclear interactions, or a survey of theories beyond the Standard Model.

Other Resources

Books on particle physics that are accessible to undergraduates are rare. Many of the books listed at the end of Griffiths' introduction are more advanced. Perhaps the best choices at a comparable level would be the following two: F. Halzen and A. Martin's *Quarks and Leptons* provides somewhat more detail in the "nuts and bolts" of constructing scattering amplitudes, but is also at a slightly higher level. D. Perkins' *Introduction to High Energy Physics* has more discussion of the experimental side than our text.

The Particle Data Group (PDG) publishes the *Review of Particle Properties*, [C. Amsler *et al.*, *Physics Letters B* **667** (2008) 1] a comprehensive collection of measurements, and a shorter summary, the *Particle Data Booklet*, both of which may be found at pdg.lbl.gov. The PDG also has a popular-level site called *The Particle Adventure* at www.particleadventure.org. The CERN web site, cern.ch, includes a lot of materials explaining the physics being explored at the world's largest elementary particle physics experiment, the Large Hadron Collider. Domestically, FermiLab and SLAC publish *Symmetry Magazine* online at symmetrymagazine.org. A variety of laboratories collaborate to produce interactions.org, a web site collecting news about particle physics from many sources.

At some point *after* this course, anyone truly interested in elementary particle physics will want to study quantum field theory. If you're looking for some "light" summer reading on the topic, you may want to consider David McMahon's *Quantum Field Theory Demystified*. It's far more readable than any "serious" QFT text listed in Griffiths, though it still leaves plenty of mysteries and may foster a few misconceptions. Moving into the graduate level, A. Zee's *Quantum Field Theory in a Nutshell* looks like a good next step. The best choice among the ones Griffiths lists is probably Peskin and Schroeder's *Introduction to Quantum Field Theory*, a standard advanced graduate-level text, more readable than many. My own favorite, P. Ramond's *Field Theory, A Modern Primer*, makes good use of Feynman's path integral approach, but is very terse.

On a less technical side, there are numerous (semi)popular books on modern theoretical ideas, including string theory, extra dimensions, "M-theory", and quantum cosmology. Authors include Brian Greene, Lisa Randall, Lenny Susskind, Michio Kaku, and others.