Physics 412: Particle Physics

**Instructor:** Gardner Marshall  
**Office Phone:** (843) 953-1015  
**Office Hours:** JC Long Room 222  
**MWF 10:00 - 11:00 am**  
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This is an introductory, undergraduate level course on modern particle physics. In this course you will study the rules governing the most fundamental building blocks of the world around us. You will learn about the reason for things such as radioactive decay and understand the concepts behind the creation of exotic particles at large colliders such as the LHC. You will learn how to combine quantum mechanics with special relativity and work with some of the tools of cutting edge physics.

We will discuss concepts you may have heard about in the popular science literature such as antimatter, virtual particles, the Higgs boson, “quantum foam,” and the difficulty in incorporating gravity within a fully unified, quantum theory. Most importantly however, you will learn how to take the ideas we learn and translate them into actual, real-world results. In other words, you will learn how to rigorously formulate the above ideas mathematically so that quantitative results can be obtained.

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**Homework:** Several homework sets will be assigned over the course of the semester. Homework will account for 40% of your grade. Each student must submit a physical copy of his or her own work by the stated deadline. Late homework will not be accepted. Working together on homework is allowed. However, simply copying answers from others is prohibited.

**Tests:** There will be a total of three tests in this course: two midterms and a final. All three of these will be in-class, and each is worth 20% of your final grade.

**Grading:** As stated above, homework will count for 40% of your final grade, and each of the three tests will count for 20%. Letter grades correspond to the percentages as outlined in the table below.

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**Mathematics:** There is only one formal pre-requisite for this course: quantum mechanics. Since quantum mechanics is a requirement, it is assumed that students will have had some experience with advanced mathematical work such as solving nontrivial differential equations, manipulating vectors and matrices, and calculating multidimensional integrals. Please be aware that the mathematical demands of this course will be substantial. Given the nature of the subject matter, this is inescapable. I firmly believe that everyone with a desire to learn this material can do so, but unless your name is Richard Feynman, it is no walk in the park. Be ready to work hard and struggle. If you do, you will be rewarded.
**Attendance:** You should attend every class. I will take attendance. Bonus points will be awarded at the end of the semester based on your attendance record. Failing to be present during class for any reason whatsoever whether it is documented and/or excused or not will be considered an absence. Students absent for more than three classes may be dropped from the course without warning at the discretion of the instructor and will receive an automatic WA (Withdrawn Excessive Absences).

**Textbook:** The official textbook for the course is *Introduction to Elementary Particles* by David Griffiths. I strongly encourage everyone to purchase a hardcopy of this book and read it inside and out. Sleep with it under your pillow!

*Tentative Lecture Schedule:*

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
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<tbody>
<tr>
<td>Monday, January 8th</td>
<td>Course Introduction (1 day)</td>
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<tr>
<td>Wednesday, January 10th</td>
<td>Overview of Particle Physics (1 day)</td>
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<tr>
<td>Friday, January 12th</td>
<td>Special Relativity (4 days)</td>
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<tr>
<td>Monday, January 22nd</td>
<td>Tensors and Four-vectors (1 day)</td>
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<tr>
<td>Wednesday, January 24th</td>
<td>Rules for Decays and Scattering (5 days)</td>
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<tr>
<td>Monday, February 5th</td>
<td>Feynman Diagrams and Particle Interactions (2 days)</td>
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<tr>
<td>Wednesday, February 7th</td>
<td>The Dirac Equation (2 days)</td>
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<td>Friday, February 16th</td>
<td>Relativistic Quantum Mechanics (1 day)</td>
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<tr>
<td>Monday, February 19th</td>
<td>Quantum Electrodynamics (4 days)</td>
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<tr>
<td>Wednesday, February 28th</td>
<td>Catch-up &amp; Review (1 day)</td>
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<tr>
<td>Friday, March 2nd</td>
<td>Midterm Exam 1</td>
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<tr>
<td>Monday, March 5th</td>
<td>The Weak Interaction (4 days)</td>
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<td>Wednesday, March 14th</td>
<td>The Born Approximation (2 days)</td>
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<td>Monday, March 19th</td>
<td>Midterm Exam 2</td>
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<td>Monday, March 26th</td>
<td>★ SPRING BREAK! ★</td>
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<td>Monday, April 2nd</td>
<td>Lagrangian Formalism (3 days)</td>
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<td>Monday, April 9th</td>
<td>Gauge Invariance (3 days)</td>
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<td>Monday, April 16th</td>
<td>The Higgs Mechanism (3 days)</td>
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<td>Monday, April 23rd</td>
<td>The Standard Model (3 days)</td>
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<td>Wednesday, May 2nd</td>
<td>Beyond The Standard Model (1 day)</td>
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<tr>
<td>Wednesday, May 2nd</td>
<td>Final Exam</td>
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Disability Accommodations: Any student eligible for and needing accommodations because of a disability should speak with me during my office hours at the beginning of the semester.

Honor Code and Academic Integrity: It is understood that all students enrolled in this course will uphold the college’s honor code and refrain from lying, cheating, and stealing. Violations will be reported to the honor board and may result in a failing grade in the course as well as a mark on one’s transcript indicating academic dishonesty. In short, don’t be a sleazy jerk.

Miscellaneous Details:
Term and Section: Spring 2018, Section 01
Class Meeting Location: JC Long Room 219
Course Prerequisites: Physics 403 or permission of the instructor

Learning Outcomes

- Use conservation laws to determine allowed/forbidden processes
- Use relativity to calculate the possible energies of products in allowed processes
- Apply Feynman diagrams to calculate amplitudes for particle processes
- Understand how particle interactions are described by a Lagrangian
- Extract quantitative predictions from the Lagrangian of a theory
- Calculate scattering cross sections for particle interactions
- Determine the mean lifetime of unstable particles