Introduction to Particle Physics

Phys 366

"Not only God knows, I know, and by the end of the semester, you will know." -*Sidney Coleman*

January 28, 2019

Professor: Andrew Larkoski
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Lectures: Tuesday, Thursday 10:30-11:50 am (P123)

Office Hours: Monday 1-3 pm (P124)
Tuesday, 1-3 pm (P124)
Wednesday, 2-4 pm (P124)

Text: Andrew J. Larkoski, "Elementary Particle Physics: An Intuitive Introduction", Cambridge, 2019.
This book is not yet published, but during the first few weeks of the course, you will receive access to an electronic pre-proof version.

Supplemental References:

Mark Thomson, "Modern Particle Physics", Cambridge, 2013.
Another modern particle physics textbook for undergraduates.

David Griffiths, "Introduction to Elementary Particles", Wiley, 2008.
An elementary introduction from a more historical perspective.

Sidney Coleman, "Aspects of Symmetry", Cambridge, 1985.
Notes from the Erice summer school from Sidney Coleman. Coleman's quantum field theory class at Harvard was legendary and lectures from 1975 were recorded and are available to view online at: https://www.physics.harvard.edu/events/videos/Phys253.

Ta-Pei Cheng, Ling-Fong Li, "Gauge Theory of Elementary Particle Physics", Oxford, 1984.
Graduate-level textbook surveying many fundamental topics in particle physics.

Matthew Schwartz, "Quantum Field Theory and the Standard Model", Cambridge, 2014.
A modern graduate-level book on quantum field theory.

Anthony Zee, "Quantum Field Theory in a Nutshell", Princeton, 2003.
An approachable, readable introduction to ideas in quantum field theory.

Course Website: Linked to from my Reed website: http://people.reed.edu/∼larkoski/

Course Description: This course is an introduction to elementary particle physics, the description of Nature at the shortest distance scales. This class will emphasize the theoretical underpinnings of the Standard Model of particle physics and its experimental verification.

This class will broadly consist of three parts. First, an introduction to the necessary theoretical tools like special relativity, Fermi's Golden Rule, elementary statistics, and Feynman diagrams, as well as introductions to experimental methods for measuring elementary particle interactions and their simulation with modern Monte Carlo tools.

With this introduction, we will then discuss the properties of the two fundamental forces that dominate physics at the shortest accessible length scales: the electroweak force and the strong force (quantum chromodynamics). In addition to the predictions and experimental validation of these theories, students will also analyze real data that has been collected by the experiments at the Large Hadron Collider.

Course Requirements: There will be three graded aspects of this course: weekly homework problems, a final exam, and an oral exam. In calculating your final grade, your one lowest homework score will be dropped.

Homework: Homework will consist of of problems taken from the textbook, and will develop methods discussed in lecture. Homework should be written by hand (with pen/pencil and paper) or typed up and is assigned through the course website during the week of classes on that topic. Homework is due in class the Thursday of the following week. Late homework will not be accepted.

Final Exam: There will be a take-home final exam assigned at the end of the semester. It will cover all topics discussed in the class and you will have one week to complete it.

Oral Exam: An important part of science is the ability to efficiently verbally communicate. In addition to the final exam, there will also be an individual oral exam in which you will discuss experimental and theoretical aspects of particle physics one-on-one with me. You will sign up for a 30 minute slot during finals week.

Grading: The amounts to which the homework, final exam, and oral exam contributes to your grade are:

Homework	50%
Final Exam	30%
Oral Exam	20%

Weekly Lecture Topics: The following page shows a list of topics we'll discuss this semester during each week. This isn't a final schedule, and may possibly change as the semester goes on.

Week:	Date:	Topic:	Textbook:
1	1/29	The Big Picture: The Standard Model	Chap. 1
	1/31	Dimensional Analysis, Natural Units, and Relativity	Sec. 1.4, 2.1
2	2/5	Review of Special Relativity I	Sec. 2.1
	2/7	Review of Special Relativity II	Sec. 2.2
3	2/12	A Little Group Theory	Sec. 3.1-3.2
	2/14	The Quark Model	Sec. 3.3
4	2/19	Fermi's Golden Rule	Sec. 4.1-4.2
	2/21	Space-Time (Feynman) Diagrams	Sec. 4.3
5	2/26	Particle Physics Detectors	Sec. 5.1-5.5
	2/28	Statistical Analyses	Sec. 5.6
6	3/5	Electron-Positron Annihilation	Sec. 6.1
	3/7	Hadron Production in Electron-Positron Annihilation	Sec. 6.2
7	3/12	The Parton Model	Sec. 7.1-7.2
	3/14	The Gluon	Sec. 7.3
8	3/19	Non-Abelian Gauge Theories	Sec. 8.1-8.2
	3/21	Quantum Chromodynamics	Sec. 8.3
		Spring Break	
9	4/2	Parton Evolution	Sec. 9.1-9.2
	4/4	Jets in QCD	Sec. 9.3
10	4/9	Parity Violation in the Weak Interaction	Sec. 10.1-10.3
	4/11	V-A Theory Predictions	Sec. 10.4
11	4/16	Spontaneous Symmetry Breaking	Sec. 11.1-11.2
	4/18	The W and Z Bosons	Sec. 11.3
12	4/23	CP Violation	Sec. 12.1-12.2
	4/25	Neutrinos and their Mixing	Sec. 12.3
13	4/30	Discovery of the Higgs Boson	Chap. 13
	5/2	Particle Physics at the Frontier	Chap. 14

Abstract: This is the first of a series of papers in which we present a brief introduction to the relevant mathematical and physical ideas that form the foundation of Particle Physics, including Group Theory, Relativistic Quantum Mechanics, Quantum Field Theory and Interactions, Abelian and Non-Abelian Gauge Theory, and the SU(3)xSU(2)xU(1) Gauge Theory that describes our universe apart. from gravity. These notes are not intended to be a comprehensive introduction to any of the ideas contained in them. Among the glaring omissions are CPT theorems, evaluations of Feynman Diagrams, Renormalizati This page intentionally left blank. Introduction to elementary particle physics. The Standard Model is the theory of the elementary building blocks of matter and of their forces. It is the most comprehensive physical theory ever developed, and has been experimentally tested with high accuracy. This textbook conveys the basic elements of the Standard Model using elementary concepts, without theoretical rigour. While most texts on this subject emphasise theoretical aspects, this textbook contains examples of basic experiments, before going into the theory. This allows readers to see how measurem This book presents fundamental concepts in particle physics and gives an accessible introduction to topics such as quantum electrodynamics, Feynman diagrams, relativistic field theories and much more. This is a free eBook for students. Sign up for free access.Â Download 1,700+ eBooks on soft skills and professional efficiency, from communicating effectively over Excel and Outlook, to project management and how to deal with difficult people. Written by industry-leading experts. Bite-sized format (1-2hr reading time). Easy-to-use and accessible eReader. Continue reading from where you stopped. New eBooks added every week.