Topics in Elementary Particle Physics

Fall 2005 | Physics 365 | 8:00 A.M. even CD

Instructor:

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Office Hours: 1:30 P.M. Days 2 & 6
Informal Office Hours: 8:00 A.M. – 5:00 P.M.

Texts:

- *The Ideas of Particle Physics* by Coughlan & Dodd (Cambridge, 1991) Chapters: 1–45
- *Particle Physics Booklet* by the Particle Data Group
- http://www.physics.csbsju.edu/365/

Grading:

Your grade will be determined by averaging four scores: net homework score, midterm exam score, and the final exam score (which is double-counted). Assigned homework is due at the beginning of the next class period. Approximate exam dates are: November 21 (Monday) and 5 P.M. December 16 (Friday).

Questions:

There is no such thing as a dumb question. Questions asked during lecture do not "interrupt" the lecture, rather they indicate your interests or misunderstandings. I'd much rather clear up a misunderstanding or further develop a topic of interest than continue a dull lecture. We will be covering a great deal of material in a short period of time. The approach will be qualitative with relatively little math (more like biology than physics!). New vocabulary will be defined and put to use shortly after, and it is easy to lose track of what's what. Remember: you are almost never alone in your interests, your misunderstandings, or your problems. Please help your classmates by asking any question vaguely related to physics. If you don't want to ask your question during class, that's fine too: I can be found almost any time in my office (PEngel 111) or the nearby labs.

Topics:

This course deals with "the dreams that stuff is made of": quarks, leptons, gauge bosons, and Higgs particles. These 'elementary' particles are believed to be the building blocks from which all the stuff we see around us is constructed. Two quibbles must immediately be recorded. First, it is generally believed (based on hints rather than data) that these 'elementary' particles are in turn composites (perhaps of strings). Second, there is good evidence that the sort of 'stuff' we see around us is in fact atypical of the the Universe as a whole. The nature of the typical components of the Universe, 'Dark Matter' and 'Dark Energy' which are detected in various astrophysical situations, is currently a mystery. This course will not focus on these mysteries, rather we'll stay of the firm ground of the 'known' particles and their behavior—things that have been detected and measured, or at least widely expected.

The name 'Particle Physics' is perhaps confusing: our concern here is only with sub-atomic particles, i.e., the particles that make up atoms (electrons, neutrons, protons) and related particles. ('Atomic Physics' and 'Nuclear Physics' deal with those larger objects.) Particle Physics is also known as 'High Energy Physics' (HEP) which brings to mind the huge particle accelerators ('atom smashers' in the vocabulary of the 1950s) used to study these particles. According to de Broglie, high energy is required to produce the short wavelength particles which can record fine detail. You'll find below a book titled *Femtophysics*, which is referring to the short distance scales (femtometer = 1 fm = 10^{-15} m) studied in particle physics. While the dramatic collisions of high-speed particles are at the core of particle physics, it also includes seemingly lethargic experiments, like monitoring huge volumes of water looking for the rare spontaneous decay of a proton, or monitoring large cryostats at a temperature of 0.01 K at the Soudan mine for Dark Matter collisions.

The primary tool of theoretical particle physics is quantum field theory (QFT), most easily understood in the graphical form of Feynman diagrams. While the ideas of QFT can be explained at an undergraduate level (see for example, Feynmann's book *QED* listed below), this is a topic way beyond the aims of this course. As a result much of this course will be descriptive rather than quantitative. The primary tool[1] of experimental particle physics is the high speed electronic detector. Modern detectors are larger than a house an employ a variety of detection techniques. Consideration of these fantastic devices would immediately lead to issues of high speed electronics, which is again beyond the aims of this course. The end result of most HEP experiments is huge amounts of data to 'crunch'. The Bubble Chamber lab gave you a tiny taste of this…think about scaling up that lab by a factor of a billion.

A final word about 'mysteries'. Classroom physics is typically a report about the known; Real physics is about the boundary between the known and the unknown.[2] We usually think of the unknown as far removed from everyday life: for example, in the ever smaller distance scales revealed in ever higher energy collisions or at extremely remote distances or times. The extraordinary conditions of the Big Bang are an obvious nexus for both particle physicists and astrophysicists. Nevertheless, the unknown really is all around us. For example, the mechanism of 'high temperature superconductivity' (material we easily made twenty years ago) remains a mystery today.

References

An Introduction to the Standard Model of Particle Physics by Cottingham (1998) QC794.6.S75

Introduction to Nuclear and Particle Physics by Das (1994) QC776.D37

Femtophysics : a Short Course on Particle Physics by Bowler (1990) QC793.2.B68

The Experimental Foundations of Particle Physics by Cahn (1989) QC793.2.C34

Modern Elementary Particle Physics by Kane (1987) QC793.2.K36

Quarks and Leptons : an Introductory Course in Modern Particle Physics by Halzen (1984) QC793.5.Q2522.H34

Introduction to High Energy Physics by Perkins (1982) QC793.2.P47

The Quantum Theory of Fields by Weinberg (1995) QC174.45.W45

Dreams of a Final Theory by Weinberg (1992) QC21.2.W428

The God Particle : If the Universe is the Answer, What is the Question? by Lederman (1993) QC793.5.B62.L43

QED : the Strange Theory of Light and Matter by Feynman (1985) QC793.5.P422.F48

Beamtimes and Lifetimes : the World of High Energy Physicists by Traweek (1988) QC774.A2.T73

[1] Design and construction of the accelerator itself is the discipline called 'Accelerator Physics'.

[2] In HEP lingo: "Today's signal is tomorrow's background".