Nuclear and Particle Physics, Spring 2012

	Monday	Wednesday	Friday
January	2 Definitions and Units Chapter 1	4 Basic Properties of Nuclei Chapter 3	6 Rutherford Scattering
	9 **PS1** Binding Energy Chapter 4	11 Liquid Drop Model	13 Shell Model Chapter 5
	16 M. L. King Day	18 **PS2** Shell Model, cont.	20 Spin and Parity Chapter 6
	23 Decay Rates and Half Lives Chapter 7	25 Energy in Nuclear Decays	27 **PS3** Radioactive Dating
	30 **Review Session and Test** (Through Chapter 7)	1 Ionizing Radiation	3 Nuclear Medicine
February	6 **PS4** Alpha Decay in Detail Chapter 8	8 Fermi Theory of Beta Decay Chapter 9	10 Parity Violation
	13 Gamma Decay in Detail Chapter 10	15 **PS5** Nuclear Reactions Chapter 11	17 Fission Chapter 12
	20 Presidents Day	22 Fusion Chapter 13	24 **PS6** Particle Accelerators Handout
	27 **Review Session and Test** (Through Chapter 13)	29 Particle Detectors	2 Four-Vectors Handout
March	5 Relativistic Quantum Mechanics	7 **PS7** Feynman Diagrams Handout	9 Quantum Electrodynamics
	12	14 Spring Break	16
	19 Radiative Corrections	21 Classification of Particles Chapter 14	23 **PS8** Quarks Chapter 15
	26 Quantum Chromodynamics	28 Weak Interactions Chapter 16	30 **PS9** W and Z Bosons
April	2 The Higgs Mechanism	4 Grand Unified Theories Chapter 17	6 **PS10** Supersymmetry
	9 **Review Session and Test** (Particle Physics)	11 String Theory work on projects	13 Quantum Gravity work on projects
	16 Cosmology work on projects	18 Final Project Presentations during final exam time	20

Physics 3710 General Information

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Office hours: MWF 9:30–10:20, TTh 1:30–2:30. I'll often be around at other times as well; my full schedule is posted next to my office door. Feel free to make an appointment if you like.

Course Description. This is a course on physics at extremely small length scales, e.g., inside the atomic nucleus. Everything behaves quantum mechanically at this scale and because short wavelengths correspond to high energies, most things behave relativistically. Over tiny distances, besides the familiar electromagnetic force, protons and neutrons attract each other via the "strong" nuclear force. Stranger still is the "weak" nuclear interaction through which protons can convert into neutrons and vice-versa.

Through an incredible balance among all these effects, it turns out that more than 250 different combinations of protons and neutrons (isotopes) are stable. Hundreds of other combinations are unstable, but still last long enough for us to study them in laboratories and, often, put them to practical use. In this course we will study the reasons for stability and instability, the various decay modes of the unstable isotopes, and a wide variety of applications of nuclear physics ranging from astrophysics to medicine.

At still smaller length scales (and correspondingly higher energies), the protons and neutrons are made of quarks and gluons. These are "elementary" particles, like electrons and neutrinos, with no known substructure. We will study the classification of the known elementary particles, the description of their fundamental interactions in terms of Feynman diagrams, and the experiments through which we probe these interactions. The course will end at the frontier of high-energy physics with speculations about unification, the origin of mass, and the nature of the dark matter.

Textbook: Dunlap, *The Physics of Nuclei and Particles* (Brooks/Cole, 2004). This book provides a good treatment of nuclear physics at just the right level for this course. Its chapters on particle physics are less complete but I will provide some supplementary materials when necessary.

Problem sets will be assigned roughly once a week, and due by 4:00 p.m. on the days indicated on the syllabus ("PS1" for the first problem set, and so on). Late problem sets will not be accepted. Your homework grade will be based on only your 9 highest problem set scores (out of 10), so you may miss one problem set without penalty. This policy should give you enough flexibility to deal with most scheduled absences, illnesses, family emergencies, term papers, unexpected romances, and the like; exceptions will be granted only in the case of extended illness or other long-term exigency.

I *strongly* encourage you to talk with your classmates as you work on the problem sets. This gives you an opportunity to learn from each other, to prevent careless errors, to practice putting ideas into words, and to work in an environment more like the "real world". Don't think of the homework as a "test" of what you can do on your own—it is rather an opportunity for you to *learn*, and most of us learn better from other people than from a book. It is unethical, however, to simply copy someone else's work or to borrow an idea that you don't understand yourself. Never look at another person's written solution before finishing your own. When you do receive significant help from someone on a problem, you should give that person credit in your written solution.

I will grade each problem set on a scale of 0 to 5, with the score based not only on your getting the right answers but also on the completeness of your solutions and on how well you communicate on paper. Your solutions should be written so that any classmate could read and understand them. Solutions that are incomplete, illegible, or poorly organized will receive significantly less credit, even if the answer is correct. I will make official solutions to each problem set available soon after the due date.

Tests (three of them) will be closed-book, given in the Science testing center (SL 228) with a 90-minute time limit. You will have a two-day window within which to take each test: the date indicated on the course schedule and the following day. You may use a calculator on tests to do arithmetic, but not to store information. There will be no comprehensive final exam.

No make-up tests will be given without *advance* permission.

Projects. During this short semester we won't have time to cover every aspect of nuclear and particle physics. You'll inevitably become curious to learn more, and you'll have a chance to do so in your final project. The idea is to choose a peripheral topic in nuclear or particle physics that we're not covering in class, and learn as much about it as you can. This must include performing some nontrivial calculations, at the level of this course. Then write up what you've learned in a formal paper, using your best English, typed and illustrated. You'll also give a short presentation on your topic to your classmates at the end of the semester, during our scheduled final-exam time.

Most of the good final project topics are in the detailed applications of nuclear physics to such fields as geology, medicine, astronomy, energy, and warfare. Feel free to choose a specific example of any of these, or see me if you're interested in doing a project on some other topic.

Grades will be computed according to the following weights:

problem sets (highest 9)	45%
tests (3 weighted equally)	45%
project	10%

If you choose a harder-than-average project topic, and do a good job on it, you may earn some extra credit.

In deciding borderline grades I will also consider class attendance and participation. (It is the *effort* at participation that matters; how much knowledge you demonstrate makes no difference at all.)

Academic dishonesty, though rare, occasionally does occur in physics classes, so the following policies are necessary. Inappropriate collaboration on homework will result in a zero grade for that problem set on the first occurrence and failure in the course thereafter. Dishonesty of any sort on a test, if clearly documented, will result in automatic failure in the course. In serious cases, evidence of dishonesty may also be presented to the appropriate hearing committee for possible further sanctions.

Special notice: Any student requiring accommodations or services due to a disability must contact Services for Students with Disabilities (SSD) in room 181 of the Student Service Center. SSD can also arrange to provide course materials (including this syllabus) in alternative formats if necessary.

Hints and Suggestions

This course deals with some of the most advanced ideas in the physics curriculum, so we won't be able to treat every topic with the mathematical precision that you're used to, for example, in classical mechanics. Rather, our goal will be to understand as much as possible in a one-semester course, using the tools that you already have in hand: a good understanding of the principles of relativity, quantum mechanics, and electromagnetism.

The challenge, then, will be for you to recognize how much you can and cannot understand at the level of this course. If you're ever in doubt about what level of understanding is expected, please ask!

Since the ideas of subatomic physics are closely linked to each other, the material of this course will be highly sequential. It is therefore crucial that you not fall behind. Class attendance is not required, but is strongly recommended. If you ever have a question during class, ask immediately—don't just write it down and hope that you'll figure it out later. Most important of all, do the homework on schedule; don't put it off until the last minute (or later).

Extensive research has shown that the students who do best in physics (and other subjects) are those who involve themselves *actively* in the learning process. This involvement can take many forms: writing lots of questions in the margins of the book; asking questions in class or during my office hours or by email; discussing physics with classmates; inventing your own examples; writing careful English explanations in homework assignments. Try to do things like these as often as possible!

A Final Word . . .

Physics is not so much a collection of facts as a *way* of looking at the world. My hope is that this course will not only teach you many of the *ideas* of subatomic physics, but will also improve your *skills* in careful thinking, problem solving, and precise communication. In this course you will gain lots of experience with qualitative explanations, rough numerical estimates, and careful quantitative problem solving. When you understand a phenomenon on all of these levels, and can describe it clearly to others, you are "thinking like a physicist" (as we like to say). Even if you eventually forget every fact learned in this course, these skills will serve you well for the rest of your life.