PHYS 314: Nuclear Physics and Radioactivity - Spring 2017

Lectures Monday and Thursday @ 11:30 - 12:50; *Elliot 162*
Professor Dr B.D. Sawicka, barbara@uvic.ca; *Elliot 402B*
You're welcome to stay for a chat after each lecture, and come by during office hours.
Email for appointment at other times. Office hours: TBA

Course content

- Cosmological evolution from the hot Big Bang to nuclei and atoms; the building blocks of matter, fundamental forces, force carriers; spin, symmetries, statistics; Standard Model
- Some concepts of QM and of special relativity. Antiparticles. Yukawa potential.
- Interactions involving particles and nuclei; space-time symmetries and conservation laws. Feynman diagrams.
- Nuclear phenomenology: nuclear constituents and interactions; radioactive decay, spontaneous and induced; nuclear reactions; radioactivity and radiation in our environment and life.
- Interaction of radiation with matter; instrumentation: detectors, accelerators, spectrometers, ...
- Models and theories of nuclear structure; theories of nuclear decay.
- Applications of nuclear physics
    - Nuclear reactions in the Early Universe, stellar nucleosynthesis, origin of chemical elements
    - Nuclear power on Earth: fission and fusion reactors, small power generators
    - Nuclear- and radiation-based techniques in science, industry, art, and medicine
- Frontiers of nuclear physics; outstanding questions

Motivation

- Nuclear physics studies atomic nuclei and reactions among them. Nuclear science seeks to explain, at the most fundamental level, the origin, evolution, and structure of the visible matter of the universe. Nuclear processes and matter play a fundamental role in the physical world, including fundamental interactions (all four fundamental forces act in the nucleus); constituents and structure of visible matter (the Universe visible to us is basically space and nuclei); nuclear reactions in the Early Universe and stellar nucleosynthesis.

- Nucleus is an A-body, complex quantum mechanical system of interacting nucleons; its theoretical description required developing new concepts in description of physical processes. Nuclear models use QM formalism developed for atom, but the structure and behaviour of nuclei are more complex, and several nuclear models are in use to interpret different classes of nuclear phenomena. A future goal is a universal model of the nucleus based on the many-body QM theory applied to interacting nucleons (currently possible for light nuclei), and a more fundamental theory based on interacting quarks.

- Nuclei are involved in a wide variety of pure and applied research, hence nuclear physics overlaps with various fields of science. Radioactivity and nuclear physics play a role in science, technology, medicine, industry, art, and other fields. A wide range of applications includes radioactive dating, radioactive tracing, analytical techniques (NAA, NRA, ERD, HFI, ...), imaging techniques (projection, MRI, PET, SPECT, CAT), medical diagnostics and treatment, and power generation. With the emission-free nature of nuclear power, safely operating nuclear power reactors could be part of the solution to the global warming and pollution.

Specific goals of this course

- to gain an understanding of structure, processes, and theoretical descriptions of the nucleus
- to learn about radioactivity, theory of radioactive decay, nuclear reactions, and interaction of radiation with matter
- to explore a range of applications of nuclear processes and techniques in the modern world

Course organization

Textbook **B.R. Martin, *Nuclear and Particle Physics: An Introduction*** (J. Wiley 2009)
Chapters 1, 2, 4, 7, 8, 9, and Appendices A, B, C, E; see page *Lectures* on the course website.

Tables of nuclear data and physical constants can be found in the course textbook, other textbooks (see below) and on-line, see *Useful links* of the course webpage for hints.

The course shall follow the material of the textbook, Chapters and Appendices as listed above. Some material from other sources shall be added, for illustration/clarification or to add a relevant topic. Some sections of the textbook will be left for students to read on their own. There is lots of on-line material relevant to this class, and some lectures shall have assigned web reading. Slides shown in class intend to summarize and illustrate the course material, and shall be available in pdf format.

Assignments and midterms: Assignments are due in the class, typically one week after the issue date, unless specified otherwise. Submission one day late shall have 25% penalty. Submissions more than one day late shall receive no credit. No make-up midterms. There will be several homework assignments on a weekly basis, and a research project to be prepared on individually assigned topics, to be presented at the poster session.

Policy on collaboration**:** You may discuss homework problems with your classmates, but you are then expected to work on the assigned problems on your own. All work that you hand in must be your own and it must be clear from it that you understand what you are presenting.

Grading scheme and posting: The final grade shall be a composite of grades for homework assignments and midterm (one or two), research project, and the final exam, approximately 20%-20%-20%-40%. If you miss many classes the value of your final grade might be reduced by up to 10%. Grades shall be posted using the students' numbers in numerical order, without students' names.
UVic's conversion of percentage scores to letter grades: A+ >89 (exceptional), A 85-89 (outstanding), A- 80-84 (excellent), B+ 77-79 (very good), B 73-76 (good), B- 70-72 (solid), C+ 65-69 (satisfactory), C 60-64 (minimally satisfactory), D 50-59 (marginal), F < 50 (unsatisfactory), N Not Completed.

Other books (NOT compulsory, but might be helpful, and have tables of data):
1. There are many books relevant to this course; some are listed on the course website, page *Useful Links*.
2. Two books are available for you at the UVic's library, Reserve Section:
   - K.S. Krane, *Introductory Nuclear Physics* (J. Wiley 1986) provides a comprehensive coverage of theory and experiment at the introductory level, written in a very accessible way.
   - J.S. Lilley, *Nuclear Physics; Principles and Applications* (J. Wiley 2001-2008) reviews basics of nuclear physics (briefly but well) in part 1, and discusses various applications (thoroughly) in part 2.
3. A simpler version of the course material, which might be useful for some of you as introductory reading, can be found in relevant chapters of any *Modern Physics* textbook, e.g., K. Krane (2012), R.A. Serway, e.a. (2005 or later), or S. Thornton & A. Rex (2006 or later).

Course webpage http://web.uvic.ca/~barbara/phys/Phys314/

All materials of this course shall be posted on the course website