PHYS 314: Nuclear Physics and Radioactivity - Summer 2015

Course content

- Cosmological evolution from the Big Bang and elementary particles to nuclei and atoms.
  Spin, statistics, classification of particles. The fundamental forces. The Standard Model.
  Space-time symmetries and conservation laws. Nuclear constituents and interactions.
- Special relativity and antiparticles. Some concepts of QM.
- Interactions involving particles and nuclei. Pictorial methods of Feynman diagrams.
- Nuclear mass, shape, density, binding energy, stability/instability. SEMF.
- Radioactivity. Spontaneous and induced radioactive decay. Nuclear reactions.
- Interaction of radiation with matter. Radiation in our environment and life. Biological effects.
- Instrumentation: detectors, accelerators, etc.
- Models and theories of nuclear structure. Exotic nuclei.
- Theories of α- β- γ-decays.
- Applications of nuclear physics
  - Nuclear power on Earth. Fission and fusion reactors, small power generators.
  - Nuclear reactions in the early universe; stellar fusion, origin of chemical elements
  - Nuclear- and radiation-based techniques in science, industry, art and medicine
- The frontiers of nuclear physics. Outstanding questions and future prospects.

Motivation

Nuclear physics studies atomic nuclei and reactions among them. Nucleus is an A-body, complex quantum mechanical system: its modelling required developing new concepts in the description of physical processes, and it continues to be a challenge today. The Universe visible to us is essentially space and nuclei. 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 the fundamental role in the physical world, including fundamental interactions and basic constituents of matter, nuclear reactions in the Early Universe and in stars, and synthesis of chemical elements. 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 are used in many fields of science, technology, medicine and industry. A wide range of applications includes radioactive tracing and dating; analytical techniques (neutron activation analysis, neutron diffraction, PIXE, hyperfine interactions, etc.); imaging techniques (projection imaging, MRI, PET, CAT, SPECT); medical diagnostics and treatment; and power generation using nuclear fission and fusion. 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 are:

- to gain an understanding of structure, processes, and theoretical descriptions of the nucleus
- to learn about radioactivity, properties of radioactive nuclides, theories 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

Lectures Tuesday, Wednesday, Friday @ 11:30 - 12:20; *David Strong Blg (DSB) C126*
Professor Dr B. D. Sawicka, barbara@uvic.ca; *EOW 331;* Office hours: TBA
You're welcome to come by any time during office hours. Email for appointment at other times.

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

Course organization
The course'll cover the material in the textbook chapters and relevant Appendices, as listed above. Some sections shall be left to read on your own. Selected material from other chapters and other sources will be added, mostly to illustrate or clarify, but also to add a relevant topic. There is lots of Internet material relevant to this class, and some lectures shall have assigned web reading.
There will be several homework assignments (~7), on a weekly basis, and one longer-term research project, on an individually assigned/selected topic, to be presented in the class.
All the course material, including slides shown in the class, shall be posted on the course webpage.

Other recommended reading (not compulsory, but helpful):

- K.S. Krane, *Introductory Nuclear Physics* (J. Wiley 1986), provides a comprehensive and detailed coverage of both experiment and theory at the introductory level, excellent reading material
- J.S. Lilley, *Nuclear Physics; Principles and Applications* (J. Wiley 2001-2008), discusses principles of nuclear physics (briefly but well) in part 1, and a wide range of applications (thoroughly) in part 2; some sections of part 2 shall be included in this course.

Both books are available for the students at the UVic's Library Reserve. Both have tables of nuclear properties, somewhat more extensive than those in Martin's textbook. Tables of nuclear properties and physical constants are also accessible on-line, see page "Useful links" on the course website.
A simpler version of the course material, which might be useful as introductory reading for some of you, can be found in relevant chapters of any *Modern Physics, e.g.,* K. Krane (2012), R.A. Serway, C. Moses & C. Moyer (2005 or later), and S. Thornton & A. Rex (2006 or later); these books also have tables of nuclear properties.

Assignments and midterms
Assignments are due in the class one week after the issue date, typically on Fridays, unless specified otherwise. One day late submission shall have 25% penalty. No partial credit will be given for submissions more than one day late. No make-up midterms.

Policy on collaboration
You are allowed to discuss homework problems with your classmates, however, 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, midterms, research project, and the final exam. UVic's standard conversion of percentage scores to letter grades is: A+ 90-100, A 85-89, A- 80-84, B+ 77-79, B 73-76, B- 70-72, C+ 65-69, C 60-64, D 50-59, F < 50, N Not Completed. The grades will be posted using the students' numbers in numerical order, without the names. If you would like to opt out of this arrangement, please notify me prior to the tests and examination.