PHYS 314: Nuclear Physics and Radioactivity - Summer 2016

Course content

- Cosmological evolution from Big Bang and elementary particles to nuclei and atoms
- Classification of particles; spin, statistics. Fundamental forces, Standard Model.
- Space-time symmetries and conservation laws. Nuclear constituents and interactions.
- Some concepts of QM. Relativity and antiparticles. Yukawa potential.
- Interactions involving particles and nuclei. Feynman diagrams.
- Nuclear phenomenology. Spontaneous and induced radioactive decay. Nuclear reactions.
- Interaction of radiation with matter. Instrumentation: detectors, accelerators, spectrometers, ...
- Radioactivity and radiation in our environment and life
- Models and theories of nuclear structure
- Theories of α- β- γ-decays
- Applications of nuclear physics
    - Nuclear reactions in the early universe, stellar fusion, 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

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), nuclear reactions in stars and in the Early Universe, synthesis of chemical elements, and - since the Universe visible to us is essentially space and nuclei - basic structure and constituents of visible matter.
- Nucleus is an A-body, complex quantum mechanical system of interacting nucleons; its theoretical description required developing new concepts in description of physical processes, and continues to be a challenge today. Nuclear models use QM formalism developed for atom, but nuclei are bound states of nucleons held together by a strong, charge-independent, short-range force, and their structure and behaviour are more complex. Different nuclear models are used to interpret different classes of nuclear phenomena. Future goals are a universal model that would use the many-body QM theory applied to interacting nucleons (already 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 are used in many fields of science, technology, medicine, industry, art, and other fields. A wide range of applications includes radioactive dating, radioactive tracing, analytical techniques (neutron activation analysis, neutron diffraction, PIXE, 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 and properties of radioactive nuclides, interaction of radiation with matter, theories of radioactive decay and nuclear reactions
- to explore a range of applications of nuclear processes and techniques in the modern world

Lectures Tuesday, Wednesday, Friday @ 10:00 - 11:20; *CLE B315*

Professor Dr B. D. Sawicka, barbara@uvic.ca; *Elliot 108*

You're welcome to stay for a chat after each lecture or come by during office hours.
Email for appointment at other times. Office hours: Wednesday 13-14

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.

Other recommended books (not compulsory, but helpful)
- K.S. Krane, *Introductory Nuclear Physics* (J. Wiley 1986) provides a comprehensive and detailed coverage of theory and experiment at 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 range of applications (thoroughly) in part 2.

Both books are @ UVic's Library, Reserve Section; helpful reading for some topics of the course.
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, C. Moses & C. Moyer (2005 or later), or S. Thornton & A. Rex (2006 or later). There are many books relevant to specific topics of this course; some are listed in *Useful Links* on the course website.

Course organization
The course shall cover material from 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 internet material relevant to this class, and some lectures shall have assigned web reading. Lecture notes intend to summarize and illustrate the material, and shall be available in pdf format on the course webpage. There will be several homework assignments on a weekly basis. There will be a research project on individually assigned/selected topics to be presented at the poster or oral session in the class. Tables of nuclear data and physical constants can be found in textbooks and on-line, see page *Useful links* for hints.

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.

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(s), research project, and the final exam. If you miss many classes the value of your final grade will be reduced by up to 10%.
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.
Grades shall 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 tests and exams.

All the course materials shall be posted on the course website

Good luck, work hard, and have fun