University of Maryland Department of Physics, College Park, MD 20742
Physics 441,Topics in Particle and Nuclear Physics, Fall 2017

Instructor: Prof. Thomas Cohen (I prefer to be addressed as Tom)
Office: 3158 Physical Science Complex
Phone: 301-405-6117
E-mail: cohen@physics.umd.edu

Course Information and Assignments
Problem sets and exam dates will be made available on the courses Canvas page.

Time and Place:
T-Th 2:00-3:15 2315 Atlantic Building

Office Hours
Official Office hours are from 3:15 Tuesday. I am also generally available in my office and happy to see students; just drop by--or, better yet, send me a email and then drop by.

Course Description
The course is intended as an introduction to various aspects of particle and nuclear physics with an emphasis on the role of symmetry.

There are many ways such a course could be taught ranging from purely qualitative descriptions of phenomena discussed in a historical manner to formal treatments in terms of quantum field theory or detailed analysis of experimental methods. Alternatively, one can emphasize experimental methods and results. The precise approach used here will be kept somewhat flexible and will depend in large part on students' backgrounds and interest. Currently the plan for the basic philosophy underlying the class is to introduce many of the fundamental ideas in nuclear and particle physics using relatively sophisticated mathematical tools---but to do so in as a simplified a context to explain the underlying ideas. Thus, for example the Higgs mechanism could be discussed in terms of an Abelian Higgs model. The goal is for students to develop an understanding of many the underlying issues in a relatively sophisticated way.

Tentative Course outline:

- The big picture
- Introduction to nuclear physics—a somewhat historical treatment
    - The discovery of radioactivity
        - α, β and γ radiation/distinction of strong, weak and electromagnetic interactions
    - Exponential decay; half-life

- Rutherford and the nucleus
- The prediction of the neutrino by Pauli

- Constituents of the nucleus/the discovery of the neutron
- Basic ideas of nuclear level and reactions
- The semi-empirical mass formula; short range nature of nuclear forces
  - Yukawa's idea of the meson
  - Electron scattering, form factors and nuclear sizes.
- Modeling the nucleus
- Current problems in nuclear physics

- Mathematical Tools
  - Relativity and four vectors
  - The Klein-Gordon and Dirac Equations; antiparticles
  - Quantum Field theory and Feynman Diagrams
    - QED
    - The Yukawa potential
    - Fermi Theory of weak interactions
  - Renormalization and renormalizability
  - Gauge theories; nonabelian gauge theories
- Symmetry & Symmetry Breaking
  - Symmetry in Quantum Mechanics and field theory
    - Continuous and Discrete Symmetries; Parity, time reversal
      - Discovery of parity violation
        - $\theta-\tau$ puzzle
        - Lee-Yang suggestion
        - Wu experiment
      - Discovery of time reversal violation
    - Isospin
  - Selection Rules; the Wigner-Eckert theorem (baby version); applications to hadronic and nuclear physics
  - Spontaneous symmetry breaking, Goldstone's theorem
    - Chiral symmetry, its breaking; pions
  - The Higgs Mechanism
  - Anomalies
- Towards the standard model of particle physics
  - Who ordered that? The discovery of the muon
  - Strangeness and SU(3) flavor
  - The quark model
    - Need for color
  - Deep inelastic scattering and the parton model
  - QCD and asymptotic freedom
  - Electro-weak unification
- Beyond the Standard Model/open problems

Reading

There is no textbook for the course. Lecture notes will be made available on Canvas/Elms

However, the following books may be useful to students as references:

- *Introduction to Nuclear and Particle Physics*, A. Das and T. Ferbel, ISBN-13: 978-9812387448 (This book is a survey written at the undergrad level and emphasizes experimental as well as theoretical physics and covers both nuclear and particle physics)

- *Introduction to Elementary Particles,* D. Griffiths, ISBN-13: 978-3527406012 (This book is very well written, it is at the undergrad level and covers particle physics.)

- *Foundations of Nuclear and Particle Physics,* T. W. Donnelly, J. A. Formaggio, B. R. Holstein, . R. G. Milner and B. Surrow ISBN-13: 978-0521765114 (This book is at a somewhat more advanced level. It emphasizes nuclear physics.)

  These books are all available on Amazon.com ; they will also be place on reserve in the engineering library.

Assignments and Grading Policies

▪ Problem sets: It is not possible to learn the material without working through problems. A list of problems will be given on the course Canvass site. Problems sets will be given from this list. However, the list will include extra, unassigned problems to give you a chance to work through extra problems.

- Problem sets will be assigned most weeks

- You are permitted—and strongly encouraged—to work with classmates on problem sets. However, simply copying a classmate's assignment is not permitted.

- Only a subset of the problems will be graded; solutions will be provided on the course wrb site.

  - Solutions may be correct solutions turned in by other students in the class (with the name removed). If you do not want your solutions used this way, indicate this on the assignment when you turn it in.

▪ Exams. It is currently planned that there will be one midterm take-home exam and a take-home final.

Because the exams are take-home, it is imperative that all of you live up to the highest standards of intellectual integrity. In this regard, it is worth noting that science depends on the intellectual integrity of those engaged in it. Science depends on trusting that other scientists are not cooking the data. By giving take-home exams, I am depending on you to live up to the ethical norms of the field.

- Paper. Students will be required to write a paper about some aspect of nuclear or particle physics.

  The paper should be 10-15 pages in length and deal with either a topic covered in the class by exploring it in more detail or a topic in contemporary nuclear or particle physics that was not covered in the class. The paper should be written with an appropriate level of sophistication. The paper will be due the last day of class

- Grading policies

  - Grades will NOT in general be given according to the scheme in which numerical scores greater than 90 corresponds to an A, between 80 and 90 a B etc. The reason for this is that assignments are of varying difficulty. Moreover, it is sometimes not clear even to the writer of an exam just how hard it is. Similarly the class will not be graded according to a rigid curve in which a predetermined fraction of students are given A's , B's etc. Rigid curves can lead to inequitable grade assignments. Instead, every attempt will be made to assign grades in a fair manner taking into account the actual difficulty of the exams.

  - The approximate weight of the various assignments is tentatively: hw 15%, paper 20%, midterm 30%, final 35%.