33-779 **Introduction to (Nuclear &)Particle Physics** Fall 2020

Syllabus

Instructor: Brian Quinn (bquinn@cmu.edu) Wean 8412 (412) 268-3523

Schedule: MWF 12:00-12:50 Doherty Hall 1212 and/or on zoom at:
https://cmu.zoom.us/j/97364125284?pwd=dW9PY3dic1Q0NHMxaHV4N3BrVzFiUT09
zoom meeting ID: 973 6412 5284 zoom passcode: 123456
Class follows the CMU calendar starting Aug. 31 and ending Dec. 11.
There will be no class on CMU no-class days: Sept. 7, Oct. 16 & 23, Nov. 25 & 27.
Class will be entirely on-line after the Nov. 25-29 Thanksgiving break.

Office hours: Tuesday 2.30-3.30 pm
https://cmu.zoom.us/j/95749310503?pwd=OENYajcvK2xvOVY1SE9qRkZtRXB1QT09
zoom meeting ID: 957 4931 0503 zoom passcode: 123456
or just contact me to set up a time to meet on zoom at other times.

Textbook: "Modern Particle Physics" by Mark Thomson,
1. Edition, Cambridge University Press, ISBN 978-1-107-03426-6.

Webpage: http://www.cmu.edu/canvas/ Please let me know if you do not have access to this web site!

Course Description and Goals

This course is the first semester of a two-semester sequence in particle physics at the graduate level. There are no strict prerequisites for this class but students are expected be familiar with electrodynamics and advanced non-relativistic quantum mechanics.

The course introduces and explores the standard model of particle physics suitable for second year graduate students who want to conduct research in particle physics but is also accessible for students who are just interested in the topic and do not plan to further study particle physics. The course mixes phenomenology with a basic description of the main theoretical and experimental tools and seeks to provide a solid foundation to understand the main concepts of particle physics. By the end of the semester, students will have been exposed to many of the basic concepts governing the standard model of particle physics and will be equipped with the tools needed to successfully start research in medium or high energy physics as well as take the second part of this course sequence.

The list of topics covered in this class is outlined in the course schedule below. By the conclusion of this course, students are expected to have gained the ability to understand the basic concepts of particle dynamics and interactions, and apply this knowledge to analyze Feynman diagrams, as well as apply particle physics phenomena such as electron-positron annihilation, electron-proton elastic scattering or deep inelastic scattering to recognize and understand actual measurements performed at particle accelerators and carry out elementary calculations of decay rates or cross sections.

Assignments

Homework problems will be assigned and collected by your instructor. The assignments will normally be handed out on Wednesday via Canvas and your solutions turned in the next Wednesday also via Canvas. Solutions to assigned problems will be posted on the Canvas.

You may discuss the material covered in class and general methods to solve problems with other students. However, you are expected to work the assigned problems by yourself and the actual solutions should be yours alone! If you need some help in solving homework problems, contact me.

Exams

There will be at least one, possibly two, in-term exam(s) during the semester plus a final exam. The exams are closed-book exams, but you are allowed to use one page (front and back) of self-prepared notes. We will try to arrange exams to be 'proctored' via zoom, which will permit you to ask questions during the exam.

Grades

50% of your final grade will be based upon the exams (20% for the in-class exam(s) and 30% for the final exam), while the remaining 50% come from the homework assignments. An overall curve will be established from the distribution of final grades, but you should expect to receive an A if your overall score is 88% or above, at least a B if your score is 75% or above, at least a C if your score is 63% or above, and at least a D if your score is 50% or above.

Covid-19 Considerations

Because of the pandemic, the course is being offered simultaneously on zoom and in-class. If you choose to attend some or all lectures remotely, you are encouraged to attend the on-line session in real time so you have the option of making comments or asking questions. However, the zoom sessions will be recorded and made available on Canvas particularly to accommodate those who may be in different time-zones. You can also take advantage of this to re-play anything you may have missed. (Note: By law, these recodings may only be shared by students in the class.)

My present understanding is that Pitt students are only permitted to attend remotely. I regret that, but I think most Pitt students were planning remote attendance, anyway.

Students attending in-person are expected to maintain social distancing, to use only indicated seats and not move furniture, and to wear an appropriate protective mask throughout the lecture. For my safety and yours, I will also wear a mask while teaching in-class lectures. For in-class students, I expect to project onto a screen what is being seen by students on zoom. In-class students are welcome to also joint the class via zoom, if they wish, but should be sure to mute microphone and speakers to prevent acoustic feedback.

CMU plans to change to all-remote teaching after the Thanksgiving break. In addition we may have to change to remote teaching if Doherty Hall is closed due to Covid exposure or if conditions make it temporarily unsafe to continue in-class lectures. If it is not possible to have an in-class lecture, you should assume the lecture will go on as scheduled but will be held via zoom.

Course Schedule

The estimated course schedule with suggested readings from the textbook is given below.

- History and Introduction
  - Units - p30-33
  - Quick overview of particle physics and standard model - Notes & p1-12
  - Interaction of particles and matter - Notes & p13-22
  - Particle detectors and experimental techniques - Notes & p13-22
  - Brief history of nuclear/particle - Notes

- Special Relativity - p33-40
  - Boosts, 4-vectors and invariants
  - 4-momentum, 4-derivative, summation notation
  - Mandelstam variables

- Review of Non-Relativistic Q.M. - p40-54
  - Review of prob. current, rate of change, compatible observables, orb. ang. mom.
  - Fermi's golden rule

- Intro to nuclear physics - Notes
  - Semi-empirical mass law and curve of binding energy
  - Collective excitations and liquid drop model
  - Shell model, magic numbers, single-particle excitations, isospin

- Relativistic form of Fermi's golden rule - p58-77
  - Lorentz-invariant phase space
  - Decay rates and cross sections
  - Lorentz-invariant flux
  - Differential cross section

- Relativistic Q.M. - p80-110
  - Klein-Gordon equation and solutions
  - Dirac spinors, spin, γ-matrices, covariant current
  - Antiparticles, charge-conjugation, helicity, parity

- Feynman diagrams and QED - p114-126 & notes
  - Time-ordered perturbation theory
  - Feynman diagrams
  - Introduction to QED
  - Feynman rules for QED

- Example calculations in perturbation theory - p128-152
  - Basic calculations in perturbation theory
  - Spin, chirality
  - Trace techniques ?? (May skip)

- Electron-Proton Elastic Scattering - p160-176 & notes
  - Rutherford and Mott scattering
  - Form factors (Dirac and Pauli, relation to Sachs)

- Rosenbluth separation, the dipole and scaling approximations
- Importance of higher-order effects (two-photon exchange ?)

- Deep Inelastic Lepton Scattering - p173-202
  - Kinematics
  - Deep inelastic scattering and scaling
  - Electron-quark scattering
  - The quark-parton model and parton distributions

A Final Word

Take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is almost always helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at http://www.cmu.edu/counseling/. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

If you have questions about this or your course work, please let me know.