Introduction to Nuclear and Particle Physics (33444)

"Not only God knows, I know, and by the end of the semester, you will know."
-Sidney Coleman

Course Description: This course is an introduction to elementary particle physics, the description of Nature at the shortest distance scales. This class will emphasize the theoretical underpinnings of the Standard Model of particle physics and its experimental verification. The first part of the course will focus on the implications of combining Quantum Mechanics and Special Relativity. This union turns out to incredibly restrict the types of theories and particle interactions allowed. In the second part of the course we will focus on the experimental methods for measuring elementary particle interactions and highlight the structure of the Standard Model. With this introduction, we will survey various areas of active research including: the study of the Higgs boson, neutrino mixing, and the need for physics beyond the Standard Model. In this later part, emphasis will be placed on what we do and do not know now and what we might know in 20 years.

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Prerequisites: Intermediate Electricity and Magnetism I (33338)
Quantum Physics (33234)

Lectures: Wean Hall 5312
Monday, Wednesday, Friday, 3:35-4:25 pm

Remote Connection: Zoom Link
Passcode: 000000
Meeting ID: 966 6638 7337

Office Hours: Thursdays 2-3 pm or by appointment.

References: The material for this course will be largely based on my notes, which I will make available on the course webpage.

The course textbook is: Andrew Larkoski, "Elementary Particle Physics: An Intuitive Introduction", Cambridge, 2019, and will be used for some background reading and assignments.

It is often helpful in this subject to get other points of view. I have found the following books useful.

Matthew Schwartz, "Quantum Field Theory and the Standard Model", Cambridge, 2014.
A modern QFT and particle physics textbook for undergraduates.

Brian Martin and Graham Shaw, "Particle Physics", 4th Edition , Wiley, 2017.
A modern particle physics textbook for undergraduates.

David Griffiths, "Introduction to Elementary Particles", Wiley, 2008.
An elementary introduction from a more historical perspective.

Course Website: https://canvas.cmu.edu/courses/28085

Course Requirements: There will be three graded aspects of this course: ∼weekly homework problems and two in-class exams. In calculating your final grade, your lowest homework score will be dropped. Homework will develop methods discussed in lecture or flesh out sketches of arguments and unproven claims made in class. Late homework can not be accepted.

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Grading: The amounts to which the homework, mid-term and final exam contributes to your grade are:

Homework	33%
Mid-term Exams	33%
Final Exam	33%

Homework Collaboration Policy: Speak to each other! You often learn just as effectively through discussion with your peers as you do from lecture. However, all homework you submit should be written individually and independently by you. When it comes to discussing homework, any records of the discussion must be destroyed before you make any kind of write-up. If you have collaborated with anyone then you should declare who you worked with and the nature of your discussion. *(Think citation for a publication)* You will not be penalized for declared homework collaboration. Undeclared collaboration is plagiarism and is considered cheating. All the work you submit should be your own work and reflect your understanding.

Homework Philosophy: Homework intended to

- Fill in claims/sketches of arguments that I make in class.
- Reiterate concepts discussed in class.
- Introduce/exercise “straight-forward” concepts from your reading.
- Set the stage for future topics.
- “Fun facts”: ideas/calculations that are interesting (or historically important) that you can now understand.

Preliminary Schedule: The following is a rough outline of topics we will discuss each week. This is a work in progress and will change as the semester goes on.

Week 1	Big picture / Correct way to think about the world	Jan -/19/21	Ch 1
Week 2	Relativity Refresher / Symmetries / Lie Algebras	Jan 24/26/28	2.1/3.1/3.2
Week 3	Quantum Refresher	Jan/Feb 31/2/4	N/A
Week 4	Particles / QM + Relativity	Feb 7/9/11	N/A
Week 5	Lagrangians / Relativistic Eq of Motion	Feb 14/16/18	2.2
Week 6	Feynman diagrams Soft-photon/Soft-gluon theorems	Feb 21/23/25	Ch 4
Week 8	The Standard model / Mid-Term	Feb/Mar 28/2/-	N/A
Week 9	Spring Break	Mar -/-/-	-
Week 10	Collider Physics Intro	Mar 14/16/18	Ch 5
Week 11	Collider Physics Details	Mar 21/23/25	Ch 5
Week 12	Weak Interaction	Mar/Apr 28/30/1	N/A
Week 13	Electro-weak Unification	Apr 4/6/-	N/A
Week 14	Neutrinos / MidTerm	Apr 11/13/15	N/A
Week 15	Neutrinos	Apr 18/20/22	N/A
Week 16	Scales in Nature / SM breakdown	Apr 25/27/29	N/A