Physics 5522 Syllabus Spring 2025

INSTRUCTOR

Professor Evelyn Thomson

EMAIL

thomsone@upenn.edu

CLASS HOURS

MW 12:00-1:30pm

DRL room TBD

OFFICE LOCATION

DRL 4N16b

OFFICE HOURS

TBD

COURSE OVERVIEW

Introduction to experimental particle physics. Review of special relativity for energy thresholds for reactions and for kinematics of particle decays. Properties of particles and their interactions with matter. Detector design and reconstruction techniques to measure particle momentum, energy, and type. Dirac equation and QED. Proton structure and QCD. Weak interaction and parity violation. Electroweak physics. Top quark physics. Discovery and measurements of the properties of the Higgs boson. Searches for supersymmetry and dark matter at colliders. Measurements of neutrino oscillations and more searches for dark matter. Design and goals of future experiments. Statistical interpretation of data will be highlighted throughout.

REQUIRED TEXT

"Modern Particle Physics", *Mark Thomson*
Classic papers (links will be provided through Canvas and Penn libraries)

RESOURCES

Additional reading for graduate students "Quarks and Leptons", Francis Halzen and Alan Martin
Additional reading for undergraduates "Introduction to Elementary Particles", David Griffiths
Light reading for general background for all "The Hunting of the Quark", Michael Riordan

COURSE SCHEDULE

The goal of the class is to provide a solid foundation in experimental particle physics to graduate students and senior undergraduates. The class meets for 90 minutes on Mondays and Wednesdays. Usually, the first 60 minutes will be on material for the topic of the week. For Monday classes, the final 30 minutes will be dedicated to the particle of the week. For Wednesday classes, the final 30 minutes will be dedicated to the detector of the week. Exceptions are the first two weeks of the semester, when the University schedule means that our class only meets once per week, and the weeks with a discussion section on Wednesday.

If you have not studied special relativity at the level of PHYS 1230 and the textbook "Special Relativity" by T.M. Helliwell before, then please contact me before the semester begins. I have taught special relativity in PHYS 1230 several times and can provide materials to bring you up to speed. You are expected to already know about special relativity for this class. Our class will review special relativity in the first class for the effects of time dilation and utility of invariant mass in calculations of thresholds for reactions and of kinematics of particle decays.

There will be several experimental particle physics seminars on Wednesdays from 3:30pm that are optional for undergraduates and strongly recommended for graduate students. The schedule for those seminars is kept up-to-date on the department events website and will be advertised in class.

WEEK	SUBJECT (CHAPTER)	PARTICLE OF THE WEEK	DETECTOR OF THE WEEK
Jan 15	Special relativity review (1, 2)	-	Only 1 class on Wed this week
Jan 20	Passage of charged radiation through matter	-	Only 1 class on Wed this week too
Jan 27	Decay rates and cross sections (3)	Electron/Positron/Photon	Electromagnetic Calorimeters
Feb 3	Dirac equation and QED (4, 5, 6)	Muon	Discussion 1
Feb 10	Proton structure and quarks (7, 8, 9)	Gluons and protons and neutrons	Hadron Calorimeters
Feb 17	QCD (10)	Pions	Tracking detectors
Feb 24	Weak interaction & Parity violation (11, 12)	Kaons	Discussion 2
Mar 3	CKM matrix (14)	J/psi and upsilon	b-jet identification algorithms
Mar 10	Spring Break		
Mar 17	Electroweak Physics (15, 16)	W boson	Jet reconstruction algorithms
Mar 24	Higgs boson (17)	Z boson	Water Cherenkov detectors
Mar 31	Supersymmetry searches	Top quark	Discussion 3
Apr 7	Neutrinos Solar and Atmospheric (13)	Vector-like fermions*	Liquid Argon TPCs
Apr 14	Neutrinos Long Baseline (13)	Axion*	Class choice of topic
Apr 21	Dark matter searches	Class choice of topic	Discussion 4
Apr 28	Final paper presentations by students		

ASSIGNMENT SCHEDULE

DUE DATE (WED)	ASSIGNMENT	CHAPTER IN MODERN PHYSICS
Jan 29	Homework 1	1, 2, 3
Feb 5	Discussion 1 on classic papers (Particle discoveries)	
Feb 12	Homework 2	4, 5, 6
Feb 19	Homework 3	7, 8, 9
Feb 26	Discussion 2 on classic papers (Detectors)	
Mar 5	Homework 4	10, 11, 12
Mar 12	Spring break	
Mar 19	Homework 5	14
Mar 26	Homework 6	15, 16
Apr 2	Discussion 3 on classic papers (Electroweak, Top, Higgs)	
Apr 9	Homework 7	17
Apr 16	Homework 8	13
Apr 23	Discussion 4 on classic papers (Neutrinos)	

EXAM SCHEDULE

DATE	TYPE
Friday April 25 2025 11:59pm	Submit paper on topic of your choice (5-6 pages)
Fri May 9 2025 11:59pm	Take-home final exam (available from Mon May 5)

ASSIGNMENT POLICY

All assignments will be posted on the Canvas site for this class. For each of the 8 homework assignments, your solutions are required to be uploaded to Canvas for 2 of the assigned questions by the due date at 11:59 PM Wednesdays. Students are encouraged to work together to solve homework assignments, please do include the names of students you worked with on your homework submissions. Homework will be graded, and the lowest assignment will be dropped. Solutions will be posted shortly after the due date so please inform me if you need an extension…

For each of the 4 discussion assignments, each group of students will be assigned a different classic paper to read. Each group should read this paper, meet to discuss the paper, and prepare a presentation with up to 5 slides about the paper. The presentation should be about 5 minutes followed by 5 minutes discussion. The presentations will take place in the last 30 minutes of the Wednesday class and replace the detector of the week segment. The goals of this discussion assignment are (1) to develop your reading skills for papers in the field, (2) to develop your discussion skills in your small group and in the larger class, (3) to develop your presentation skills, and (4) for the rest of us to benefit from your group's explanation of the paper, what your group learned from it, and what questions your group has about it. Small group roles (presenter, authors, reviewers) will rotate for each of the 4 assignments so that the load is evenly shared across the semester. A working document will be provided to guide your group in the development of the presentation (attached here). In brief, the presentation should have 5 slides following this general outline:

- information about the topic (up to 3 slides)
- information about the most important things *your group* learned from reading the paper (1 slide)
- three questions *your group* has about the paper to promote discussion after the presentation (1 slide)

ADDITIONAL INFORMATION

Grading scheme:

30% Homework assignments (2 questions from each required to be submitted on Canvas, drop lowest)

30% Discussion assignments (small groups of 4 students, 5 minutes + 5 minutes discussion)

25% Take-home final exam available May 5, due by Friday May 9 11:59pm

15% Paper of 5-6 pages (not including references) on a particle physics topic of your choice, due Friday April 25 2025 11:59pm, and presentation in last week of classes

- Meet with Professor Thomson to discuss your choice of topic in second half of February 2025 (3%)
- Share first draft with Professor Thomson by April 16 2025 11:59pm (3%)
- Upload final draft to Canvas by Friday April 25 2025 11:59pm (6%)
- In-class presentation during last week of classes on April 28 or April 30 2025 (10 minutes + 5 minutes discussion) (3%)

PHYS 5522 DISCUSSION ASSIGNMENT #1

Project Name:	Classic papers: particle discoveries
Due Date:	Wednesday February 5 2025

This is the tracking document for the discussion assignment. Please keep it up to date! Roles of authors and reviewers should rotate through the four assignments to balance the load.

- Authors and reviewers should:
  - read the paper
  - meet to discuss what the group learned and to formulate 3 questions
- Authors should:
  - write a draft of the slides and share the draft with reviewers
  - incorporate comments from reviewers
  - rehearse a 5 minute in-class presentation (recommended)
  - upload the final version of the slides to Canvas
  - one of the authors should give a 5-minute in-class presentation [Presenter]
- Reviewers should:
  - provide comments on a draft of the slides
  - provide comments on rehearsal of presentation (recommended)

PARTICIPANTS

Name	*Role*	*Contact information*
Marie Curie	Author & Presenter	Enter contact information
Albert Einstein	Author	Enter contact information
Max Planck	Reviewer	Enter contact information
Lise Meitner	Reviewer	Enter contact information

MILESTONES

Milestone	*Target date*	*Status*
All: First pass reading of paper completed	Wed Jan 29	Enter status
Authors: Draft of 3 slides sent to reviewers	Wed Jan 29	Enter status
All: Discussed what group learned & 3 questions	Fri Jan 31	Enter status
Authors: Draft of 5 Slides sent to reviewers	Fri Jan 31	Enter status
Reviewers: Comments sent back to authors	Mon Feb 3	Enter status
Authors: Reviewer notes incorporated	Tues Feb 4	Enter status
All: Presentation rehearsed	Tues Feb 4	Enter status
Authors: Slides uploaded to Canvas	Wed Feb 5	Enter status

PROJECT RESOURCES

Add a link for the Canvas page for your group.
Add a link to a meeting room on Zoom for your group.
Add a link to shared resources (eg Google Drive or PennBox) with drafts of your slides and notes on the paper.