Syllabus for PHY493/803, Spring 2025
Introduction to Elementary Particle Physics

Instructor: Sophie Berkman
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Class: Monday, Wednesday, Friday: 03:00 PM - 03:50 PM
Office hours: Preliminarily: Fridays 4-5pm (or by appointment)
Classroom: BPS 1415

Course Summary:

This course is an introduction to elementary particle physics for advanced undergraduate students. The course is taught from the phenomenological and experimental perspectives, covering details of the underlying theory and the experimental techniques. We will discuss the physics of quarks, leptons and gauge bosons, including the weak, electromagnetic and strong forces. In addition, the course will include a focus on experimental techniques, particle accelerators and modern experimental measurements. The mathematical rigor will be minimal, but students should have a background in quantum mechanics and special relativity.

Required Textbook:

"*Introduction to Elementary Particles*" (Second Edition) D. Griffiths, Wiley-VCH
ISBN: 978-3-527-83463-1

Recommended References:

- For those who will go on to study particle physics:
  "*Particle Physics*" (Third Edition) B.R. Martin & G. Shaw, WILEY; ISBN 978-0-470-03294-7

- Classic & concise book on special and general relativity:
  "*Theory of Relativity*" (Third Edition) W. Pauli, Dover; ISBN: 978-0-486-64152-2

- Convenient & free summary of particle physics measurements and reviews of methods:
  "*Review of Particle Physics*", Particle Data Group
  - Print, read, or order for free at http://pdg.lbl.gov

Reading Assignments, Homework, Quizzes and Exams:

There is a reading assignment listed in the Course Schedule that is associated with each lecture. There are suggested chapters from the books listed above. Reading is not mandatory, but the homework, in-class quizzes, and exams will be based heavily on the reading and not all the material on the homework, quizzes and exams will be covered in class. It is the student's responsibility to be well versed in the assigned reading material.

There will be 7 homework assignments. The homework will be collected at the beginning of class and the **due dates are indicated in the Course Schedule**. Homework handed in late will only be graded in approved circumstances. Questions about homework grading must be brought to the attention of the

grader within one week after the homework is returned. No adjustments will be made after one week has elapsed. Disputes about the homework grading will be addressed first by the grader, with any unresolvable issues handled by Prof. Berkman. If you have a documentable reason for not finishing the homework on time (e.g., extended illness) you must contact Prof. Berkman immediately to request an extension. Extension of more than one homework assignment is in general not permitted and will only be considered in extreme circumstances.

There will be in-class quizzes (*OPEN book and notes*), that will be administered on a roughly weekly basis. These quizzes will be 10-15 min in duration and will be based on the recommended reading for each class period (which is outlined in the Course Schedule) and on any material covered before that week. There are no make-ups for the in-class quizzes. If you miss several quizzes due to a documentable reason, your quiz grade will be assigned as the average of the remaining quizzes. This will only be done in extreme circumstances.

Two, 50-minute midterm exams (*CLOSED book and notes*) will be given on February 21 (Fri) and April 2 (Weds) (**see the Course Schedule**). The exams will be based on quiz questions, homework, readings, and material presented in the lectures. **There is no final exam**. You may miss one exam due to a properly documented medical emergency. Make-up exams are not guaranteed and it will be determined on a case-by-case basis how to assign a grade for any missed exam. Missing both exams will result in a score of zero points for the relevant exams, and exceptions will be considered only in extreme circumstances. In any event that you will miss an exam with a legitimate excuse, you should inform Prof. Berkman by email in advance.

This class has a strict ban on cellular phones during class and exams. Students who are found to have a cellular phone in their possession for any reason during an exam will receive a score of zero for that assignment. Students are advised to store their cellular phones in the off position in their bags for the duration of the class session.

Please note: Senior physics majors may be visiting and selecting graduate schools during the spring semester. If you are going to miss classes due to these travels please communicate this with Prof. Berkman as soon as possible in advance. Students will not be penalized in their grade for visiting graduate schools if acceptable documentation of travel dates is provided.

Tier II Writing Assignment (PHY 493):

Physics 493 is intended to fulfill the Tier II writing requirement for physics majors. Therefore, a term paper is assigned. There are two options for your paper, which are described in more detail below: (1) a review of an important measurement or (2) an original proposal to improve an existing experimental measurement or theoretical technique. The paper should include necessary equations, figures, and a full list of citations. It will be graded on style and grammar as well as physics content and presentation of the material. **The grading rubric to be used is included on page 7 of the syllabus.** The paper should be on a topic from particle physics, at the content level of a Scientific American article, scientifically literate but not too technical. The paper must be original work. Plagiarism is strictly forbidden and is considered a violation of academic honestly.

The first step is to choose a topic for your paper. The topic should be narrow enough so that you can focus on the salient material in the paper length limits. For example, you should not embark on presenting the history of particle physics. If you already have a topic of interest for you in particle physics, you may ask for it to be approved. A list of possible topics is provided on page 6 of the syllabus. Other possible sources of topics include: the textbooks, research seminars, Annual Review of Particle Physics, etc.

Students who choose to write a review of a measurement or theoretical concept should produce a paper 10-12 pages in length. The paper should include an introduction of the topic and a summary of the historical context in which the concept was developed, or the measurement was made (e.g. the state of particle physics at the time of the discovery of the muon). The paper should discuss the importance of the topic and how it applies to our modern understanding of the relevant field. If the topic involves experimental measurements, the paper should include a discussion of the existing measurements and their uncertainties.

Students who choose to write a proposal to improve an existing measurement should produce a paper 6-8 pages in length. The paper should be in the style of a proposal to a funding agency, wherein the motivation for the improved measurement should be clearly defined. The format should be a description of the related physics, a review of the existing measurements, the proposal for the new measurement and a description of the impact of the improved measurement on our understanding of the relevant physics topic. At least one page must be devoted to a description of the costs associated with the improved measurement (i.e. the funds which need to be awarded to perform the measurement). This estimate of the costs should be based on a thoroughly researched and documented concept (i.e., it should attempt to be realistic and not imaginary or a "guess"). For example, if you use a number to support costs, you should reference it.

The paper milestones are listed below in the Course Schedule. Your topic choice must be submitted to Prof. Berkman by February 14 and an outline must be handed in by February 28. **If you would like feedback on your first draft (this is optional)** it must be submitted by March 28. To earn credit for your first draft it must be submitted by April 11. The final paper is due April 25. The paper format should be 1-inch margins, 12 pt. font and double-spaced lines. Single-spacing and smaller fonts can be utilized when it makes sense to do so or improves readability (e.g., figure captions, tables, lists, etc.).

Paper Review

As a part of the class you will be reviewing a sample paper. The review should be in the style of a journal review and address physics motivation and content, clarity, appropriateness of description (1/2 to 1 page total), and grammar and textual comments. Guidelines for the paper review will be distributed during the semester.

PHY 803 Students

Students enrolled in PHY 803 are required to have additional course breadth to quality for graduate-level credit. This will be achieved in two parts. First, PHY 803 students will have one additional problem for each homework assignment and each exam.

Second, students enrolled in PHY 803 are not required to complete the Tier-II writing requirement. In lieu of the paper students will write an original synopsis of a research paper in particle physics. Specifically, students will choose a paper of at least 20 pages from an approved, peer-reviewed physics journal and summarize the work in a short, letter-format paper of 5-7 pages. This exercise will serve to solidify student's scientific writing skills and awareness of salient aspects in the communication of physics results via publications. Approved journals are Physical Review D (prd.aps.org), Physics Letters B (http://www.journals.elsevier.com/physics-letters-b/) or the Journal of High Energy Physics (http://www.springer.com/physics/particle+and+nuclear+physics/journal/13130). Examples of short, letter-format papers can be found in Physics Review Letters (prl.aps.org).
The paper milestones are listed below in the Course Schedule. Your topic choice must be submitted to Prof. Berkman by February 14 and an outline must be handed in by February 28. **If you would like**

feedback on your first draft (this is optional) it must be submitted by March 28. To earn credit for your first draft it must be submitted by April 11. The final paper is due April 25.

Grading Policy

Your grade will be determined based on your scores on the two exams, your homework, the in-class quizzes and your term paper. A full score for the homework will be based on 90% of the total points, wherein a score of 90% will receive full points and scores below 90% will be prorated accordingly. In the same fashion, the in-class quiz scores will be based on 80% of the total quiz points (allowing for intermittent absences from class). The exams will be graded on a curve determined by the class average. Final grade assignments will be determined based on the mean score in the course after adjusting for corrections and/or documented student absences. Each of the intermediate paper stages: topic selection, outline, and first draft, are worth 1% of the your paper grade (3% total); if one milestone is missed the maximum grade for your final paper will be 14%, etc.

The cumulative grade will be calculated as follows:

Midterm Exams:	30% (15% first midterm + 15% second midterm)
Homework:	30%
Quizzes:	15%
Paper:	15% (12% final paper + 1% topic + 1% outline + 1% draft)
Review Assignment:	10%

Grader

The TA for PHY493/803 for Spring 2025 is Alejandro Salas. His email address is salasale@msu.edu. Questions about grading and requests for meetings should be first communicated with Alejandro via email with Prof. Berkman copied on the email. Alejandro will not have fixed office hours, but students can schedule in-person meeting times as needed.

PHY 493/803 Schedule, Spring 2025

W	D	Date	Subjects Covered	Reading	HW Due	Paper Milestone
1	M	1/13	Introduction	Griffiths, Ch1		
	W	1/15	Particles			
	F	1/17				
2	M	**1/20**	**MLK Day: No class!**			
	W	1/22	Particle Dynamics	Griffiths, Ch2		
	F	1/24				
3	M	1/27	Relativity	Griffiths, Ch3	#1	
	W	1/29				
	F	1/31				
4	M	2/3	Symmetries	Griffiths, Ch4		
	W	2/5				

	F	2/7				
5	M	2/10	Bound States	Griffiths, Ch5	#2	
	W	2/12	Feynman Rules	Griffiths, Ch6		
	F	2/14				Select Topic
6	M	2/17				
	W	2/19	Particle Accelerators	PDG Review, Ch 29		
	F	2/21	Exam #1			
7	M	2/24			#3	
	W	2/26				
	F	2/28	Particle Interactions with Matter	PDG Review, Ch 32		Outline Due
8		3/2-3/9	**Spring Break: No Class!**			
9	M	3/10				
	W	3/12	Particle Detectors	PDG Review, Ch 33 & 34		
	F	3/14				
10	M	3/17	Modern HEP Experiments		#4	
	W	3/19	QED	Griffiths, Ch 7		
	F	3/21				
11	M	3/24				
	W	3/26	Quark Dynamics	Griffiths, Ch8		
	F	3/28				First Draft Due for feedback **(optional)**
12	M	3/31				
	W	4/2	Exam #2			
	F	4/4	Weak Interactions	Griffiths, Ch9		
13	M	4/7			#5	
	W	4/9				
	F	4/11	Gauge Theories	Griffiths, Ch 10		First Draft Due for credit
14	M	4/14	Neutrinos	Griffiths, Ch11		
	W	4/16			#6	
	F	4/18				Review Due
15	M	4/21	The Future!	Griffiths, Ch12		
	W	4/23				
	F	4/25			#7	Final Draft Due
16		4/28-5/2	**No Final Exam!**			

Example Research Paper Topics (PHY 493):

1. Strong CP violation, axions
2. Dark matter and/or dark energy
3. New detector developments
4. Future accelerators and accelerator technology
5. Linear colliders
6. Neutrino-less double beta decay
7. The discovery of the bottom/top/strange/charm quark
8. The discovery of the positron
9. The discovery of the Higgs boson
10. The discovery of beta decay
11. The discovery of electroweak gauge bosons
12. The discovery of the neutrino
13. The observation of neutrinos from supernova 1987a
14. Neutrino masses and neutrino oscillations
15. Neutrino mixing measurements
16. The "solar neutrino puzzle" and its impact on understanding neutrino oscillations
17. Measurements of the strong coupling constant
18. Tests of parity violation in atomic systems
19. The quark-gluon plasma
20. The search for proton decay
21. The discovery of parity violating weak charged and neutral current interactions
22. The discovery of time reversal violation and CP violation in neutral kaon systems
23. The discovery of the J/Y vector particle and its impact on the quark model
24. Is the neutrino a Majorana particle?
25. Is the Higgs boson responsible for mass generation?

Grading Rubric for the Final Paper

PHY493, Spring 2025
Paper Grading Form

Name:

Paper Format & Length: 20 pts

Spelling & Gramar: 10 pts

Overall Writing Style: 10 pts

Physics Content & Understanding: 50 pts

- Originality: 10 pts
- Demonstration of Physics Understanding: 15 pts
- Explanation of Physics Concepts: 15 pts
- Clarity and Organization of Material: 10 pts

Citations & Accuracy: 10 pts

Total: _____ / 100 pts