PHY771: High Energy Particle Physics

Fall 2024

Course details

- **Instructor:** Professor Steve Blusk
- **Office:** 327 Physics Building
- **Email:** sblusk@syr.edu
- **Meeting times/location:** Mon & Wed, 2:15 – 3:35. Rm 208 Physics
- **Office Hours:** Monday 3:45 – 5:00 pm (tentative)

Course Description: This course will provide a comprehensive introduction to the Standard Model of Particle Physics. The course will give a historical account of the important discoveries throughout the 20th century, leading to our current best theory of fundamental particles and the interactions between them.

Pre-requisites: It is expected that you have a good understanding of quantum mechanics, electricity and magnetism, special relativity, and to some extent classical mechanics. Strong mathematical skills are also important, most notably in calculus, matrix algebra, complex variables, and to some extent differential equations. PHY662, or equivalent.

Primary Textbook: David Griffiths "Introduction to Elementary Particles", 2nd Ed, ISBN:978-3-527-40601-2.

There are numerous good books in particle physics. Some books do some things better than others, or have greater (or less) depth. Some other references of interest (non-exhaustive) include

- *A. Bettini, “Introduction to Elementary Particle Physics”, 2nd Ed.
- F. Halzen and A. Martin, “Quarks and Leptons: An Introductory course in Modern Particle Physics” (A classic)
- D. Perkins, “Introduction to High Energy Physics”, 4th Ed. (another classic text)
- M. Peskin, “Concepts of Elementary Particle Physics”.
- * W. Cottingham and D. Greenwood, “An Introduction to the Standard Model of Particle Physics”
- * R. Mann, “An Introduction to Particle Physics and the Standard Model”, 2010.
- D. Horvath and A. Zoltan, “Introduction to Particle Physics”. Nice sections on Experimental Methodology in Part II, and Basic Experiments (Part III)
- P. Renton, “Electroweak Interactions: An introduction to the Physics of Quarks and Leptons”.
- I. J. R. Aitchison and A.J.G. Hey, “Gauge Theories in Particle Physics”, 1989.

* Available digitally through library.syr.edu, typically requires Adobe Digital Editions software.

Homework: Will be assigned regularly during the class. There may be assignments due each class period.

Exams: There will be one midterm exam.

Course grades are determined by

- Attendance: 5%
- Participation: 5%
- Homeworks: 50%
- Midterm Exam: 20%
- Final presentation: 20%

- **Attendance is mandatory**. The attendance grade is formed as follows.
  - ≤1 class missed □ 5 points
  - Beyond 1 missed class, for every class you miss, 1 point is subtracted from the 5 points.
  - Excused absences do not count toward the allowed missed class, and include: medical emergency, COVID, required travel, or other extenuating circumstances. The instructor should be notified in advance whenever possible.

- **Participation:** Students are expected to actively participate by asking questions, and answering questions posed in class by the instructor or other students. There will also be times when you may be asked to present a HW solution to the class. All together, these contributions are 5% of your grade.

- **Homeworks are to be handed in on time.** Late homeworks will only be accepted when the instructor has been contacted at least 1 day in advance, and the extension has been agreed to. Usually this will be a 1-day extension, unless extenuating circumstances dictate that extra time is needed. Extensions are for extenuating circumstances, and should not be a weekly occurrence.

- **Final presentation**: The final presentation will be a 30 minute presentation on a topic in particle physics that has not been covered in the course. This could include more advanced phenomenology in particle physics, or a talk that highlights experimental results. Experimental results should make connection to the underlying theory that is being tested. Slides should be concise and clear. You will be graded on the clarity, level of depth and your ability to answer questions related to your presentation. You are free to propose your own topic, but some example topics could be:
  - **Experimental-style talks**
    - B^0 and B_s mixing phenomenology
    - CP Violation in B decays
    - Unitarity Triangle and measurement of the sides of the UT
    - Unitarity Triangle and measurement of the angles of the UT
    - Flavor anomalies in b physics
    - Historical overview of neutrinos and neutrino mixing
    - Pentaquarks or Tetraquarks
    - Measurements of properties of the top quark: mass, cross-sections, etc,
    - Mu2e conversion or μ □e γ
    - Parton distribution functions, what are they and how are they probed?
  - **Phenomenology-style talks**
    - Majorana neutrinos, see-saw mechanism

- Heavy Quark Expansion and b-hadron lifetimes
- Effective field theory & Wilson coefficients
- Axions
- Supersymmetry
- Extra dimensions

Topics to be covered (tentative)

Class #	Day	Chapter(s) in Griffiths	Topics
1	8/26	Ch 1	Historical tour of particle physics, Part 1
2	8/28	Ch 1	Historical tour of particle physics, Part 2
	9/2	Ch 1	No classes
3	9/4	Ch 1	Historical tour of particle physics, Part 3
4	9/9	Ch 1	Historical tour of particle physics, Part 4
5	9/11	Ch 1	Historical tour of particle physics, Part 5
6	9/16	Ch 2	Elementary Particle Dynamics
7	9/18	Ch 3	Relativistic Kinematics
8	9/23	Ch 4	Symmetries I
9	9/25	Ch 4	Symmetries II
10	9/30		Feynman diagrams
11	10/2	Ch 5	Bound States
12	10/7	Ch 6	Feynman Calculus
13	10/9	Ch 6-7	Quantum Electrodynamics
14	10/14	Ch 7	Quantum Electrodynamics
15	10/16	Ch 7	Quantum Electrodynamics
16	10/21	Ch 8	Electrodynamics and Quantum Chromodynamics of Quarks
17	**10/23**		**Midterm Exam**
18	10/28	Ch 9	Weak Interactions
19	10/30	Ch 9	Weak Interactions
20	11/4	Ch 9	Weak Interactions
21	11/6	Ch 10	Gauge Theories
22	11/11	Ch 10	Gauge Theories
23	11/13	Ch 10	Gauge Theories
	11/18		Thanksgiving Break, No Classes
	11/20		Thanksgiving Break, No Classes
24	11/25	Ch 11	Neutrinos
25	11/27		Advanced topics I
26	12/2		Advanced topics II
27	12/4		Student Presentations
28	12/9		Student presentations
	TBA		Student presentations

Academic Integrity Statement

Syracuse University's Academic Integrity Policy reflects the high value that we, as a university community, place on honesty in academic work. The policy holds students accountable for the integrity of all work they submit and for upholding course-specific, as well as university-wide, academic integrity expectations. The policy governs citation and use of sources, the integrity of work submitted in exams and assignments, and truthfulness in all academic matters, including course attendance and participation. The policy also prohibits students from: 1) submitting the same work in more than one class without receiving advance written authorization from both instructors and, 2) using websites that charge fees or require uploading of course materials to obtain exam solutions or assignments completed by others and presenting the work as their own. Under the policy, instructors who seek to penalize a student for a suspected violation must first report the violation to the Center for Learning and Student Success (CLASS). Students may not drop or withdraw from courses in which they face a suspected violation. Instructors must wait to assign a final course grade until a suspected violation is reviewed and upheld or overturned. Upholding Academic Integrity includes abiding by instructors' individual course expectations, which may include the protection of their intellectual property. Students should not upload, distribute, or otherwise share instructors' course materials without permission. Students found in violation of the policy are subject to grade sanctions determined by the course instructor and non-grade sanctions determined by the School or College where the course is offered, as outlined in the Violation and Sanction Classification Rubric. Students are required to read an online summary of the University's academic integrity expectations and provide an electronic signature agreeing to abide by them twice a year during pre-term check-in on MySlice.

Disability Statement

Syracuse University values diversity and inclusion; we are committed to a climate of mutual respect and full participation. There may be aspects of the instruction or design of this course that result in barriers to your inclusion and full participation in this course. I invite any student to contact me to discuss strategies and/or accommodations (academic adjustments) that may be essential to your success and to collaborate with the Center for Disability Resources (CDR) in this process.

If you would like to discuss disability-accommodations or register with CDR, please visit Center for Disability Resources. Please call (315) 443-4498 or email disabilityresources@syr.edu for more detailed information.

Discrimination or Harassment

The University does not discriminate and prohibits harassment or discrimination related to any protected category including creed, ethnicity, citizenship, sexual orientation, national origin, sex, gender, pregnancy, disability, marital status, age, race, color, veteran status, military status, religion, sexual orientation, domestic violence status, genetic information, gender identity, gender expression or perceived gender.

Any complaint of discrimination or harassment related to any of these protected bases should be reported to Sheila Johnson-Willis, the University's Chief Equal Opportunity & Title IX Officer. She is responsible for coordinating compliance efforts under various laws including Titles VI, VII, IX and Section 504 of the Rehabilitation Act. She can be contacted at Equal Opportunity, Inclusion, and Resolution Services, 005 Steele Hall, Syracuse University, Syracuse, NY 13244-1120; by email: titleix@syr.edu; or by telephone: 315-443-0211.

Faith Tradition Observances

Syracuse University does not set aside days for any religious holiday. **Students must notify instructors of any religious observances by the academic drop deadline**. For any observances occurring before the academic drop deadline, students must notify faculty at least two academic days in advance. Please remind students in class of their obligations to do so. Students register their observances using MySlice. Suggested syllabus language:

Syracuse University's Religious Observances Policy recognizes the diversity of faiths represented in the campus community and protects the rights of students, faculty, and staff to observe religious holy days according to their traditions. Under the policy, students are given an opportunity to make up any examination, study, or work requirements that may be missed due to a religious observance, provided they notify their instructors no later than the academic drop deadline. For observances occurring before the drop deadline, notification is required at least two academic days in advance. Students may enter their observances in MySlice under Student Services/Enrollment/My Religious Observances/Add a Notification.

Inclusion

Everyone in this class is an equally valued member of this university and our community. We expect you to treat your classmates as honored colleagues in the collective endeavor we are all involved in - to understand the natural world and use that understanding to improve our society.

In particular, bias against or denigration of anyone in our class because of their gender or how they express it, their sexual orientation, their religion, their national origin, their race or ethnicity, or a disability they may have will not be tolerated. If you are the target of this sort of bias or if you witness it, please report it directly to the instructors and we will take swift action. If you don't feel comfortable talking to instructors, you may report it anonymously to the Physics Department feedback form: https://syracuseuniversity.qualtrics.com/jfe/form/SV_9pORpTKnq6pLeyF