

Univ. of Winnipeg Dept. of Physics  
Fall 2023

## PHYS-4303 Subatomic Physics

Lecture Times: MW 2:30-3:45PM

Room: 3M59

Instructor: Dr. Andrew Frey

Office: 2L26

WWW: <http://ion.uwinnipeg.ca/~afrey/FW2324/sap/>

Office Hours: by appointment on zoom

E-mail: [a.frey@uwinnipeg.ca](mailto:a.frey@uwinnipeg.ca)

Office Phone: 204-786-9215, email preferred

### Course Description

This course gives an introduction to the Standard Model of particle physics as well as basic concepts in the subject. We will discuss symmetry principles and special relativity before moving to Feynman rules for decay rates and cross sections. We will cover the Feynman rules for Quantum Electrodynamics and will include the Strong and Weak nuclear forces and other models of particle physics if time allows.

### Exceptional Circumstances Policies

**Exceptional Circumstances:** A permitted or necessary change in mode of delivery may require adjustments to important aspects of this course outline, like class schedule and the number, nature, and weighting of assignments and/or exams. When it is necessary to cancel a class due to exceptional circumstances, every effort will be made to inform students via UWinnipeg email. Frequently asked questions about COVID can be found at <https://www.uwinnipeg.ca/covid-19/index.html>.

**Masks:** *An individual in this class has a medical accommodation requiring that everybody in the class be masked. If you are not prepared to wear a mask in class you should withdraw from this course and select a different course.*

**Illness and Absences:** If you feel ill or have new or worsening symptoms of COVID-19, please do not come to class (or the university at all)! My lecture notes are available on the course webpage. If you let me know about an absence in advance, I will attempt to set up zoom in the class room for you to attend remotely. Additionally, if I need to stay home due to illness but am well enough to teach, I will teach remotely via zoom and let you know in advance via UWinnipeg email (see Exceptional Circumstances above).

### Textbooks

There are two required texts, one supplemental text, and several other texts on library reserve for your reference. The lectures may refer to any of these.

- **Required:** *Introduction to Elementary Particles* 2nd ed by David Griffiths, 2008.
- **Required:** Review of Particle Physics by the Particle Data Group, 2023 version.

There are two books on reserve in the library that you may find useful. In addition, it is possible that I may assign extra reading (from other texts, journal articles, etc).

### Topics

We will discuss

- Overview of the Standard Model and particle physics
- Symmetries — Conservation laws and groups —  $C$ ,  $P$ ,  $T$  symmetries — Angular momentum — Flavor symmetry — Hadronic states

- Special Relativity — Lorentz transformations & 4-vectors — Relativistic energy & momentum — Collisions — Spinors
- Scattering — Decay rates — Cross sections — Scalar Feynman rules
- Quantum Electrodynamics — Dirac & Maxwell equations — QED Feynman rules — Dirac algebra — QED processes
- Quarks & Quantum Chromodynamics — Hadrons in QED — QCD Feynman rules — QCD processes
- Weak interactions — Feynman rules — Weak processes — CKM matrix — Electroweak unification & Higgs boson
- Additional topics — Neutrino oscillation — Dark matter — Baryogenesis — Grand unification — Others...

Not all topics above will be covered equally. Also, some topics may be skipped due to time constraints or taught in different orders.

**Teaching Outcomes & Expectations:** By the end of the course, you should have a conceptual and quantitative understanding of the above topics. While the course lectures are the primary means of communicating new concepts to you, I will not work out examples for every type of problem in class. This is necessary in part because there are a limited number of easily calculable problems for some of the course topics.

I view homework assignments as a necessary way for you to learn the material; therefore, they will sometimes teach you new concepts or tools as well as evaluate what you have learned in lectures. Among other tools, the homework assignments should help you gain experience with using differential equations, approximation methods, and possibly computational resources in physics.

Finally, tests and exams evaluate not just your ability to reproduce what we have already done but also your understanding of how to apply the material to new situations.

## Assignment Policies

**Reading:** Reading assignments will be posted on the course web page for each subject (usually 5-15 pages per week, sometimes with different perspectives on the same material). You are responsible for keeping up with the reading; material covered in the reading will not necessarily be discussed in the class lectures but may be relevant to homework assignments.

**Homework:** Assignments will be posted on the course web page (see above) in PDF format; please let me know if you require alternate delivery. Typically, I will post assignments each Monday, but there will be some exceptions due to university closures, midterm tests, etc; I will tell you in advance about changes to the homework schedule. The assignment will then be due at 10:59PM on the listed due date. Make sure to mark your solution with your name. See below for submission instructions. Homework solutions will be posted on the course web page as soon as possible after assignments have been collected. Collaboration on the problems is allowed, but each student must write up the solutions independently. Late assignments will **not** be accepted without prior permission from the instructor.

**Test and Exam:** The midterm test will be held in-class with instructions provided in advance; no resources (including electronic devices) will be allowed except as specified in the instructions. The final exam will also be in-person with instructions provided in advance under the same conditions. The date will be determined based on University scheduling. Please follow the detailed instructions on the tests and final exam. Students should be prepared to present identification at the final exam.

**Project:** Each student will carry out a review and analysis of an assigned topic in particle physics. Detailed instructions will be provided in late Oct. Effort level should be similar to one or two homework assignments.

**Assignment Submission Instructions:** All homework assignments should be uploaded as PDF files to this link: <https://uwcloud.uwinnipeg.ca/s/dcYrc2Yys2jsSrZ> (also listed on the course homepage). Note

that you will not be able to see or edit your submission, so you must resubmit the whole file if you need to make changes. Assignment PDF files may be black-and-white scans (preferred) or photographs of a written hardcopy or prepared with L<sup>A</sup>T<sub>E</sub>X or other software. If you do not have access to a scanner, there are apps available for Apple and Android mobile devices; if you need to submit photographs, they *must* be converted to PDF. L<sup>A</sup>T<sub>E</sub>X submissions should be in PDF format. Alternately, you may type your assignment with a word processor and *must* use an equation editor for mathematics; you *must* submit your work in PDF format. Please label your files with your first initial, last name, and assignment number (for example, AFrey\_hw1.pdf); if you need to break your assignment into multiple parts, label them in order with lower case letters (AFrey\_hw1a.pdf, AFrey\_hw1b.pdf, etc). You will each receive via email a personalized link to a shared folder where I will return your marked assignments. **Only PDF files will be accepted for all assignments.**

**Assignment Organization:** Your homework and test/exam solutions should be written (or typed) neatly with steps explained *as if you were writing a research paper or lab report*. Not all algebra need be shown if the steps are explained in words; however, showing your work may improve your credit if you make a mistake. Homework that is not neatly organized and written will not be graded and will be given **zero credit** (one warning will be allowed).

**Regrading:** If you feel that there is a mistake in grading, I will regrade each problem in question completely. It is possible that newly discovered mistakes will reduce your credit. Please also see the section on appeals.

**Religious Holidays:** You may choose not to attend class or write tests/examinations on holy days of your religion, but you must notify me at least two weeks in advance. If so, I will provide the opportunity to make up work without penalty. A list of religious holidays can be found in the 2023-24 Undergraduate Academic Calendar. <https://www.uwinnipeg.ca/academics/calendar/docs/important-notes.pdf>

## Evaluation

**Grades:** Course grades will be comprised of the following components:

- Homework Assignments: 40%
- Midterm Test: 15%
- Course Project: 15%
- Final Exam: 30%

Guidelines for the assignment of numerical percentage grades to letter grades are as follows:

- A+ = 95-100%
- A = 87-94%
- A- = 80-86%
- B+ = 74-79%
- B = 67-73%
- C+ = 61-66%
- C = 53-60%
- D = 50-52%
- F = 0-49%

Note that these are guidelines. Final grades shall be approved by the Department Review Committee and may be subject to change.

**Exam & Other Important Dates:** Dates to note include

- First Lecture: Sept 6, 2023
- Fall Reading Week: Oct 8-14, 2023
- Midterm Test: mid-late Oct, 2023
- Voluntary Withdrawal Date: Nov 13, 2023  
(without academic penalty)
- Project Due: late Nov, 2023
- Last Regular Lecture: Dec 4, 2023
- Final Exam: To be announced

Note that withdrawing before the Voluntary Withdrawal date does not necessarily result in a fee refund.

**Regulations, Policies, and Academic Integrity:** Students are encouraged to familiarize themselves with the “Regulations and Policies” found in the University Academic Calendar at: <https://uwinnipeg.ca/academics/calendar/docs/regulationsandpolicies.pdf>. Particular attention should be given to sub-sections 8 (“Student Discipline”), 9 (“Senate Appeals”), and 10 (“Grade Appeals”).

Please note the importance of maintaining academic integrity, and the potential consequences of engaging in plagiarism, cheating, and other forms of academic misconduct.

Even “unintentional” plagiarism, as described in the UW Library video tutorial “Avoiding Plagiarism” (<https://www.youtube.com/watch?v=UvFdxRU9a8g>) is a form of academic misconduct.

Similarly, uploading essays and other assignments to essay vendor or trader sites (flesharing sites that are known providers of essays for use by others who submit them to instructors as their own work) is a form of misconduct, as it involves “aiding and abetting” plagiarism. The library site outlining principles of Academic Integrity can be found at <https://library.uwinnipeg.ca/use-the-library/help-with-research/academic-integrity.html>.

More detailed information can be found here:

*Academic Misconduct Policy and Procedures*: <https://www.uwinnipeg.ca/institutional-analysis/docs/policies/academic-misconduct-policy.pdf> and <https://www.uwinnipeg.ca/institutional-analysis/docs/policies/academic-misconduct-procedures.pdf>.

**Academic Integrity and AI Text-generating Tools:** The use of artificial intelligence (AI) tools is prohibited in this course. Students may face an allegation of academic misconduct if using them to do assignments.

## Miscellaneous

**Emails:** The primary method of email communication for this course will be through your official university email address. Students have the responsibility to regularly check their University of Winnipeg e-mail addresses to ensure timely receipt of correspondence from the University and/or their course instructors. However, if you contact me from a different email account, I may respond to that account. I will notify you through your university email and/or by announcement in class if I also need to communicate through your other email accounts.

**Comments:** I welcome feedback and comments on the course. If you are more comfortable commenting anonymously, please upload a plain text file to the homework upload link (PDF and word documents are ok but may contain information that identifies you).

**Copyright and Intellectual Property:** Course materials are owned by the instructor who developed them. Examples of such materials are course outlines, assignment descriptions, lecture notes, test questions, and presentation slides. Students who upload these materials to flesharing sites, or in any other way share these materials with others outside the class without prior permission of the instructor/presenter, are in violation of copyright law and University policy.

Students must also seek prior permission of the instructor/presenter before, for example, photographing, recording, or taking screenshots of slides, presentations, lectures, and notes on the board (or computer). Students found to be in violation of an instructor’s intellectual property rights could face serious consequences pursuant to the Academic Misconduct or Non-Academic Misconduct Policy.

**Accessibility Services:** Students with documented disabilities, temporary or chronic medical conditions, requiring academic accommodations for tests/exams or during lectures/laboratories are encouraged to contact Accessibility Services (AS) at 204-786-9771 or <http://www.uwinnipeg.ca/accessibility-services> to discuss appropriate options. All information about a student’s disability or medical condition remains confidential.

**Research Ethics:** Students who plan to conduct research interviews, focus groups, surveys, or any other method of collecting data from any person, even a family member, must obtain the approval of the appropriate ethics committee before commencing data collection. Exceptions are research activities in class as a learning exercise. See <http://www.uwinnipeg.ca/research/human-ethics.html> for submission requirements and deadlines.

**Respectful Learning Environment:** Students are expected to conduct themselves in a respectful manner on campus and in the learning environment irrespective of platform being used. Behaviour, communica-

tion, or acts that are inconsistent with a number of UW policies (e.g. *Respectful Working and Learning Environment Policy* <https://www.uwinnipeg.ca/respect/respect-policy.html>, *Acceptable Use of Information Technology Policy* <https://www.uwinnipeg.ca/institutional-analysis/docs/policies/acceptable-use-of-information-technology-policy.pdf>) could be considered “non-academic” misconduct. More detailed information can be found here: *Non-Academic Misconduct Policy and Procedures*: <https://www.uwinnipeg.ca/institutional-analysis/docs/student-non-academic-misconduct-policy.pdf> and <https://www.uwinnipeg.ca/institutional-analysis/docs/student-non-academic-misconduct-procedures.pdf>.

**Privacy:** Students are reminded to know their rights in relation to the collecting of personal data by the University (<https://www.uwinnipeg.ca/privacy/admissions-privacy-notice.html>), especially if Zoom is being used for remote teaching (<https://www.uwinnipeg.ca/privacy/zoom-privacy-notice.html>) and testing/proctoring (<https://www.uwinnipeg.ca/privacy/zoom-test-and-exam-proctoring.html>).

**Zoom Etiquette and Privacy:** If you are attending by zoom or we hold a lecture remotely, please follow this basic etiquette. Please leave your microphone muted unless you are speaking. Since it can be difficult for me to see the participant list and chat window while I am screen sharing, please unmute and speak to ask any immediate questions. To help create a sense of community in our class, please turn on your video; you should find a space so anything visible in the background respects your privacy.