Univ. of Winnipeg Applied Computer Science Dept.
Fall 2022

GACS-7401-601 Quantum Field Theory and Computing Applications

Lecture Times: TBA, 1.5 hr/week Room: TBA

Instructor: Dr. Andrew Frey
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Office Hours: by appointment (zoom)

Course Description

Quantum field theory is a vibrant subject in physics that is also the focus of intense computational study, including highly parallel computing and machine learning. This course presents an introduction to fundamental concepts in relativistic quantum field theory for these computational applications. The major topic is developing the theory of the S matrix in perturbation theory, mostly in the path integral formalism of quantum mechanics, including loop corrections and renormalization.
3 credit hours; approximately 18-20 lecture hours; 7 Sept to 23 Dec 2022 (inclusive of examination dates)

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.

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

- **Required**: *Quantum Field Theory* by Mark Srednicki
- **Supplemental**: David Tong's lecture notes
- **Supplemental**: *Fields* by Warren Siegel (arXiv:hep-th/9912205)
- **Supplemental**: Sidney Coleman's lecture notes

I may also assign some extra reading (from other texts, journal articles, etc) provided online. I have chosen references that are largely available online. However, there are many excellent textbooks on quantum field theory, and I am happy to discuss what other books may be useful and available through the university library.

Topics

We will discuss

- Relativity and Quantization — Relativistic Quantum Mechanics & Lorentz Invariance — Canonical Quantization — Path Integral Quantization
- Correlation Functions and Scattering — LSZ Formula — Feynman Rules — S-matrix — Cross Sections & Decay Rates
- Loops — Loop Diagrams — Renormalization — Effective Action — Resonances & Infrared Physics — Wilsonian Renormalization

Each secondary topic (marked with —) will take about a week, but not all topics above will be covered equally. Also, some topics may be skipped due to time constraints or taught in different orders. If time allows, we may discuss other topics (particularly related to symmetries).

Teaching Outcomes: By the end of the course, students should be able to derive Feynman rules, use them to calculate physical observables (cross sections and decay rates), and renormalize a quantum field theory.

Assignment Policies

Reading: Reading assignments will be posted on the course web page and homework assignment each week. Students are responsible for keeping up with the reading and must submit a list of questions about the reading in advance of the class meeting according to the deadline listed on the homework assignment.

Homework and Presentations: Assignments will be posted on the course web page in PDF format on a weekly basis; they will consist of ungraded practice problems and problems to be marked. During our class meeting before the assignment is due, students will present their work on one or more homework problems and should be prepared to discuss all (practice and marked) problems.

The assignment will then be due at 10:59PM on the listed due date (typically one week later); 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.

Final Exam: The final exam will be take-home format with scheduled times. You will receive detailed instructions about allowed resources in advance of the scheduled dates. You should prepare your test/exam solution following the Assignment Submission Instructions below using "exam" instead of assignment number and upload it to the given link by the scheduled deadline. Please follow the detailed instructions on the exam.

Assignment Submission Instructions: All assignments should be uploaded as PDF files to the link specified on the course webpage (and assignments). 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 LaTeX 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. LaTeX 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.** You will receive a personalized link for access to your marked assignments during the term. *Please keep this link private since that is personal information.*

Organization: Your homework and 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.

Evaluation

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

- Homework Assignments: 60%
- Participation (see below): 10%
- Final Exam: 30%

Historically, numerical percentages have been converted to letter grades using the following scale. However, instructors can deviate from these values based on pedagogical nuances of a particular class, and final grades are subject to approval by the Department Review Committee.

- A+ = 90+-100%
- A = 85-90%
- A- = 80-84%
- B+ = 75-79%
- B = 70-74%
- C+ = 65-69%
- C = 60-64%
- D = 50-59%
- F = 0-49%

Participation: The participation grade will be based on submission of questions based on reading assignments and presentations of homework problems during the class meeting following the assignment of homework (see Reading and Homework and Presentations above). If a student submits reading questions and is prepared to discuss the assigned problem (that is, demonstrates that they have thought about the problem), then the student will receive full credit for that week. Otherwise, the student will receive no credit for that presentation. Presenting students are encouraged to take advantage of office hours for advice on the problems. If a student must be absent from class, we will make other arrangements for the participation grade that week.

Exam & Other Important Dates: Dates to note include

- First Lecture: Sept 7, 2022
- UWinnipeg Reading Week: Oct 9-15, 2022
- UManitoba Reading Week: Nov 6-12, 2022
- Voluntary Withdrawal Date: Nov 16, 2022 (without academic penalty)
- Last Regular Lecture: Dec 7, 2022
- Final Exam: To be announced

I may schedule a make-up lecture for the additional reading week off.

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 subsections 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 (filesharing 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. 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`.

Miscellaneous

Emails: The primary method of email communication for this course will be through your official university email address. Please check that account regularly. 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 listed "preferred" 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 filesharing 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, communication, 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: This course will be conducted partially using Zoom software. As 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.