PHYS 5000: Quantum Mechanics I (Fall 2022)

Course Instructor:	Tom Kirchner, Department of Physics and Astronomy, York University, Petrie 228, (416) 736-2100 x33695, **tomk@yorku.ca**
WWW:	eClass
Class Times:	MWF 10:30 – 11:30 (Lumbers 306 and via Zoom)
Student Hours:	F 14:30 – 15:30 in PSE 228 or by appointment
Recommended Texts:	J. J. Sakurai and J. Napolitano, *Modern Quantum Mechanics* (3rd edition), Cambridge University Press 2021 R. Shankar, *Principles of Quantum Mechanics* (2nd edition), Plenum Press 1994 further references will be provided during the course
Class Notes:	will be posted on eClass (and classes will be recorded)

Content

A review of the fundamentals and formalisms of quantum theory, followed by a detailed treatment of selected advanced topics

Approximate List of Topics:

1 Review of Fundamental Concepts (Sakurai, Chap. 1; Shankar, Chaps. 1, 4, 9)

- postulates: states, observables, expectation values and statistical interpretation, fundamental commutation relations, measurements, time evolution. Discussion will include mini-reviews of Dirac notation, uncertainty relations, wave mechanics

2 Angular Momentum and Spin (Sakurai, Chaps. 3.1–3.2, 3.5, 3.6, 3.8; Shankar, Chaps. 12, 14, 15)

- rotations and angular-momentum commutation relations, spin 1/2 systems and finite rotations, angular momentum eigenvalue problem, orbital angular momentum, addition of angular momentum

3 Quantum Dynamics (Sakurai, Chaps. 2.1–2.4, 2.6, 3.4; Shankar, Chaps. 8, 21)

- two-level systems, density operator, evolution operator, Heisenberg picture, propagators and path integrals

4 Relativistic Quantum Mechanics (Sakurai, Chap. 8; Shankar, Chap. 20)

- Klein-Gordon equation, Dirac equation, Klein paradox, relativistic hydrogen problem

Learning Outcomes

- Demonstrate a systematic understanding of the framework and the principles of (nonrelativistic) quantum mechanics and their mathematical representation.
- Explain the fundamentals of relativistic quantum mechanics.
- Apply the principles of quantum mechanics to analyze and solve problems in the field and describe applications in new settings.
- Appreciate the complexity, broader implications, and limitations of nonrelativistic and relativistic quantum mechanics in the description of physical phenomena.
- Gather, organize, synthesize, and critically evaluate information from quantum mechanics textbooks and/or review and research articles on specific quantum mechanics topics.
- Demonstrate the intellectual independence, professional integrity and interpersonal skills required for successful research in physics.
- Communicate effectively concepts, methods, and research results of quantum mechanics to peers orally and in writing.

Marking scheme

- assignments (4–5 problem sets, pro-rated): 20 % of final grade
- midterm test (only one) : 20 % of final grade
  test date: tbd
- project/presentation: 20 %
  some time in November
- comprehensive final exam: 40 % of final grade

Other Considerations and Relevant Policies

- The course will be taught in what is now known at York as Hyflex mode, i.e., our classroom (Lumbers 306) is equipped with computer, whiteboard, microphone, and camera and I will livestream (via Zoom) and record classes and save the class notes and recordings and post them on eClass (within 24 hours).
- **Live class attendance (either in person or via Zoom) is highly recommended.** The link to join the Zoom sessions will be posted on eClass.
- I will take advantage of the fact that I pre-recorded a number of lectures during the COVID-19 pandemic, and augment the material to be discussed in class with some of those recordings (made available via eClass). **The material covered, in the pre-recorded and the live lectures, is the material that will be relevant for the midterm test and the final exam**.

- All class materials will be available on the course eClass site. It is imperative that you consult it regularly.

- I will be available to meet with you (in-person in my office) on Fridays, 2:30 – 3:30 pm. Please swing by if you have questions, concerns etc. If this time slot doesn't work for you and/or you prefer to meet via Zoom, email me and we will work something out.

- It is VERY important that you do the assignments, which will be posted on eClass and will have (firm) due dates. You can submit your homework either in person or via eClass. In addition to the graded homework problems you will be provided with ungraded practice problems and quizzes during the term. My advice: Do them all. There are many more problems available in the two recommended texts and in numerous other quantum mechanics textbooks, and you are encouraged to try at least a few of those as well. It is a good idea to work together with your peers, but it is a bad idea to copy solutions from others or from the internet. This is dishonest and you won't learn anything by doing this. **I expect everybody to hand in their own, original solutions**.

- In November you will have to do some project work. You will team up in small groups (ideally pairs) to work on these projects (readings on special topics) and present them in writing (by handing in an 8–12 page report) and orally (in terms of a $\sim$30 minute per team presentation in class). For the latter we will most likely set up an extra meeting or two close to the end of the term. More details and project topics will be provided after Reading Week in October.

- Minimal formula sheets will be provided for the midterm test and the final exam and will be posted on eClass a few days before the exam dates. The exams will be in-person and closed-book, i.e., they will happen in a classroom and the formula sheets will be the only permitted aids. The midterm will last one hour and the final exam three hours.

- If you miss the test/exam, email me as soon as possible. A make-up test/exam may be scheduled. A missed make-up exam cannot be made up.

- Here is some legal language I am obliged to include in this syllabus:

  Hyflex sessions are digitally transmitted and may be recorded to support teaching and learning in the classroom. As a result, York University may collect your image, voice, name, personal views and opinions, and course work under the authority of The York University Act, 1965, and for use in related educational purposes. Students who participate in a Hyflex session are consenting to have their video or image transmitted and/or recorded. If you have concerns with such transmission or recording, sit in the designated seating area which is outside of the camera range. In addition, students who participate orally are consenting to have their voices, personal views and opinions transmitted and/or recorded. If you do not consent to the transmission or recording of your voice, please use the text-based chat function communicate during class. Students are not permitted to use any third-party

software or application to record a transmitted Hyflex session. If you have any questions about the collection or use of your personal information, please contact your instructor or the Privacy Office at info.privacy@yorku.ca.

- Cheating and plagiarism—the attempt to gain unfair academic advantage—will not be tolerated. Note that this includes allowing another student to submit original work—whole or in part—that you yourself have done. Note also that exams, tests, and other assignments are the copyrighted works of the professor assigning them, whether copyright is overtly claimed or not. Scanning or sharing these documents constitutes copying, which is a breach of Canadian copyright law, and the breach is aggravated when scans are shared or uploaded to third party repository sites.

- Any offence against the standards of academic honesty is a serious matter. It is expected that you are familiar with the York Senat Policy on Academic Honesty and the academic integrity module in the Student Papers & Academic Research Kit (SPARK) that can be accessed via eClass.

- Other relevant York University policy statements deal with the student code of rights and responsibilities, with academic accommodation, and accessibility for persons with disabilities. They can be found at `https://secretariat-policies.info.yorku.ca/` or via eClass.

- Please be aware of University-wide important dates to be found at `https://gradstudies.yorku.ca/current-students/student-status/important-dates/`

- Please consult the Graduate Student Handbook 2022-2023 of the Graduate Program in Physics and Astronomy for further information (such as York's grading scheme for graduate courses and academic standing regulations) and links to student support services and other useful resources.

- We all have to follow York's guidance on COVID-19, which may change during the term, e.g., we may have to change plans and dates of tests and exams or oscillate between in-person and online delivery. Any such changes will be communicated promptly (via eClass). Meanwhile, visiting `https://www.yorku.ca/bettertogether/` regularly will help everybody to stay updated on the latest York COVID-19 information and guidance.

- If you are in doubt about any of the above or require access to other resources, please ask. I am committed to fostering an environment for learning that is inclusive for everyone and I welcome emails or in-person communications on this or any other issue so long as they pertain to this course. Just use one of the communication channels mentioned on the first page and get in touch. It is understood that we will all adhere to "common sense" guidelines to communicate courteously and effectively.