PHYS 4011/5050: Atomic and Molecular Physics/Structure (Winter 2022)

(This is a tentative version (updated on Jan 6, 2022). The final version will become available soon.)

Course Director:	Tom Kirchner, Department of Physics and Astronomy, York University, Petrie 228, (416) 736-2100 x33695, tomk@yorku.ca
WWW:	**eClass** (York's Learning Management System)
Class Times:	MWF 13:30 – 14:30, Lumbers 306 and/or via Zoom
Office Hours:	WF 14:30 – 15:30 (or by appointment)
Recommended Text:	H. Friedrich, *Theoretical Atomic Physics*, Springer 2017 further references will be provided during the course
Lecture Notes:	posted on eClass and www.yorku.ca/tomk/phys4011.html

Content

Application of quantum mechanics to atomic and molecular structure

Topics (some optional)[1]:

1 The Schrödinger Hydrogen Problem Revisited

- Effective one-body problem, relative motion, bound-state solutions of the Coulomb problem in coordinate space and momentum space, hydrogen-like ions and exotic systems, atomic units

2 The Hydrogen Atom in an Electric Field: Stark Effect

- Stationary perturbation theory for nondegenerate and degenerate systems, linear and quadratic Stark effect, further applications of perturbation theory: fine and hyperfine structure

3 Interaction of an Atom with Electromagnetic Radiation

- Semiclassical Hamiltonian, time-dependent perturbation theory, photoionization, outlook on field quantization

4 Many-Electron Atoms

- Identical particles, many-electron wave functions, independent electron model and Hartree-Fock method

5 Molecules

- Born-Oppenheimer approximation, rotations and vibrations, hydrogen molecular ion, outlook on electronic structure methods for many-electron molecules

6 The Relativistic Hydrogen Atom

- Dirac equation, relativistic hydrogen problem (fine structure)

[1] depending on preferences and prior knowledge

Learning Outcomes

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

Prerequisites

PHYS 4010 (for PHYS 4011), a good working knowledge of quantum mechanics (for everybody)

Marking scheme

PHYS 4011

- assignments (five in total, pro-rated, best four out of five will count): 20 % of final grade
- tests (two in total): 40 % of final grade
  test formats and dates: tbd
- comprehensive (in-person) final exam: 40 % of final grade

PHYS 5050

- assignments (five in total, pro-rated, best four out of five will count): 10 % of final grade
- tests (two in total): 40 % of final grade
  test formats and dates : tbd
- project: 10 % of final grade
  (after Reading Week)
- comprehensive (in-person) final exam: 40 % of final grade

Other considerations

- As per York's announcements from December 14 and January 6, courses will be delivered online until January 31. Accordingly, we will **meet on Zoom in the first three weeks of the term**.

- Our classroom (Lumbers 306) is equipped with computer, whiteboard, microphone and camera. This will allow me to livestream (via Zoom) and record classes and to save the class notes throughout the term—no matter whether the delivery is in-person or remote.

- **Live class attendance (either in person or via Zoom) is highly recommended.** The material covered in class is the material that will be relevant for the midterm tests and the final exam.

- Class recordings and notes will be posted on eClass (within 24 hours). **The course eClass site** (to which all registered students will have access before classes begin) **will host all course materials (recordings, notes, assignments, solutions, etc.) as well as the Zoom links to the live classes.** It is imperative to consult it regularly.

- **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 assignments in person (once we are back on campus) or in digital format (pdf files are strongly preferred) through the eClass site. In addition to the graded homework problems you will be provided with a few ungraded practice problems and/or quizzes during the term. My advice: Do them all. There are many more problems available in the recommended text and in related 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. **I expect everybody to hand in their own, original solutions.**

- The project work for PHYS 5050 will involve a problem and a written report on a special topic you will be provided with. You will do this work in groups of one or two students.

- A minimal formula sheet will be provided for the (closed-book) final exam and will be posted on eClass a few days before the exam date.

- If you miss a test the weight of that test will be pushed to the final exam.

- 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 York's academic honesty policy to be found at: `https://www.yorku.ca/secretariat/policies/` 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, e.g., with the student code of rights and responsibilities, with academic accommodation, and accessibility for persons with disabilities. They can be found at: `https://www.yorku.ca/secretariat/policies/` or via eClass.

- Please be aware of University-wide "Important Dates" to be found at `https://registrar.yorku.ca/enrol/dates/2021-2022/fall-winter` and `https://gradstudies.yorku.ca/current-students/student-status/important-dates/`

- 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. Any other questions, suggestions, criticisms are welcome as well. 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 effectively and courteously.