Physics 4410
Quantum Mechanics 2
Fall 2020

OVERVIEW

This is the second semester of the undergraduate quantum mechanics sequence.

Lectures: M/W/F 4:10-5:00 PM, Ekeley E1B20, and streamed live

Instructor: Andrew Lucas (`andrew.j.lucas@colorado.edu`).
Office hours: Su 3:00-4:00 PM, M 8:00-9:00 PM, Tu 8:30-9:30 AM, via Zoom (link in Canvas), or by appointment. Office hours are an open forum. If you want to talk privately we should set up a separate call.

Public Website: https://sites.google.com/colorado.edu/andrew-lucas/teaching/p4410f2020

Canvas: https://canvas.colorado.edu/courses/62421

Books: Recommended for background reading:

- D. H. McIntyre. *Quantum Mechanics* (Pearson, 2012).
- D. Tong. *Lectures on Applications of Quantum Mechanics* (online notes).

Recommended Prerequisites: Physics 3220 and Physics 3310, or equivalent.

HYBRID IN-PERSON/ONLINE COURSE POLICIES

- Due to the COVID pandemic, this course will be run in a hybrid in-person/online fashion. For this class, in person classes are **optional**, as is viewing them synchronously online. Course policies are designed so that you can take this course anywhere on Earth with an Internet connection.
- The university allows at most 16 students in our specific classroom at a time. If you attend in person **you must wear a face covering at all times**, including while speaking, and must follow public health ordinances. I will poll the class on who wants to attend in person lectures. You must respond if you want to attend. Based on the responses, I will assign students days on which they can attend in person. I will also set up a discussion thread on Canvas where students can swap days; please record any swaps there, even if it is just with your friend.
- If you are watching remotely, keep your microphone muted by default. To avoid technology overload, I will try to manage in-class problem-solving activities via Zoom. If this becomes unwieldy, I may adopt further technology. Zoom links for lectures will be available through Canvas. Recordings will also be posted.
- A skeleton of each lecture will be posted in advance on Canvas and on the publicly available course website. I encourage you to fill in the skeleton every lecture; these can form your class notes.
- All of your graded work (homework and exams) must be turned in electronically on Canvas.
- If you are sick, do not come to campus. There is no penalty for not attending class.

GRADES

- **35% homework:** Homework can be found on the course website. Homework is **due at or before 11:59 PM on the due date**. **Late homework is not accepted**. Solutions will be posted on the website the following morning. You must upload every homework assignment electronically into Canvas. Your 3 lowest homework scores will be dropped at the end of the course. You are welcome to – without explanation – not turn in a homework assigmment should you wish for it to be dropped. You can work together on homework, but you must write up your own solutions.

- **55% take-home exams:**

  - **Exam 1.** September 30 (12:00 PM) to October 1 (11:59 PM)
  - **Exam 2.** November 9 (12:00 PM) to November 10 (11:59 PM)
  - **Exam 3.** December 9 (12:00 PM) to December 11 (11:59 PM)

  Half of your lowest exam score will be dropped. **A late submission will receive no credit. You must work on the exams alone.** You may consult any book, and even use online resources like Wikipedia, if you find them helpful. However, **asking PhysicsForums, Chegg, Quora, or any similar website for help on an exam, is strictly forbidden.**

  If you truly cannot take the test at this time, let me know as soon as possible. Unless you do not have 4 free hours during the allocated time window, I will expect you to take the exam at its scheduled time.

- **10% oral exam:** Each student will take an $\approx$ 15 minute oral exam, which will take place a few days after one of the take-home exams. Approximately one third of the class will do the oral exam after each take-home; each student will only do one oral exam. Within reason, you may pick your preferred time for the oral exam (if it is empty). You will be asked to explain the solution to one or more of the previous take-home exam questions, along with "follow up" questions. You will be able to look at solutions to the take-home exams prior to your oral exam.

On homework and exams, **cite every reference that you use, outside of your class notes, course-assigned books/references, and instructor. This includes fellow students** (whom you may consult only on homeworks). Failure to cite references is considered dishonest. Citation style doesn't matter, so long as it is reasonable.

Depending on circumstances, the consequences for violating the rules above could include: (*1*) a warning (on homeworks); (*2*) 0% on the assignment; (*3*) automatic final grade reduction, possibly to F; (*4*) reported Honor Code violation.

The large number of dropped scores should accommodate any circumstances that may arise for you over the semester, such as religious holidays, personal or professional events, and/or illness. Unless extraordinary circumstances arise, do not ask for any further dropped scores.

If, for whatever reason, Canvas has difficulty accepting submissions, you can e-mail it to me. Do not make a habit out of submitting homework or exams this way.

Points will be assigned along the lines of a holistic grading policy, which is summarized on the course website. Different parts of a problem can be graded separately. We are primarily looking to see that your solution demonstrates clear physical understanding.

The minimum percentage required for each grade is as follows: 85% A, 80% A-, 75% B+, 70% B, and so on. This curve may be more generous than what you are used to. I expect homework and exams will be a little more difficult in this class, for two reasons: (*1*) we learn best by overcoming challenges; (*2*) this allows for a more generous curve, which is in turn more forgiving of minor errors.

COURSE OUTLINE

The following is a list of planned lectures along with affiliated reading.

1:	Review: finite-dimensional systems	(review McIntyre 1-3)
2:	Review: free particles	(review McIntyre 5-6)
3:	Harmonic oscillator: introduction	(McIntyre 9.1)
4:	Harmonic oscillator: algebraic solution	(McIntyre 9.2, 9.8)
5:	Harmonic oscillator: wave functions	(McIntyre 9.3)
6:	Harmonic oscillator: series solution	(none)
7:	Coupled harmonic oscillators	(none)
8:	Bosons and fermions	(McIntyre 13.1, 13.2)
9:	Exchange interactions	(McIntyre 13.3)
10:	Many-particle wave functions	(none)
11:	The Fermi gas	(none)
12:	Translation symmetry	(McIntyre 15.1-15.3)
13:	Bloch's Theorem	(McIntyre 15.4-15.9)
14:	Metals and insulators	(McIntyre 15.10)
15:	Rotational symmetry	(review McIntyre 7)
16:	Angular momentum algebra	(McIntyre 11.2, 11.3)
17:	The hyperfine interaction	(McIntyre 11.1, 11.4, 11.5)
18:	Addition of angular momentum	(McIntyre 11.6)
19:	Clebsch-Gordan coefficients	(none)
20:	The variational principle	(Tong 6.1.1)
21:	The helium atom	(Tong 6.1.2)
22:	The Born-Oppenheimer approximation	(Tong 6.3.6, 6.3.7)
23:	The Hartree-Fock approximation	(Tong 7.3)
24:	Time-independent perturbation theory: introduction	(McIntyre 10.1, 10.2)
25:	Time-independent perturbation theory: non-degenerate, first order	(McIntyre 10.3)
26:	Time-independent perturbation theory: non-degenerate, second order	(McIntyre 10.4)
27:	Time-independent perturbation theory: degenerate, first order	(McIntyre 10.5)
28:	Effective low-energy Hamiltonians	(none)
29:	Fine structure of hydrogen: relativistic corrections	(review McIntyre 8, read McIntyre 12.2)
30:	The Zeeman effect	(McIntyre 12.3)
31:	Time-dependent perturbation theory	(McIntyre 14.1)
32:	Slow and fast perturbations	(none)

33:	Fermi's Golden Rule	(McIntyre 14.2)
34:	Spontaneous emission of radiation	(McIntyre 14.3, 14.4)
35:	The WKB approximation	(Tong 6.2.1)
36:	The Bohr-Sommerfeld approximation	(Tong 6.2.2-6.2.4)
37:	Quantum tunneling	(Tong 6.2.5)
38:	Quantum metastable states	(none)

STANDARD UNIVERSITY POLICIES

Standard university policies regarding appropriate conduct apply to this class, and can be found in writing on the course website. Please talk to me right away if you have any needs or concerns.