Physics 181: Statistical Mechanics and Thermodynamics

Spring 2024 Syllabus

Course Description

This course provides an introduction to statistical mechanics and thermal physics. It surveys the fundamental elements of classical and quantum statistical mechanics (ensembles and partition functions) and thermodynamics (temperature, heat, work, free energy) and their application to a variety of physical systems. Topics covered may include heat engines, solid-state physics, blackbody radiation, phase transitions, physical chemistry, stellar physics, quantum information, Bose-Einstein condensation, and transport phenomena.

Prerequisite

- Physics 143a or equivalent.

Reading

The main reading material will be lecture notes that can be found in the Files section of this site. (These are Matt Schwartzâ€™s lecture notes, which I will follow mostly.) In addition, there are a number of books with good parts (see below) â€“ but there is no need to go and buy all of them! There will be a reading assignment (from the lecture notes) with a little set of comprehension questions (â€œquizzesâ€) due before each class.

Supporting Reading Material

These texts are either directly linked or on library reserve in printed or electronic form.

â€¢ *M. P. Kennett, Essential Statistical Mechanics (Cambridge University Press, 2021)* is short but fits the course pretty well. Also not very expensive.

â€¢ *D. Schroeder, An Introduction to Thermal Physics (Pearson 1999)*, is a popular book for Physics 181. It treats thermodynamics well and has a number of excellent explanations and examples. Unfortunately, its treatment of statistical mechanics is not as strong as other books. It does not even discuss ensemble theory, which is the main modern method and way of thinking about stat mech. Its treatment of entropy is also subpar.

â€¢ *F. Reif, Fundamentals of Statistical and Thermal Physics (Waveland Press, 6th ed. 2008)*. This is an excellent book. It has long careful explanations of statistical treatments, probability theory and derives thermodyanmics from statistical mechanics. I like this approach. Reifâ€™s treatment of thermodyanmics is not as good as Schroeder.

â€¢ *R. K. Pathria and P. D. Beale, Statistical Mechanics (Academic Press, 3rd ed, 2011)*. If you want to buy one book for this course, this one should perhaps be it (in addition or instead of Kennett). It does both stat mech and thermo well and is rather comprehensive. In addition, Pathria has quite a few more advanced topics than the others, so you will find the book a good reference for material related to the course that we do not have time to cover. This is also a popular grad course textbook.

â€¢ *R. Feynman Feynman Lectures of Physics, Volume 1 chapters 39-46* (online at [http://www.feynmanlectures.caltech.edu/I tocLinks to an external site.](http://www.feynmanlectures.caltech.edu/I_toc)). Feynmanâ€™s casual style and deep understanding make these lectures a pleasure to read. They cover some kinetic theory and basic thermodynamics but not statistical mechanics.

â€¢ *J. Sethna, Entropy, Order Parameters and Complexity. (Oxford, 2006)*. This book is commonly used in our graduate course, Physics 252. It has terse but precise explanations and lots of great problems (some of which I will be using).

â€¢ *P. Atkins, Physical Chemistry (Oxford, 11th edition 2017)*. More for chemists than physicists, but has some very practical and informative treatments of many topics.

â€¢ *K. Huang, Statistical Mechanics (Wiley 2nd ed., 1987, there might be a newer one)* is a standard grad text book. Relatively comprehensive, but (in my opinion) not a pleasure to read.

Equity & Inclusion

Cooperation, diversity, and accessibility strengthen our academic community. We therefore prioritize collaboration and aim to provide a welcoming and inclusive environment for all students.

Students should always feel free to reach out to the Instructors about any concerns that they may have. The Accessibility Office offers a variety of accommodations and services to students with documented disabilities. Please visit https://accessibility.harvard.edu for more information. In the event that students feel unhappy about their general circumstances this semester, they can always speak confidentially with a health care professional through the Counseling and Mental Health Services (CAMHS). Please visit https://camhs.huhs.harvard.edu for more information.

Course Schedule

The â€œmodulesâ€ section on canvas will have the up-to-date course schedule. This will consist of 24 lectures following 15 lessons:

1. Probability
2. Diffusion
3. Equilibrium
4. Temperature
5. Thermodynamics
6. Entropy
7. Ensemble theory
8. Free energies
9. Phase transitions
10. Quantum statistical mechanics
11. Phonons and Photons
12. Bose-Einstein condensation
13. Metals
14. Semiconductors
15. Stars/Black Holes

Teaching Staff

Course Head

Prof. Susanne Yelin

Office: Lyman 322

Office Hours: Monday, TBD

Email: syelin@g.harvard.edu

Teaching Fellows

- Andi Gu (andigu@g.harvard.edu)
  - Office Hours: Thursday 3-4pm in Lyman 330
- Alex Frenett (afrenett@g.harvard.edu)
  - Office Hours: Sunday 3-4pm in Jefferson 356

Course Assistants

- Athalia Meron
  - Office Hours: Sunday 8-9pm in Lowell Dining Hall
- Kevin Xu
  - Office Hours: Tuesday 6-7pm in Lyman 330

Section

Section happens probably twice weekly and is optional but recommended once a week.

- Andi Gu
  - Section: Monday 12-1:30pm in Jefferson 256
- Alex Frenett
  - Section: Friday 3-4:30pm in Jefferson 453

Both are covering the same material, so you should go only once. In addition to answering questions that might have come up in class, and mostly to go through some problems.

Lectures

Lectures will be given in person weekly on Tuesday and Thursday from 12:00 to 1:15 p.m. Before each lecture, there will be some required reading with a quiz (on canvas) that is due at midnight the night before. The lectures will be based on explaining the principles and class discussion.

Quizzes

There will be reading assigned before each class with a few simple comprehension questions that are on Canvas as a quiz. The quizzes will make a total of 10% of the final grade and are due before class starts every lecture.

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Assignments

There will be a problem set due each week. You are encouraged to collaborate on those, but everybody needs to formulate and submit their own solution and list the names of people you worked with.

All assignments will be posted on Canvas and will be due before midnight (11:59 p.m.) on the due date (TBD). Solutions will be posted on Canvas shortly after the due date.

Late Assignments & Extensions

All assignments must be submitted electronically on Canvas following given formatting instructions. Everybody will get a total of seven days of late-submission allowance that you can take any time (but you must notify the instructor or a TF of this before the homework deadline via email). Beyond that, there will be absolutely no late submission.

Exams

There will be one take-home midterm exam instead of homework, posted on February 22 and due early in March (TBD). This will work like a homework, only that collaboration is not permitted and instructors will not give the usual help.

The final exam will be in person as assigned by the registrar.

Academic Integrity & Collaboration

Collaboration is the lifeblood of science, and plagiarism is its bane. For assignments in this course, you are encouraged to consult with your classmates as you work on problem sets. However, after discussions with peers, tutors, or teaching staff, make sure that you can work through the problem yourself and ensure that any answers you submit for evaluation are the result of your own efforts. You must cite any books, articles, websites, etc. that have helped you with your work using appropriate citation practices. You must also list the students with whom you have collaborated on all homework and projects.

For more information, please consult Harvardâ€™s policy on academic integrity, in the Undergraduate Handbook. The relevant section is found at https://handbook.fas.harvard.edu/book/academic-integrity

Use of Generative AI

Certain assignments in this course will permit or even encourage the use of generative artificial intelligence (GAI) tools such as ChatGPT. The default is that such use is disallowed unless otherwise stated. Any such use must be appropriately acknowledged and cited. It is each studentâ€™s responsibility to assess the validity and applicability of any GAI output that is submitted; you bear the final responsibility. Violations of this policy will be considered academic misconduct. We draw your attention to the fact that different classes at Harvard could implement different AI policies, and it is the studentâ€™s responsibility to conform to expectations for each course.

Grading

Your grade will be computed as the sum of following components:

Breakdown of Coursework by Percentage of Grade

Course work	Points
Problem Sets Midterm Exam Final Exam Quizzes & Participation	60 10 20 10
Total	100

How to do well in this course

1. **Practice regularly**. This course is for participants not spectators. Like an athlete, you need to work out regularly. Be active in class, on homeworks, and in collaboration with your peers, and do the reading assignments. In doubt, contact course instructors!
2. **Question everything**. Donâ€™t just accept a concept without understanding the logic. Ask questions during class and office hours. We will be happy to repeat any explanation until it is clear!
3. **Collaborate**. Reach out to us and your classmates to discuss the material and the homework. This will sharpen your mastery of the subject by clearing up misconceptions and by providing different perspectives.