UC Berkeley
Physics 112 – Introduction to Statistical and Thermal Physics
Spring 2023
Syllabus

Instructor Information

Instructor Information	Lecture Information	Office Hours
Austin Hedeman (he/him) 258 Physics North aphysicist28@berkeley.edu	MWF, 8:00am – 9:00am **4 Physics North**	TBA **258 Physics North** and/or via **Zoom**

Physics 112 Zoom Link as Needed			
Zoom Link:	https://berkeley.zoom.us/j/98796109501?pwd=eDQ1Y3pOOEY4cWVya1hrNGVuNHZyUT09		
Zoom ID:	987 9610 9501	**Password:**	112123

All times are for the Pacific Time Zone.
Standard Time (UTC-8) ends and Daylight Savings Time (UTC-7) begins on March 12, 2023.

Course Information

Enrollment: This course is **Physics 112 - Lecture 001 – Introduction to Statistical and Thermal Physics**.

Lecture: 3 hrs/week **Discussion:** 1 hrs/week **Unit Value:** 4

Prerequisites: The Physics 7 series or the physics 5 series; Math 53; Math 54 or Physics 89.

Recommended Upper-Division Courses: While not formal prerequisites, Physics 105 (Classical Mechanics) and Physics 137A and 137B (Quantum Mechanics) will be useful in this course.

Data Science Domain-Emphasis: This is a domain-emphasis course for the data science major. Some knowledge of Python is required for some of the homework sets. Please see the section "Resources" for support.

Lecture and Discussion Times:
- Lecture 01 MWF 8:00am – 9:00 am 4 Physics North
- Section 101: M 9:00am - 10:00am 3108 Etcheverry
- Section 102: W 2:00pm - 3:00pm 3106 Etcheverry

Graduate Student Instructors:

Chitraang (Chi) Murdia
murdia@berkeley.edu
Section 10x
Office Hours: TBA
Zoom Link: TBA

Yu-Hsuan (Eugene) Lin
yuhsuanlin1123@berkeley.edu
Section 10x
Office Hours: TBA
Zoom Link: TBA

Sections will be devoted to working through examples. You are highly encouraged to attend! Discussion sections will start on W 1/18 and M 1/23.

Course Materials

Course Website:

- bCourses: https://bcourses.berkeley.edu/
  The course website will be hosted through the bCourses system. If you having trouble accessing the website, please e-mail me at aphysicist28@berkeley.edu so we can get you set up!

Texts:

First, a note. Textbooks are expensive! You can find some of these references online and through our libraries in both physical and digital formats. Any problem that I assign out of a book I will actually typeset so if you choose to use a different textbook or an earlier edition, that is fine and you will not be missing anything. there are a lot of options out there. I just require that you do *some* sort of relevant textbook reading so that you are getting different perspectives.

- **Schroeder, *An Introduction to Thermal Physics***. This is a popular textbook in statistical and thermal physics, is very readable, and comes highly recommended. It is structured slightly differently than some of the other standard texts since it puts thermodynamics up front. This is the **required** text for this semester. (Though see the caveat above).

I chose Schroeder as our required text based on readability and its strong reputation as a great textbook. I personally really enjoy it and think it is clearly written and laid out. Student feedback also rated this book very highly.

That said, it is important to get many different perspectives on the subject, since you never know which one may 'click' for you. Different authors have different writing styles, emphases, and organizational schemes. Listed below are other standard Statistical Mechanics and Thermal Physics texts that I am using to build my lecture notes and which you may find useful! They are available at the Physics Library:

- Kittel and Kroemer, *Thermal Physics.* This is a common text that is being and has been used for other sections of 112 and is one of the most commonly used books for similar courses. This is a **recommended** text.
- Reif, *Fundamentals of Statistical and Thermal Physics*. This is another standard and widely used text (and what I used in my undergraduate stat mech course).

Course Notes:

Since I have taught this course previously I will post up past course notes on our bCourses site. I am also in the process of reworking some things so as new course notes are prepared and updated I will scan and post them.

Other Resources:

I encourage you to use our Ed Discussion page to share any other books and resources (like online course notes from other professors or institutions, blogs, video series, etc.) you find useful. I will have a pinned post containing some that I have found and used.

Course Description

Official Course Description:

"Basic concepts of statistical mechanics, microscopic basis of thermodynamics and applications to macroscopic systems, condensed states, phase transformations, quantum distributions, elementary kinetic theory of transport processes, fluctuation phenomena. Some knowledge of Python required for homework assignments. Students who have not taken Physics 77 or Data Science 8 are encouraged to complete the Python tutorials provided by the Physics Department."

Content:

This course is roughly broken up into 4 parts:

- **Part I: Classical Thermodynamics**
  We will start with a review of thermodynamics as you may have been introduced to it in Physics 7B or Physics 5C and begin to define and develop the concept of *entropy* and various *thermodynamic potentials*. We will conclude this section with a brief tour of *kinetic theory* which was one of the first statistical models that explained thermodynamic phenomena.
- **Part II: Classical Statistical Mechanics**
  Next, we will build classical statistical mechanics by defining the *microstates* and *macrostates* of a system with a large number of particles, including both discrete and continuous states. We will be introduced to the notion of a *statistical ensemble* and explore the *microcanonical ensemble* (fixed energy, volume, and number of particles), the *canonical ensemble* (fixed temperature, volume, and number of particles), and the *grand canonical ensemble* (fixed temperature, volume, and chemical potential and thus a variable number of particles). Throughout this section we will use three key systems to develop our intuition: *binary systems* like the paramagnet, the *Einstein oscillator model* of a solid, and the *ideal gas*.
- **Part III: Quantum Statistical Mechanics**
  There are a few places in classical statistical mechanics that hint at deeper physics, including the need to specify a unit of "volume" in phase space and the Gibb's paradox for the entropy of an ideal gas. This is where *quantum mechanics* comes to the rescue! Of central importance is how the treatment of *identical particles* in quantum mechanics affects our statistical ensembles. We will study the *blackbody spectrum* (which inspired key insights into the development of quantum mechanics in the first place), *phonons*, *Bose gases* (including Bose-Einstein condensation), and *Fermi gases* (and white dwarfs!).
- **Part IV: Applications**
  Finally, we will look at some applications and other features of statistical mechanics, through we will primarily focus on *phase transitions*. Other topics that might be covered time permitting include *interacting systems* and the *Ising model*.

Learning Activities

Lectures:
I will deliver the course material to you via lectures. However, please note that you cannot learn physics by passively listening to someone talk about physics – you must actively participate and *do* physics! During lecture, take notes, think through things, try to connect what we are saying to past courses, try to see how things fit into mental models you have and work to build new ones. Visualize, come up with metaphors, poke at the boundaries, ***ask questions***! Formulate questions to ask later. I'll be learning with you how best to transmit and communicate this material. Give me feedback! Check my work for signs and 2s and πs! ***Ask questions!***

I know the early-morning scheduling of the lecture and availability of course capture (see below) will make it tempting to not come to in-person lecture but I urge you all to actually come to lectures live if you are healthy and able. I also request (but do not require) that you wear an appropriate mask properly when in the classroom.

Course Capture:
I have signed up for ***course capture*** for the semester so all lectures will be recorded and posted on our bCourses site. Lecture recordings will be uploaded to our **bCourses page** within **24 hours** of the lecture.

Zoom:
Lectures will be simulcast on Zoom. If you have a question during lecture and do not feel comfortable with your voice on the recording, please type your question into the chat. I will then repeat the question aloud and address it.

Lecture Tapbacks:
Last year I also taught the 8am section. Given the simulcast, availability of course capture, and the fact that 8am is just too early, in-person attendance was quite low. As learning during the pandemic demonstrated, having access to the recordings makes it very tempting to put off the material. I urge you to stay current with the lecture

recordings. This is crucial for the problem sets and staying on top of course material. If you find yourself falling behind, please reach out to the course staff!

In order to maintain active course engagement (while acknowledging again the reality of our 8am course time) I am trying out something new this semester inspired by the linguistics departments – ***lecture tapbacks***. These are intended to be very low-impact – each tapback is intended to take less than 5 minutes. The tapbacks will consist of three components for each lecture – you will submit one short reflection, one question, and one short comprehension question.

Lecture tapbacks will be due for each lecture. Ideally you can complete them immediately following lecture – this will give me time to read your responses. I will try to collect frequently asked questions for each lecture and address them in lecture and/or on Ed Discussion. The deadline for tapback submission will be ***one week*** following the publication of the course capture video for that lecture.

The lecture tapbacks will be worth 5% of the course grade. Each lecture tapback will be worth one point and accumulate to a maximum of 30 points. Since there are 40 lectures in the semester, this means that if you submit tapbacks for at least 75% of the lectures you will receive full credit.

This is my first time trying Lecture Tapbacks and I will request feedback periodically to improve. If you have prior experience with these I would love to hear about them!

Reading:
On the course schedule, you will find a tentative outline of topics and dates for this course. In italics listed next to most of the topics are the relevant sections of Schroeder. I will also post the correlated sections in Kittel and Kroemer to give you the greatest flexibility, although the mapping is neither one-to-one nor onto. Whichever source you use, I ask that you should read these sections **before** coming to lecture.

In addition to the textbook readings I will also post some short articles or papers as supplemental readings. These may include deeper dives into topics like nondimensionalization, order-of-magnitude analysis, etc. which will be very useful tools.

Office Hours:
My office hours will be posted online and will be held in 258 Physics North Hall or via Zoom by appointment. The GSI will also hold office hours and the schedule will be posted on the course site. These office hours may change based on student availability. I am available by appointment outside scheduled office hours times.

Problem Sets:
There will be problem sets posted on bCourses at least one week prior to the due date of the assignment. You are encouraged to work together on these assignments, but each student must submit their own work. Problem sets will typically be due **Thursdays at 11:59pm** with the late deadline typically being Fridays at 11:59pm. This timing is to maximize the utility of discussion sections and office hours while trying to avoid other courses' due dates and not overburdening your weekends.

You will submit your problem sets primarily via **Gradescope**. You will be responsible for "tagging" which pages go with which parts. Problem sets submitted within 24 hours or **one business day** after the deadline (Monday for any assignments due on Friday) will be accepted with a **25% penalty**. These should also be submitted via Gradescope.

In each problem you do over the semester it is important to not only *show* your work, but also to *explain the steps you are taking*. As with any physics problem set, the answers are not typically as important as knowing *how* to get the answers. Think of these as opportunities to show off what you know. If you can explain what you are doing and why you are doing it, you are well on your way to understanding what is going on!

You are encouraged to work with your peers on these problem sets. Discussing problems, explaining your thought processes to other people, and hearing how others approach the problems are excellent ways of expanding your understanding of the material. That being said, students must turn in their *own* work.

There will be 11 problem sets given throughout the semester and one additional ***optional*** homework set due on the last day of RRR week that covers the last week's material. Since we all have bad weeks and I know you all have lots of competing obligations, at the end of the semester only the **top ten** homework scores will be counted. Problem sets will account for 45% of your final grade.

Solution sets for the problem sets will be posted on bCourses roughly one week after the due date. We will strive to have the problem sets graded within two weeks of submission.

Note: The purpose of the problem sets is *not* to test you. Rather, they are the exercises you will use to strengthen your understanding of mathematical physics. I try to write the problems to help guide you through. You will see new systems and ways of applying what we learn. You will be walked through some applications of thermodynamic ideas and derive some key results in statistical mechanics. There are not-for-credit parts to give you extra practice. These problem sets will be bringing you to some new territory and are trying to stretch you. Because of that, it's okay if you don't easily know how to do any given problem or part or have trouble starting a problem. Reach out and talk to us, form study groups, work together (even if you are working together remotely), discuss things!

Data Science Domain-Emphasis:
This course is a domain-emphasis course for the data science major. Some problems on the problem sets will incorporate tasks in Python. These problems will be given to you in the form of Jupyter notebooks. Our first (not-for-credit) assignment will introduce the Jupyter notebooks and allow you to familiarize yourselves with the system. There are a lot of resources to help you with Python, listed later on in the syllabus.

Exams:
There will be one midterm exam and one final exam. These will be **24-hour take-home exams**. The exams will be open-book/open-notes. You may work on the exam for any or all of the 24-hour period but I do not intend it to fill that time. Your work must be submitted to Gradescope by the deadline. Each of the two exams will be worth 25% of your final grade, with a small adjustment at the end of the semester to enhance the effect of the exam you do better on.

You are not allowed to collaborate on the exams, use AI tools, or to upload any part of the exam to an online service. Any violations of this will be brought to the Center for Student Conduct.

My prior 112 exams and solutions from prior semesters will be available on our course site.

The midterm exam will go live at **6:00pm PDT on Wednesday, March 22nd** and will be due at **6:00pm PDT on Thursday, March 23rd**. It will cover roughly up through the end of Week 8 of material.

The final exam will go live at **8:00am PDT on Monday, May 8th** and will be due at **8:00am PDT on Tuesday, May 9th**. It will emphasize the material not originally covered by the midterm (though all of that material *uses* the material from the first half).

Ed Discussion: https://edstem.org/us/courses/32230/discussion/
Ed Discussion is a service that lets students ask questions (either publicly or anonymously) that the instructor, GSI, or other students can then answer. This is great for asking questions about the homework and I highly recommend you use it!

We consider this forum to be an academic space and you are expected to follow the Berkeley Honor Code and be respectful of each other.

Estimated Total Number of Required Hours of Student Work Per Semester:
- 3 hours/week Lecture
- 1 hours/week Discussion
- 8 hours/week Reading/Problem Sets
- 6+ hours/semester Exams (1 midterm and 1 final)

Grades

Grades and Grading:
The grade breakdown will be as follows:

Category	Percent
Problem Sets	45%
Lecture Tapbacks	5%
Midterm (Released W, 3/22)	25%
Final (Released M, 5/08)	25%

I do *not* want you in competition with each other for grades so there will *not* be a traditional curve for the final grade distribution. Rather, we will use the grading bins described below as an upper-bound guideline for the number grade-to-letter grade conversion. We may choose to expand the bins downward if the situation warrants (e.g. if I feel that a lower grade boundary would still accurately reflect the letter grade) but we will *not* shift the bins upwards. In other words, we may be more generous than the bins below suggest but we won't be less generous.

In the old/curved grading guidelines with a curve, courses were limited in the percentage of As and Bs they could assign. By removing this restriction, if a large portion of the class does what we consider A-level work, every one of those students can receive the A they deserve.

The *upper-bounds* on grade boundaries (ignoring the +/- subdivisions) will be:

- 90.0 for the A/B boundary (this boundary wound up being lowered last time)
- 75.0 for the B/C boundary (this boundary was also lowered last time)
- 60.0 for the C/D boundary
- 50.0 for the D/F boundary

If you choose to take this class Pass/Not Pass, a grade of C- or higher is considered a Pass (P) and a grade of D+ or lower is considered a Not Pass (NP).

Course Policies

Disabled Students' Program: http://www.dsp.berkeley.edu/
All students who have special needs can receive appropriate accommodations. The DSP office must determine or verify these accommodations before they can be offered. Students who are requesting academic accommodations are responsible for contacting the DSP Coordinator *immediately*. Please contact the instructor when a request for accommodation has been filed.

Accessibility:
In the spirit of Universal Design for Learning, I have been working on increasing the accessibility of our course elements. Things are still far from perfect but I want to invite you all in to the conversation. First, as mentioned, I will be recording and posting our lectures. These will be auto-captioned. Auto-captioning is imperfect, especially with scientific language, so if you come across any significant flaws in the transcript please let me know so I can manually edit it. Note that the caption text should be *searchable* if you are trying to find something in the video archives.

The majority of the course documents (exams, problem sets, solution sets) are typeset in LaTeX. It is notoriously difficult to create accessible PDFs in LaTeX so if you rely on a screen reader or if you just want a peek under the hood, reach out to me and I can share the LaTeX code itself.

At present time, the most inaccessible bit of course content are my scanned handwritten lecture notes. Ideally, I would like to convert these to LaTeX but that is a much larger undertaking than I am able this semester.

I am always open to hearing more suggestions and learning about new techniques, so please don't hesitate to contact me if you have a suggestion.

Student Code of Conduct: http://sa.berkeley.edu/code-of-conduct
The instructor and students are expected to behave with the utmost of integrity, responsibility, and civility towards all members of the classroom as well as staff. Additionally, all members of the community are expected to comply with all laws, University policies, and campus regulations, conducting themselves in ways that support a thriving learning environment. For more information, see the linked document. Violation of the code of conduct can result in disciplinary steps as outlined in the code.

Honor Code:
The UC Berkeley honor code reads "As a member of the UC Berkeley community, I act with honesty, integrity, and respect for others." The instructor, course staff, and students will be expected to uphold this honor code in all respects of the course.

As in every class at Cal, you are expected to abide by the Berkeley Honor code. You are allowed (and encouraged) to discuss homework and workshop assignments with your peers or instructors, but you are personally responsible for each assignment. Plagiarism (e.g. copying from external sources verbatim without proper acknowledgement) is considered cheating and will not be tolerated. Any student caught cheating will receive academic sanctions in the course and will be referred to the Center for Student Conduct.

Use of Course Materials:
The materials provided by the instructor in this course including, but not limited to, lecture notes, homework assignments, solution sets, exams, exam solutions, and study materials (collectively "course materials") are for the use of the students currently enrolled in the course only. Distribution or public display of the course materials by students for non-enrolled students is not permitted, and may constitute academic misconduct under Sections 102.01, 102.05, and 102.23 of the student code of conduct. The course materials are also subject to copyright protection, with copyright held by the instructor. As such, the course materials may not be duplicated, distributed, publicly displayed, or modified in a manner contrary to law.

Use of AI Tools:
Similar to the widespread introduction of the calculator, personal computers, and the internet, the recent advancements in machine learning and AI tools will require a great shift in policy and pedagogy. Until we better understand how to integrate these tools into our teaching, the default policy for this course is that no AI-generated works - including text or images - may be submitted unless explicitly stated otherwise. Throughout this semester I will be preparing draft policy statements that allow more nuance and acknowledge the potential uses of these tools and welcome your input!

Resources

PA Scholar Peer Tutors:
This semester with the support of the Discover Departmental Innovation Award, the MPS Dean, and the Student Learning Center (SLC) we will have a PA Scholar Peer Tutor - an undergraduate student who has excelled in this subject. Our tutors are receiving training through the SLC to "leverage the power of peer collaboration to meet students where they are and support them in mastering their science coursework". This tutoring and homework help service is available to all students in this class free of charge and you are encouraged to use it. The study halls led by our tutors are a great way for students to connect with each other and form a collaborative and supportive learning environment with the guidance of a peer. Study halls can be host to homework parties, study sessions, and more! We will post details of meeting times and locations on our course website.

Data Science Domain-Emphasis:
This course is a domain-emphasis course for the data science major and some problems on the problem sets will incorporate tasks in Python. Physics 77 or Data Science 8 are both good preparation but are *not* prerequisites. The following is a list of resources to help you complete your programming tasks:

- In addition to the tutor for Physics 112, the SLC and Physics department will have an at-large ***PA Scholar Peer Tutor for Python***. This Python tutoring is available to all students free of charge and you are encouraged to use it. We will post details of meeting times and locations on our course website.
- The physics department has created some ***Self-Paced Python Tutorials*** using Jupyter notebooks and published through GitHub:
  https://datahub.berkeley.edu/hub/user-redirect/git-pull?repo=https%3A%2F%2Fgithub.com%2Fberkeley-physics%2FPython-Tutorials&branch=master
- If there is a demand we will hold a Physics Department ***Introduction to Python in Physics Workshop***. If you are interested please e-mail me at aphysicisist28@berkeley.edu right away.

- The ***Astronomy Python DeCal*** will be offered again this semester: **Astron 98 001 - Python DeCal**. This course provides an introduction to the Python programming language with a focus on data analysis and research in astronomy, physics, and other sciences. The primary audience for this course is those who have no prior experience with programming and are intended/declared astrophysics/physics majors. As such, if you are already well versed in software development, this may not be the class for you. We estimate the weekly workload to be 3-6 hours. To sign-up for this DeCal, please visit https://pythondecal.github.io/.
- Python resources at Berkeley: http://python.berkeley.edu/resources/

Mental Health and Other Resources:
Remote learning and the pandemic have introduced a lot more stress and challenges into the student experience. Please take care of yourself and prioritize your physical and mental health. The following links may be of use if you or a friend are in trouble:

- CAPS Website: https://uhs.berkeley.edu/caps
- CAPS COVID-19 Website: https://uhs.berkeley.edu/coronavirus/student-mental-health
- Helping a Distressed Friend: https://uhs.berkeley.edu/sites/default/files/distressed_friend.pdf
- Student Advocates Office: https://advocate.berkeley.edu/
- Division of Student Affairs COVID-19 Toolkit: https://sa.berkeley.edu/covid19
- Student Technology Equity Program: https://technology.berkeley.edu/STEP
- UC Berkeley Basic Needs Guide to COVID-19: https://docs.google.com/document/d/1WwPF-Q3Z8EXBfM-Wf_WwBzdTU39hfz85JL2F8Z5IfDE/edit?usp=sharing

Administrative Issues:
Please do not hesitate to e-mail me at aphysicist28@berkeley.com with any questions, feedback, or administrative issues!

Changes and Updates:
Any changes, corrections, modifications, amendments, or updates to these policies will be announced in lecture and posted on the course website.

If you are in trouble…
(behind in homework, doing worse in the course than you would like, struggling with certain concepts, etc.) for whatever reason, please let me know ASAP! I'll try to help!

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