Statistical physics

Spring 2020

Instructor:	Daniel Sussman	**Time:**	Tues/Thurs 10:00 – 11:15
Email:	daniel.m.sussman@emory.edu	**Place:**	MSC N215

Course description: The formal course description for PHYS 526 reads, "Entropy, temperature, free energy, statistical mechanics, Gibbs ensembles, partition function, ideal gas, Fermi and Bose gases, principles of classical thermodynamics, Carnot Theorem, phase transitions, and critical phenomena."

Statistical physics grew out of billiard-ball models of the air around us and concerns about steam engines, led to beautiful and abstract ideas like entropy and information, and today gives us a systematic framework to study complex systems (from across disciplines!), relating simple microscopic interactions to emergent macroscopic behavior. It was, by far, my favorite core subject in graduate school, and I feel privileged to be your instructor for this course.

Prerequisites: Physics 526 is a fairly self-contained graduate course. I will assume familiarity with multivariable calculus, linear algebra, and with undergraduate thermal and statistical physics at the level of, e.g., Kittel and Kroemer's *Thermal Physics* or Schroeder's *An introduction to thermal physics*.

Course webpage: I will maintain a webpage for this course at https://www.dmsussman.org/teaching/phys526/. In addition to distributing material in class, as the course progresses I will be posting problem sets, practice exams, lecture notes, etc., to the website.

Office Hours: I have reserved 2:00 - 3:30pm on Fridays for formal office hours, during which you should feel free to drop in, discuss material from the class, or just stop by and talk about physics! If this time does not work for you please just send me an email and we'll find an alternate time to meet.

Homework: As in any physics class, the homework assignments are a vital part of this course; I simply do not believe you can learn physics just from sitting through lectures.

Problem sets will be distributed at regular intervals (approximately every three to four lectures). Homework assignments should be handed in to my mailbox in N213, or emailed as a LaTeX'ed solution. Each assignment will have a due date, *and late work will not be accepted*. If you have a conflict with the due date (pre-planned conference travel, time on an external experimental facility, etc.), let me know in advance and we will make an alternate arrangement.

Exams: There will be two in-class midterms during the semester and a final exam. Get excited!

Grading Policy: Homework (30%), Midterm 1 (20%), Midterm 2 (20%), Final (30%).

Optionally, you will have the opportunity to prepare a "March-meeting"-style presentation based on a classic paper related to the material in the course (to be chosen in consultation with me). This can be used to make up for up to 15% of missed credit (due to incorrect answers on homeworks or exams). I expect the timeline for this (choosing a paper, preparing a presentation, etc.) to be multiple weeks, so talk to me early if you are interested.

Important dates: You will see on the tentative outline at the end of this syllabus that we will have midterm exams on **Feb. 11th** and **March 31st**.

Spring break is **March 9 - March 13**.

Additionally, I will miss lectures due to conference travel on **Feb. 13th**, **March 3rd**, and **March 5th**. I would like to reschedule some of these missed lectures on Fridays during the latter part of the semester; we will discuss in class how best to accommodate everybody's schedule.

References: Graduate-level statistical physics is a subject with many available textbooks and wide disagreements about which one(s) to use. I will lean heavily on Pathria's *Statistical Mechanics*, which has the virtue of being available to you (for free!) online through the Emory Library website. Other texts that helped me when I was learning this subject include:

- Landau and Lifshitz, *Statistical Mechanics (Part 1)*
- Kardar, *Statistical Physics of Particles*
- Goldenfeld, *Lectures of Phase Transitions and the Renormalization Group*
- Huang, *Statistical Mechanics*
- Ma, *Statistical Mechanics*
- Chandler, *Introduction to Modern Statistical Mechanics*
- Zwanzig, *Nonequilibrium Statistical Mechanics*

As the semester progresses I strongly encourage you to find a treatment of the subject that resonates with you! Reading broadly, and discovering the difference between a good book to learn from and a good reference text, is a valuable skill.

Feedback: I will be actively seeking feedback from you during the semester, but please let me know if you have any suggestions or comments about the class. If you prefer to send anonymous feedback, feel free to email me from a temporary, disposable email address; just include "PHYS526" in the subject line and it won't get caught in my spam filter.

Academic Honesty: I expect you to exhibit the level of integrity and honesty that being a productive member of the physics research community requires. During the course of my own work I draw inspiration, evidence, and ideas from the work of others, I argue and counter-argue with them, and I believe the scientific product that results is the better for this type of engagement.

I expect you to mirror this level of engagement with the material in this class. In practical terms, I encourage you, if you wish, to **collaborate, form study groups, and discuss** problem sets with each other, but **you must** write up solutions yourself, and those solutions must reflect your own understanding of the problem and not that of one of your peers. Just like I would never dream of using or discussing someone else's work in a paper without citing them, if discussions with your classmates helped you with a problem set you should acknowledge that fact.

You also **must not** simple seek out and use solutions to textbook problems (if they are assigned) from the internet. You are here to learn, and as noted above you cannot learn physics just from sitting through lectures and copying homework solutions.

Disability statement: Emory University is committed under the Americans with Disabilities Act and its Amendments and Section 504 of the Rehabilitation Act to providing appropriate accommodations to individuals with documented disabilities. If you have a disability-related need for reasonable academic adjustments in this course, provide the me with an accommodation notification letter from Access, Disabilities Services and Resources office. Students are expected to give two weeks notice of the need for accommodations. If you need immediate accommodations or physical access, please arrange to meet with me as soon as your accommodations have been finalized.

Equal opportunity/non-discrimination statement: As the instructor of this class, I am committed to upholding Emory's principles and policies regarding equal opportunity and nondiscrimination. Emory University is dedicated to providing equal opportunities to all individuals regardless of race, color, religion, ethnic or national origin, gender, genetic information, age, disability, sexual orientation, gender identity, gender expression, and veteran's status. Please feel free to contact me with any questions or concerns related to these policies, which can be found here: http://policies.emory.edu/1.3

Course Outline:

The following timetable provides a tentative estimate of the material we will be covering throughout the course:

Dates	Content
Jan 14 - Jan 23	**Thermodynamics:** A brief review of thermal equilibrium, the laws of thermodynamics, functions of state, Carnot's Theorem, Maxwell Relations, etc.
Jan 28 - Jan 30	**Probability:** A review of probability theory at the level we will use in this class: probability densities, cumulants, the central limit theorem, information, and entropy.
Feb 4 - Feb 6	**Kinetic theory, part 1:** Liouville's theorem, the BBGKY hierarchy
Feb 13	**1st Midterm Exam!**
Feb 18 - Feb 20	**Kinetic theory, part 2:** Boltzmann equation & H-theorem; basic hydrodynamics
Feb 25, Feb 27, March 17	**Classical statistical mechanics:** Partition functions, statistical ensembles, non-interacting systems
March 19 - March 26	**Quantum statistical mechaniscs:** Density matrix formulation; Fermi and Bose gases
March 31	**2nd Midterm Exam!**
Apr 7 - Apr 14	**Interacting systems, part 1:** Cumulant, cluster, and virial expansions; liquid state theory.
Apr 16 - Apr 23	**Interacting systems, part 2:** Phase transitions, critical phenomena
TBA	**Final Exam!** (date will be chosen in consultation with instructors for your other core courses)

The precise pace of the course will be tuned as required; time permitting, we will touch on various aspects of near- and out-of-equilibrium statistical mechanics (Langevin equations, fluctuation-dissipation theorem, Kubo formulae, response functions, etc.) at the end of the semester.