PHY214A: Statistical Physics, Winter 2023
https://canvas.eee.uci.edu//courses/52083

Instructor: Jin Yu, PhD https://www.physics.uci.edu/jin-yu
Email: jin.yu@uci.edu Office Hour: Tues 12:20-1:20 pm
Lectures: Tues/Thurs 11:00 AM - 12:20 PM (HH 236) (Jan 10 Tues– Mar 16 Thurs)
Discussion Session added (non-official yet): FRH4135 Thurs 12:30-1:20
TA: TBA Office Hour: TBA
Final Exam: Tue, Mar 21st, 10:30-12:30pm

Course overview

This is a graduate-level statistical mechanics course (I). To connect with undergraduate level of statistical physics learnings, we will start with fundamentals of thermodynamics, probability theory, and kinetic theory of gas. Then we will proceed to classical ensemble theory, covering from micro-canonical to canonical and grand canonical ensembles, dealing with ideal and then interacting systems. We will further move toward quantum mechanical basis of statistical mechanics and cover theory of simple gases, ideal Bose and Fermi systems. Last, we will briefly introduce ideas in phase transition, statistical samplings, as well as fluctuations toward non-equilibrium statistical mechanics, so that to support advanced learnings.

Recommended textbook(s)

1) Statistical Physics of Particles by Mehran Kardar
2) Statistical Mechanics (3rd edition) by R.K.Pathria

Note: We will mainly follow outlines from Kardar book, especially on early chapters, then include more contents from Pathria book. Statistical Mechanics (2nd Edition) by Kerson Huang is also recommended. There are other statistical mechanics books to consult with, as long as they help you to understand better. A classic volume of Statistical Physics is by Landau and Lifshitz (Course of Theoretical Physics), and two volumes separately on Thermodynamics and Statistical Mechanics by Kubo. If you want to find an introductory level of statistical physics book or some perspectives, you can check e.g. Fundamentals of Statistical and Thermal Physics by F. Reif; Introduction to Statistical Physics (2nd Edition) by K. Huang; Statistical Mechanics: A Set of Lectures by R. Feynman; Perspectives on Statistical Thermodynamics by Y. Oono; Introduction to Modern Statistical Mechanics by D. Chandler, and recommended books therein.

Homework assignments, submission, and grading policies

- 8 HW problem sets (HW1-HW8; HW9 is optional to replace a lowest HW score)
- New assignment posted online on Tues/Thurs after class, due on next Mon/Wed (11:59 pm)
- You choose 3-4 problems to finish among those provided
- Solutions posted online Tues/Thurs morning (late submission recorded, get 30% scores)
- Grading by peer review online or by TA or mixed (for discussion & survey)
- 10 points each HW set (and a total of 80 points)
- Account for 40% of your full grade

Midterm Exam Take-home Exam (weekend of Feb 16); account for 20% of a full grade

Final Exam In-class & open-book exam (Tues Mar 21); account for 40% of a full grade

Tentative course schedules (subject to change; zoom class is occasionally scheduled)**:**

1. Summary on thermodynamics	week 1	Jan 10,12	HW1
2. Probability	week 2	Jan 17	HW2
3. Kinetic theory of gas	week 2,3	Jan 19,24	
4. Classical statistical mechanics			
1) micro-canonical ensemble	week 3,4	Jan 26, 31	HW3
2) canonical ensemble	week 4,5	Feb 2,7	HW4
3) grand canonical ensemble	week 5	Feb 9	HW5
5. Interacting systems	week 6	Feb 14	
6. Introduction on QM Stat Mech	week 6	Feb 16	Take-home Midterm Exam
7. The theory of simple gases	week 7	Feb 21,23	HW6
8. Ideal Bose systems	week 8	Feb 28, Mar 2	HW7
9. Ideal Fermi systems	week 9.	Mar 7,9	HW8
10. Phase transition to fluctuations	week 10	Mar 14	HW9‡
11. Summary and Review	week 10	Mar 16	

* Midterm and final week **Problem Sessions** (schedule with TA around the week)
‡ Optional homework (extended topics, 10-point score optional to replace a lowest score from HW1-HW8; there is also an optional course participation score for class attending, midterm/final survey, peer review etc to replace another lowest HW score)

Key topics

1. Basic Concepts in Thermodynamics
   - A. Thermodynamics
     - a. First, Second, and Third Law
   - B. Isothermal and adiabatic processes
   - C. Entropy
   - D. Thermodynamic potentials and their uses
   - E. Maxwell relations

2. Basic Notions of Probability
   - A. Probability
     - a. Probability distributions
     - b. Statistical independence
     - c. Joint probabilities, correlations
     - d. Sums of random variables and central limit theorem
     - e. Rules for large numbers (saddle points, Stirling's approximation)

3. Basic Results Related to Kinetic Theory
   - A. Kinetic theory (at the level of the Boltzmann equation)

4. Statistical Ensembles
   - A. Classical statistical mechanics
     - a. Microstates vs. macrostates
     - b. Approach to equilibrium, relaxation time
   - B. Ensembles
     - a. Microcanonical
     - b. Canonical
     - c. Grand canonical
     - d. Corresponding thermodynamic potentials
     - e. Ideal gas in various ensembles
   - C. Basic applications of statistical mechanics
     - a. Computing partition functions and averages
     - b. Ensemble of harmonic oscillators
     - c. Virial theorem

5. Quantum Statistical Mechanics
   - A. Quantum statistical distributions
   - B. Partition function for quantized energy levels, such as spins and molecules
   - C. Vibrations in solids (Einstein and Debye theories)
   - D. Specific heat for different energy dispersions
   - E. Black-body radiation
   - F. Quantum density matrix

6. Fermi and Bose Distribution
   - A. Wave functions for identical particles
   - B. Ideal quantum gases
   - C. Grand canonical formulations of quantum statistical mechanics
   - D. Non-relativistic gases
   - E. Degenerate Fermi and Bose gases
   - F. Fermi energy
   - G. Electrons in metals, white dwarfs
   - H. Bose Condensation