PHY214A: Statistical Physics, Winter 2021
https://canvas.eee.uci.edu/courses/33660

Instructor: Jin Yu, PhD https://www.physics.uci.edu/jin-yu
jin.yu@uci.edu Office Hour: Wed 12-1 pm
Lectures: Mon/Wed/Fri 11:00 - 11:50 AM (Jan 4 – Mar 12)
TA: Sunny Yu lhyu1@uci.edu Office Hour: TBD
Final Exam: Fri Mar 19, 8:00-10:00 AM

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. Statistical Mechanics: A Set of Lectures by R. Feynman; Fundamentals of Statistical and Thermal Physics by F. Reif; Introduction to Statistical Physics (2nd Edition) by K. Huang; 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 Wed after class, due 6 days on Tues (11:59 pm)
- You choose 3-4 problems to finish among those provided
- Solutions posted online Wed 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 12); account for 20% of a full grade

Final Exam In-class & open-book exam (Fri Mar 19); account for 40% of a full grade

Tentative course schedules (subject to change; zoom class preferably with co-host)**:**

1. Summary on thermodynamics	week 1	Jan 4-**6***-8	HW1
2. Probability	week 2	Jan 11	
3. Kinetic theory of gas	week 2	Jan **13**-15	HW2
4. Classical statistical mechanics			
1) micro-canonical ensemble	week 3	Jan **20**-22	HW3
2) canonical ensemble	week 4	Jan 25-**27**	HW4
3) grand canonical ensemble	week 4&5	Jan 29-Feb 1	
5. Interacting systems	week 5	Feb **3**-5	HW5
6. Introduction on QM Stat Mech	**week 6	Feb 8-**10**	Take-home Midterm Exam
7. The theory of simple gases	week 6&7	Feb 12-**17**	HW6
8. Ideal Bose systems	week 7&8	Feb 19-22	
9. Ideal Fermi systems	week 8	Feb **24**-26	HW7
10. Summary and Review	week 9	Mar 1-**3**-5	HW8
11. Phase transition to fluctuations	**week 10	Mar 8-**10**-12	HW9‡

* Each **Wed** (with new homework assignment)
** Midterm and final week **Problem Sessions** (schedule with TA around the week)
‡ Optional homework (on extended topics, 10-point score optional to replace a lowest score from HW1-HW8; there can be a course participation score for a similar purpose)

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