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 pm
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 15,24

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

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

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