Statistical Mechanics

Physics 526, Spring 2019

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Office Hours	Wed 12-1p, Fri 12-3, or by appointment.	**Classroom**	Room GRB W212 10:00AM - 10:50AM MWF

Learning outcomes:

Students will be able to

- Use **thermodynamics** to bound the efficiency of processes, determine stability, and relate measurements under different conditions (for example, constant pressure vs constant volume)
- Formally calculate **statistical averages**, classical or quantum, given a Hamiltonian & ensemble. Determine whether these averages are likely to accurately describe a physical system.
- Calculate and state properties of **ideal bosons, fermions, classical gases, oscillators, and the Ising model**.
- Formally relate a system's susceptibility to its correlations: **correlation-response relation**
- **Classify phases of matter** for a given Hamiltonian using order parameters and symmetries. **Identify gapless modes** due to symmetries and gapped excitations from topological defects.
- Use **Landau theory** to calculate properties of phases and phase transitions
- Use **universality** to quantitatively relate properties of systems in the same universality class. Use the **renormalization group** to determine these universality classes and universal properties.
- **Calculate dynamics**, combining statistical ensembles and mechanics. Use phenomonelogical models such as stochastic differential equations and Markov chains.
- Write small computer programs to solve statistical physics problems using elementary methods and **Monte-Carlo**
- **Explain** some applications to condensed matter, cosmology, biophysics, nuclear, and particle physics, as well as a couple farther-flung areas, e.g. finance and mathematics.

Course credit: 3 credits

Texts:

Pathria & Beale. *Statistical Mechanics*, 3rd edition is the main text.

We will also draw heavily from Sethna's *Entropy, Order Parameters, and Complexity* for a broader, more modern view of statistical mechanics. A pdf can be obtained for free from the author's website.

A reading list for the semester is available on canvas. Do the assigned reading *before* lecture.

Supplementary resources:

In addition to the assigned reading, **you should *always* sample from other authors on the topic to get a flavor of the diversity of approaches to the subject.** This is especially true in a subject like statistical mechanics, which is vast and which can be approached from many different starting points (thermodynamics versus statistical mechanics, ergodic vs maximum entropy foundations, traditional physics applications vs a collection of methods that is more general).

Yeomans, *Statistical Mechanics of Phase Transitions* (another text, often more straightforward if you find something confusing in the main text)
Chandler, *Introduction to Modern Statistical Physics* (quite good, can be terse and is perhaps oriented towards physical chemists)
Bellac and Baroni, Equilibrium and Non-equilibrium Statistical mechanics (modern, thorough choice of topics; more comprehensive than this course)
Chaikin & Lubensky, *Principles of Condensed Matter* (excellent, modern, classical with soft-matter focus)
Cardy, *Scaling and Renormalization in Statistical Physics* (clearest explanation of non-trivial scaling I've seen; unique approach based on operator product expansions, focusing entirely on the core technical ideas of universality, Landau theory, and renormalization group)
Goldenfeld, Lectures on Phase Transitions and the Renormalization Group (clear introduction to phase transitions),
Three other texts are Kardar, and the venerable Huang, and of course Landau & Lifshitz. **If you don't like Pathria & Beale, I highly recommend trying the equivalent sections in Karar.**

Homework and evaluation:

There generally will be a homework due at the end of day each Friday (either turned in in person by 5pm or electronically submitted in pdf form by 1am), assigned the prior Friday. Problem sets will be available online. Students are encouraged to work together to check their work and refine their solutions, but should do the bulk of the work themselves and understand and write up their own solutions. **A list of other students who they discussed with should be written at the end of the assignment.** The homework should clearly explain your approach and calculation; giving the correct answer is insufficient.

There may be "teaser questions" due at the start of class, assigned during the previous class. These guide reading and create discussion for the following class. They may be open ended. Only (thoughtful) completion is required, with no regard to the correctness of the answer. No more than 5-10 minutes needs to be spent on them.

Grades, to zeroth order, are weighted with HW as 50%, the midterm as 25% and the final as 25%. Your lowest graded homework will be dropped from the grading. If you're going to skip one, I highly recommend waiting for the last homework – you will be tired at this point, and the material will not be covered on the exam. Perturbative corrections come from my interaction with you during class and office hours, and can only improve your grade.

Grader: Yicheng Fei (yf17@rice.edu) and Zhiyuan Wang (lagrenge@163.com)

The Rice Honor Code applies to all of these assignments. Students may work together on the homework assignments, as discussed above. For the midterm and final exams, students must work alone and may consult only the materials specified on the exam cover page.

Disability and accommodations:

Any student with a disability requiring accommodations in this class is encouraged to contact the instructor after class. Additionally, students should contact the Disabled Student Services office in the Ley Student Center.