Physics 4488/6562: Statistical Mechanics
sethna.lassp.cornell.edu/Teaching/562
Course Description
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We will attempt to provide a broad view of statistical mechanics, with applications to not only physics and chemistry, but to computation, mathematics, dynamical and complex systems, and biology. Some traditional focus areas will not be covered in detail (thermodynamics, phase diagrams, perturbative methods, interacting gasses and liquids). Instead, we will focus on statistical ideas and methods that have found uses in a broad variety of fields.

Flipped format: The former lectures for this course have been carefully turned into chapters in the text. We take this opportunity to 'flip the classroom' – we will ask you to *read the lecture material before the class*, and spend class time on exercises, projects, and discussion. National research, and much local experience in Cornell's Physics department, suggests that this approach can make for significant improvements in learning (and be more interesting). Those of you headed for academic careers should watch me in this transition to see if you like the approach.

- *Load*: This class traditionally demands around *fifteen hours* of out-of-class work each week. (Physics graduate students work hard.) We will make every effort to monitor the total effort. We anticipate around four hours per week of pre-class preparation (reading and pre-class questions), and will try to keep the remaining challenging homework questions to around ten hours per week.

  For those who wish a less intense introduction into modern statistical mechanics (especially those in other fields), we have set up a companion class, Physics 4488 – same time, same place, different requirements. For Physics 4488, we ask you to do the pre-class questions for each lecture (below) and typically two of the homework exercises each week. This should provide an excellent insight into the basics, and your choice of advanced topics, with a significantly lower time investment.

- *Pre-class questions*: By 8:00am the day of class, we ask you to upload the answer to a pre-class question testing a key point in the reading. (Do it the previous evening. Upload it to Canvas at the course Canvas site.) I will be using your responses to decide how to start class the next day.

- *Canvas and the course Web site*: Handouts for this course (in-class questions and related materials, weekly homeworks, and exercise solutions) will be available on the Canvas site for the course. The Canvas site will also serve as the place to upload your solutions to pre-class questions, homeworks, and exams, and likely also the place to access grade information. The Web site for this course https://sethna.lassp.cornell.edu/Teaching/562/) will have links to the hints files for the computer exercises, together with much of the rest of the information (but not the exercise solutions).

Prerequisites: The course presumes a high level of sophistication, equivalent to but not necessarily the same as that of a first-year physics graduate student (undergrad-level quantum, classical mechanics, and thermodynamics). Only a small portion of the course (roughly one and a half weeks) will demand a knowledge of quantum mechanics; students with no quantum background have found the rest of the course comprehensible and useful, if challenging. Quantum exam questions will be likely in 6562, but will not be assigned in 4488.

Audience: This graduate statistical mechanics course has four audiences, all of whom this course will attempt to accomodate:

1. *Physics, astrophysics, and chemistry audiences* need to (i) understand how thermodynamics emerges from atomistic processes [fundamental concepts of temperature, entropy, and free energy, defining the microcanonical, canonical, and grand canonical ensembles], and (ii) understand quantum statistical mechanics [Bose-Einstein and Fermi statistics, black-body radiation, Bose condensation, superfluidity metals, neutron stars, black hole entropy, etc.].

2. *Biology and soft-condensed matter physicists* needs an emphasis on fluctuations [random walks, diffusion equations, the fluctuation-dissipation theorem] with applications to problems like polymer physics, membranes, and molecular motors. The soft-condensed matter audience, facing a bewildering variety of phases and defects, need the organizing theoretical principles we use to understand them [order parameters, phases, Landau theory, and the homotopy theory of defects].

3. *Mathematicians and computer scientists* need to understand how statistical mechanical ideas apply to computation and communications [information theory and Shannon entropy], and mathematics [ergodicity and the KAM theorem, Markov chains, entropy in dynamical systems].

4. *Complex systems* theorists need an exposure to the statistical origins of large-scale structures in space and time [avalanches, scaling, critical phenomena and continuous phase transitions, self-organized criticality, universality and the renormalization group].

Alternatives: Chemistry 7960 is a more traditional graduate statistical mechanics class, taught by Roger Loring in the fall. Physics/A&EP 4230 is a more traditional undergraduate statistical mechanics course, also taught in the fall. If you are uncomfortable with the content or format of this course, please consider 7960; people do differ in the ways they learn best, and we have all been selected to be successful in lecture classes.