Course Description
Physics 562: Statistical Mechanics
Spring 2006, James P. Sethna

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.

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.

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

(I) 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, and white dwarves].

(II) 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].

(III) Mathematicians and theoretical mechanicians need to understand how statistical mechanical ideas apply to computation and communications [information theory and Shannon entropy], mathematics [ergodicity and the KAM theorem, Markov chains, entropy in dynamical systems].

(IV) 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].