CS 8803: Statistical Physics in Algorithms and Combinatorics (Spring 2025)

Lectures: Monday & Wednesday 12:30 – 1:45 pm in Molecular Sciences 1224.

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Course webpage: `www.willperkins.org/2025-CS8803/` .

Course description
This course will introduce the fundamentals of statistical physics to students and researchers from Algorithms and Combinatorics. The aim is to give students the ability to think like a statistical physicist, with intuition for phenomena like phase transitions and correlation decay and a knowledge of some of the main tools in the field, so that the students can then apply this viewpoint to problems in their own field.

Topics

(1) Basics of statistical physics: Gibbs measures, partition functions
(2) Ising model, hard-core model, Potts model, spin glasses, perceptron model
(3) Phase transitions
(4) Cluster expansion
(5) Correlation decay
(6) Thresholds in random graphs
(7) Random CSP's
(8) Large deviations in random graphs and asymptotic enumeration in combinatorics
(9) Sampling algorithms
(10) Statistical inference and planted models
(11) Cavity method
(12) Solution space geometry and algorithmic barriers

Textbooks (for background reading) *Statistical Physics of Lattice Systems* by Friedli and Velenik; *Information, Physics, and Computation* by Mezard and Montanari. There will also be lecture notes for the course.

Assignments

- **Homework** There will be homeworks assigned roughly bi-weekly.
- **Short Survey Project** The first course project will be to write a short survey, with references, about some topic of the student's choice, either directly related to the course topics, or about something the student thinks could be amenable to methods discussed in the course. The short survey should serve as an introduction to a possible research topics.
- **Longer project** For the longer course project, the student can either do some original work (e.g., following the short survey, make progress on some research questions presented there) or alternatively, the student can write something similar to a book chapter, explaining in detail and with examples some technique that doesn't already appear in a textbook.

Grading
Students will be evaluated on

(1) Course projects (50%)
(2) Homework (30%)
(3) Class attendance and participation (20%)