Information theory, probabilistic combinatorics and physics.

Winter 2022

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Course Description: This course is a master-level course. It is an introduction to information theory and its relation to probabilistic combinatorics and statistical mechanics. During the last decade, there has been a drastic increase in the intensity of interdisciplinary research between combinatorics, statistical physics of disordered systems, and information theory. At the origin of these convergent trends are probabilistic graphical models, which describe a potentially large number of random variables coupled with each other through some dependency mechanism. The course has two main objectives: to introduce computer science/mathematics students to information theory via the approach and methods used in statistical physics of disordered systems. The course will mainly cover combinatorial optimization and inference in probabilistic graphical models.

Prerequisite(s): This course is for students who have taken at least one probability course.

Format: Classroom lectures, assigned reading, homework assignments and final exam.

Textbook(s): *Information, Physics, and Computation*, Marc Mezard and Andrea Montanari, Oxford graduate texts.

Grade Distribution: The final grade will be based on 3 homework assignments (30% of the grade) and the final exam (70 % of the grade).

Academic Honesty Policy Summary:
In addition to skills and knowledge, COLLEGE/UNIVERSITY aims to teach students academic honestly and Professional Standards of Conduct. The Academic Honesty Policy exists to inform students and Faculty of their obligations in upholding the highest standards of professional and ethical integrity. All student work is subject to the Academic Honesty Policy. Professional and Academic practice provides guidance about how to properly cite, reference, and attribute the intellectual property of others. Any attempt to deceive a faculty member or to help another student to do so will be considered a violation of this standard.

Tentative Course Outline:

The weekly coverage might change as it depends on the progress of the class. However, student must keep up with the reading assignments.

Week	Content
Week 1	• Introduction to statistical physics, basic concepts, Gibbs distributions, free energy, entropy
Week 2	• Ising model-Curie Weiss model: critical phase transitions
Week 3	• Disordered System, replica trick, spin glasses
Week 4	• Combinatorial optimization: terminology, examples (random k-SAT, graph colorings, number partitionings), phase transition in average case complexity
Week 5	• Statistical physics solution of number partitioning
Week 6	• Statistical physics of (sparse) graph partitioning problem.
Week 7	• Introduction to graphical models: Markov property and representations.
Week 8	• Factor graphs
Week 9	• Belief Propagation and cavity approximation
Week 10	• Information theory concepts: noisy channels and error-correcting codes
Week 11	• Exactly solvable models: Binary symmetric HMM
Week 12	• Statistical physics of LDPC codes