Physics 514 – Projects

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Due at the end of this term

These are ideas for final projects. Choose one of them, propose a variant of one of them, or propose a project that is entirely different from what is shown here. You should discuss your selection with us before October 12, and we will try to distribute the different projects evenly amongst participants. We will also assign you a spot for the final project presentation at the end of the semester.

1 Fluids

1.1 Monte Carlo

Write a Monte Carlo code for the simulation of a Lennard Jones fluid. Study a first order phase transition and coexistence.

1.2 Molecular Dynamics

Write a molecular dynamics code for the simulation of a Lennard Jones fluid. Study a first order phase transition. Implement a simulation in the canonical ensemble

1.3 Parallel Tempering

Explain the parallel tempering method and simulate the behavior of a particle in an oscillating potential using parallel tempering.

1.4 Wang Landau

Explain the Wang Landau method and simulate the behavior of a particle in an oscillating potential using Wang Landau.

2 Percolation

Study percolation in Monte Carlo. Perform Monte Carlo RG and determine the critical exponents.

3 Classical Spin systems, continuous PT

3.1 Ising system with Swendsen-Wang cluster update

Study the phase transition of the Ising model in 3 dimensions with the Swendsen Wang cluster update. Compute critical exponents, use the Binder cumulant to obtain T_c.

3.2 Ising system with Wolff cluster update

Study the phase transition of the Ising model in 3 dimensions with the Wolff cluster update. Compute critical exponents, use the Binder cumulant to obtain T_c.

3.3 Ising system with Swendsen-Wang cluster update in $2d$

Study the phase transition of the Ising model in 2 dimensions with the Swendsen Wang cluster update. Compute critical exponents, use the Binder cumulant to obtain T_c.

3.4 Ising system with Wolff cluster update in $2d$

Study the phase transition of the Ising model in 2 dimensions with the Wolff cluster update. Compute critical exponents, use the Binder cumulant to obtain T_c.

3.5 Heisenberg system with Swendsen-Wang cluster update

Study the phase transition of the Heisenberg model in 3 dimensions with the Swendsen Wang cluster update. Compute critical exponents, use the Binder cumulant to obtain T_c.

3.6 Heisenberg system with Wolff cluster update

Study the phase transition of the Heisenberg model in 3 dimensions with the Wolff cluster update. Compute critical exponents, use the Binder cumulant to obtain T_c.

3.7 Ising model

Study the Ising model using the Wang Landau method. Analyze the second order phase transition.

4 Classical Spin systems, Kosterlitz Thouless PT

Study the two-dimensional XY model and analyze the Kosterlitz Thouless phase transition.

5 Classical Spin systems, 1^{st} order PT

5.1 Potts model & Wang Landau

Study the $q = 10$ - state Potts model using the Wang Landau method. Analyze the first order phase transition.

5.2 Potts model & cluster updates

Study the $q = 10$ - state Potts model using a cluster update method. Analyze the first order phase transition.

6 Quantum Physics

6.1 Single-particle physics – Oscillator

- Find and visualize the bound states of a particle in a well given by $v(x) = c(x^2 - x)$, $0 \leq x \leq 1$, and $v(x) = 0$ otherwise, as a function of c.
- Solve the anharmonic oscillator numerically by directly diagonalizing the Hamiltonian matrix and by using Lanczos.

6.2 Scattering Problems

Scatter Hydrogen off of Krypton.

6.3 PIMC

Solve the Harmonic oscillator using Path Integral Monte Carlo.

Report

You are expected to hand in a short report of your project, along with the source code. The report should introduce the physics of the system you study, present the methods you use to simulate it, and show and explain your simulation results.

Presentations

Your presentation will be in the last two weeks. You are expected to give a short 10 minute talk explaining the problem and presenting your results. The presentation will be followed by five minutes of questions and discussion.