PHYSICS 212 – FINAL PAPER

- The papers are due Wednesday Thursday March 14. They should be submitted in pdf format.
- Your paper should be roughly 12-15 pages (not counting code and/or figures, or detailed appendices for algebra).
- I am looking for a concrete calculation, either analytic or numerical, not just a literature review. I want you to show your work, and/or carefully documented code, with understandable graphs and figures.
- Before you begin serious work on your paper send me an approximately one page paper proposal, including the basic references you are using. If I approve it you can proceed.
- You should send me a proposal by Friday February 15 **at the latest**.
- The paper topics below are just suggestions. You are free to come up with your own ideas or to modify one of them.
- Many of the paper topics suggested below use monte carlo techniques. A good elementary discussion of these techniques is in Gould and Tobochnik "An Introduction to Computer Simulation Methods." available on the internet.
- Other references are often best found by googling.

PHYSICS 212 – PAPER TOPIC SUGGESTIONS

1. Use cluster monte carlo techniques to study the Ising model in various dimensions. In low dimensions (2, 3) using finite size scaling and lots of statistics to get as precise a determination of some of the critical exponents and transition temperature as you can. Compare to published values. Then study in 4D, 5D and see if you can get a hint of mean field behavior.

2. Use cluster monte carlo to study ising model on different types of lattices with nearest and next nearest neighbor interactions to verify universality. As above use finite size scaling to get high precision answers.

   Show how rotational invariance is recovered in the spin spin correlation function. You may restrict yourself to 2D if you do a *very* good job there.

3. Learn how to do monte carlo simulations of lattice gauge theories. Verify numerically that the duality to the 3D ising model is correct by simulating each and showing that the critical temperatures and heat capacity exponent match. Compute Wilson loops and try to see indications of the area law.

   Study lattice gauge theory in 4D. Explore the nature of the Ising lattice gauge theory phase transition numerically.

   Study the phase diagram of Ising lattice gauge theory coupled to matter fields in 3D numerically. Show it respects an exact duality.

4. Study the Monte Carlo Renormalization Group. Test your understanding by using it to calculate critical exponents of the two dimensional Ising model. Then extend it to compute exponents of the 2D Ashkin Teller model. (This is a challenging project.)

5. Study the Monte Carlo Renormalization Group applied to the 2D $O(n)$ Heisenberg model. Redo the original work in the literature using modern computational power.

6. Learn about exact solutions of various 2D models (e.g., 2D Ising) by exact diagonalization of the transfer matrix. Exactly diagonalize the transfer matrix on finite size lattices and verify the result of the exact solution. Try this on another model. Explore the method of finite size scaling to accurately predict the critical exponents.

7. Learn about time dependent critical phenomena. Measure the dynamical exponent z in a two dimensional spin system for various kinds of monte carlo time updates. Devise a system and an updating rule that displays conservative dynamics and show the difference in z.

8. Explore chaos. Numerically study the dynamics of a classically chaotic system like Sinai billiards. Calculate Lyapunov exponents and Ruelle resonances. Study the quantum behavior of such a system and see that Random Matrix Theory results emerge.

9. Lean about the Eigenstate Thermalization Hypothesis and explore its consequences for quantum statistical mechanics. Verify it by exact diagonalization on a one dimensional chaotic quantum spin system.