Physics 6311: Statistical Mechanics - Project suggestions

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due date: Talks: Nov 30 and Dec 2, 2021

Please form teams of up to two students. Each group is to sign up for one topic and each topic can be chosen only once. Your work should result in a 20 to 25 minute talk explaining the topic to your fellow students. The talks will be given during class time in the week of Nov 30. You can earn 100 points for this project.

The following is a list of suggestions. Please feel free to propose your own topics.

1. **Bose-Einstein condensation of atomic gases**
   E.A. Cornell and C.E. Wieman, *Nobel Lecture*, Rev. Mod. Phys. **74**, 875 (2002)
   J.R. Anglin and W. Ketterle, *Bose-Einstein condensation of atomic gases*, Nature **416**, 211 (2002)
   W. Ketterle, *Experimental studies of Bose-Einstein condensation in a gas*, Physics Today, Dec 1999, p30-35
   K. Burnett et al., *The theory of Bose-Einstein condensation of dilute gases*, Physics Today, Dec 1999, p37-42
   C.J. Pethick and H. Smith, *Bose-Einstein condensation of dilute gases*, Cambridge University Press, 2002

2. **Superfluid liquid helium**
   T. Guenault, *Basic superfluids*, Taylor and Francis, London, 2003, chapters 1 and 2
   A.J. Leggett, *Quantum Liquids*, Oxford University Press, 2006, chapter 4

3. **Landau theory of Fermi liquids**
   P. Nozieres, *Theory of interacting Fermi systems*, Benjamin, New York, 1964, chapter 1
   H.J. Schultz et al, *Fermi liquids and Luttinger liquids*, arxiv.org preprint cond-mat/9807366, section 2

4. **White dwarf stars and neutron stars**
   S.A. Kaplan, *The Physics of stars*, Wiley, Chichester, 1982, chapters 5 and 6
   R.K. Pathria, *Statistical Mechanics*, Butterworth-Heinemann, Oxford, 1996, section 8.4
   Lecture 29 of David Boal's Astrophysics course, http://www.sfu.ca/∼boal/390lecs/390lec29.pdf

5. **Percolation**
   • D. Stauffer and A. Aharony, *Introduction to Percolation theory*, CRC Press, Boca Raton, 1991, chapters 1, 2, 3 + maybe parts of 5

6. **Principles of Monte-Carlo simulations**
   • Werner Krauth, *Introduction To Monte Carlo Algorithms*, cond-mat/9612186
   • K. P. N. Murthy, *An Introduction to Monte Carlo Simulation of Statistical Physics Problems*, cond-mat/0104167
   • M.E.J. Newman and G.T. Barkema *Monte Carlo Methods in Statistical Physics*, Oxford University Press, Oxford, 1999, chapters 2 + parts of 3

7. **Monte-Carlo simulations of a two-dimensional Ising model**
   • K. P. N. Murthy, *An Introduction to Monte Carlo Simulation of Statistical Physics Problems*, cond-mat/0104167
   • M.E.J. Newman and G.T. Barkema *Monte Carlo Methods in Statistical Physics*, Oxford University Press, Oxford, 1999, chapters 2, 3
   • N. Giordano, *Computational Physics*, Prentice Hall, Upper Saddle River, 1997, sections 8.3, 8.4

8. **van-der-Waals theory of the liquid-gas transition**
   • N. Goldenfield, *Lectures on phase transitions and the renormalization group*, Addison-Wesley, Reading, 1992, chapter 4 (instructor has copy)
   • R.K. Pathria, *Statistical Mechanics*, Butterworth-Heinemann, Oxford, 1996, sections 11.1, 11.2

9. **Real-space renormalization of a 2d Ising model**
   Explore the two-dimensional Ising magnet using the Migdal-Kadanoff real space renormalization group. The project is described on more detail in problem 6.4 of Plischke/Bergersen, *Equilibrium Statistical Physics.*

   (a) Derive the Migdal-Kadanoff recursion relation for $K = J/(k_B T)$.
   (b) Find the fixed points of the recursion relation and discuss the physical meaning.
   (c) Linearize the recursion relation close to the critical fixed point and calculate the critical exponent ν.

   • Plischke/Bergersen: *Equilibrium Statistical Physics*, chapter 6 (in particular 6.1 and 6.2)
   • Chaikin/Lubensky: *Principles of Condensed Matter Physics*, chapter 5 (in particular 5.5 to 5.7)