Phys. 541 Advanced Statistical Mechanics

Prof. Barry M. McCoy

Mon. Wed. Fri. 12:00-12:53

Physics PL-128

Modern statistical mechanics has close connections with condensed matter physics, quantum field theory and advanced mathematics. This course will present these topics with a focus on phase transitions, critical phenomena, solvable models and the interpretation in terms of quantum field theory.

The course will cover the following topics:

1) Theorems on the existence and non existence of order;

2) The phenomenology of critical phenomena and it's relation to quantum field theory;

3) Low density virial expansions for fluid systems;

4) Melting (freezing) transition of hard spheres, powerlaw, and Lennard-Jones potentials;

5) N vector models (known in quantum field theory as the nonlinear sigma model) will be studied by high temperature series expansions. In this context we will introduce the field theory concepts of renormalization and asymptotic freedom.

6) Commuting transfer matrices and the Yang-Baxter equation for integrable models. Solutions for the Ising model, the 6 and 8 vertex model, the RSOS models and the chiral Potts model will be derived.

7) The Ising model will be studied in great detail. In particular we will compute the free energy, spontaneous magnetization, the correlation functions and form factor expansion and we will show how renormalization theory emerges from these calculations.

8) The Yang-Baxter equation will be derived and solved for the 6 and 8 vertex models, hard hexagons and chiral Potts.

9) The non integrable Ising model in a magnetic field will be used to explore the concept of universality.

The text is "Advanced Statistical Mechanics" by B.M. McCoy. It is available in the book store. There will be no written exams. The grade will be determined by homework, a term paper and an oral examination.

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2012 Tentative Schedule

Aug. 27 Overview (Preface, Contents)

Aug. 29 Review of Thermo (Chapter 1)

Aug. 31 Review of Ensemble theory

Sept. 5 Reductionism and models (Chapter 2)

Sept. 7 Lattice gas/Ising correspondence,

Sept. 10 Classical stability (Chapter 3)

Sept. 12 Stability of matter

Sept. 14 Existence of themodynamic limit

Sept. 17 Survey of order, hard spheres (Chapter 4)

Sept. 19 Mermin and Wagner for quantum Heisenberg

Sept. 21 Lack of crystalline order in $D = 2$ and mechanism for the existence of ferromagnetism in $D = 3$

Sept. 24 Critical exponents and Ising scaling (Chapter 5)

Sept. 26 Heisenberg scaling and universality

Sept. 28 Mayer expansion and second virial coefficient (Chapter 6)

Oct. 1 Mayer's first theorem and step 1 of second theorem

Oct. 3 Finish Mayers' second theorem

Oct. 5 Groeneveld's theorems

Oct. 8 Convergence and region of no phase transitions

Oct. 10 Ree-Hoover and hard spheres (Chapter 7)

Oct. 12 High density expansions (Chapter 8)

Oct. 15 Classical high temperature expansions; stat. mech versus QFT (Chapter 9)

Oct. 17 Differential approximants and quantum high temperature expansions.

Oct. 19 Ising model summary (Chapter 10)

Oct. 22 Dimers as Pfaffians (Chapter 11)

Oct. 24 Pfaffian evaluation

Oct. 26 Ising partition function

Oct. 29 Ising correlation determinants

Oct. 31 Wiener-Hopf sum equations (Chapter 12)

Nov. 2 Szego's theorem

Nov. 5 $T = T_c$ correlation and scaling theory for Ising

Nov. 7 Form factors $T > T_c$ and $T < T_c$ and Ising Susceptibility

Nov, 9 Yang-Baxter (star triangle) equation (Chapter 13)

Nov. 12 Six vertex star triangle

Nov. 14 8 vertex star triangle and chiral Potts

Nov. 16 Hard hexagons and Hamiltonian limits
Nov. 19 Bethe's ansatz (Chapter 14)
Nov. 21 NO CLASS
Nov. 23 NO CLASS
Nov. 26 TQ equations for 8 vertex, 8 vertex free energy
Nov. 28 8 vertex free energy and order parameter
Nov. 30 Hard hexagons (Chapter 15)
Dec. 3 Ising in a magnetic field
Dec. 5 Chiral Potts
Dec. 7 Reductionism versus complexity (Chapter 16)