Phys 6305 Statistical Mechanics II: Critical Phenomena

Fall 2010

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Meeting Time: 09:00 MWF
Room: Rm 10 Science
Office Hours: 1-3 TR

Primary Text: Plischke and Bergersen, *Equilibrium Statistical Physics,* 2nd Ed. (World Scientific, 1995)

Purpose: This course is intended to provide graduate students in physics or materials science with the background knowledge and statistical techniques required to model phase transitions, and other critical phenomena in strongly interacting systems, including effects related to various forms of disorder.

General Comments: Topics are selected to provide a bridge between the standard introductory level graduate or upper level undergraduate course in Statistical Physics and the level of understanding of statistical modeling techniques required at the doctoral research level to deal with various forms of critical behavior encountered in technologically relevant modern materials. We will include effects due to disorder that are often excluded from the basic solid state and statistical physics courses, specifically examining models directly applicable to alloys, non-crystalline solids, polymers, membranes, and other forms of 'soft' condensed matter. While the focus will be on phase transitions and other critical phenomena, most of the techniques that are covered have considerably wider application. An attempt will be made to draw examples from a wide range of condensed matter and materials physics sub-areas, with particular emphasis on the relevant research interests of students taking the course.

Learning Goals: Students enrolled in this course will be expected to

- Apply simple mean field theories to standard systems displaying an ordering transition
- Perform model calculations using the Ising Model in one and two dimensions
- Examine excluded volume effects and apply the n-vector approach to models of polymer chains
- Treat excitations of model systems using linear response theory
- Obtain results for critical phenomena in specific models using renormalization group methods
- Make predictions for disordered systems based on percolation treatments
- Discuss physically relevant fundamental ideas underlying assigned problems and relevant models

Assessment Methods: Specific problems will be assigned that directly involve one or more of the listed learning goals. Students are required to write a short discussion to accompany every assigned problem. Solutions and the associated discussions will be used to determine whether a student has mastered the mathematical modeling techniques involved, and whether they have identified the basic underlying physical ideas. An extended project due at the conclusion of the course will be used to assess how well each student can apply the methods covered in this course to a research level problem, and how well they are able search out the relevant literature and to extract the pertinent information from existing sources. Questions and active participation in discussions during class meetings will provide an intermediate and ongoing assessment of the progress each student is making in grasping the basic concepts and underlying physics and how well they understand the implications of solutions to a given model.

Course Grade:

50% Regular Assignments (expect 4 to 6 Non-trivial Problem Sets)
30% Final Project: Paper and Presentation
20% Two Qualitative Exams

PHYS 6305: Anticipated Topic Coverage

Review of Thermodynamics and Statistical Ensemble Treatments	P&B Chpt 1, 2
Mean Field and Landau Theory of Phase Transitions	P&B Chpt 3
Critical Exponents, Series Expansions, and Scaling	P&B Chpt 5
Renormalization Group Approach to Critical Phenomena	P&B Chpt 6
Polymers and Membranes	P&B Chpt 8
Quantum Fluids	P&B Chpt 9
Linear Response Theory	P&B Chpt 10
Disordered Systems and Percolation Theory	P&B Chpt 11

Some Secondary Sources: Ma, *Modern Theory of Critical Phenomena*, (Benjamin, 1976)
Ma, *Statistical Mechanics*, (World Scientific, 1985)
Landau, *Theory of Phase Transitions,* (Dover Edition)
Herbut. *A Modern Approach to Critical Phenomena,* (Cambridge, 2007)
Binney, Dowrick, Fischer, and Newman, *Theory of Critical Phenomena: An Introduction to the Renormalization Group,* (Oxford, 1995)

Problem Sets: There will be a series of problem assignments, each consisting of four or five problems, many of which are likely to require significant effort, so start early. Work on the assigned problems constitute the major part of your course grade. I expect a short written discussion of the basic physics and interpretation of your results to accompany each problem. This should include a discussion of the method you are using, identification of approximations involved in the model or in the math development, and the range of their validity. This qualitative discussion is at least as important as the mathematical solutions to the problems and will indicate to me how well you understand the basic physics as well as your grasp of the basic modeling methods.

Qualitative Exams: There will be two qualitative exams that are intended to explore your understanding of the basic ideas rather than how well you can quickly reproduce the rather involved math. The required discussions related to problems should be good practice for these exams.

Final Project: Each student in this class is required to undertake a substantial project, typically exploring the literature associated with a problem of special interest to the student (perhaps related to their PhD research project). This topic should be selected early, no later than half way through the semester, and a substantial amount of work is expected. A written report in the format of a conference paper, and a 15 - 20 min presentation based on this project is due at the end of the semester and forms the basis of the grade on this part of the course. A specific format for the paper will be provided and should be followed.

Note: Presenting work other than your own as if it is yours constitutes serious academic misconduct. I expect you to use a number of different sources during this course, including seeking assistance on homework solutions, but you must document any source from which you use any content. Reference everything in a manner that anyone else can easily find that source. There are standard referencing formats that are common to the discipline – use them. This relates to discussion statements as well as to the math in the assigned homework and includes internet sites. Get into the habit of documenting where you find any relevant information.

Anyone who may require special accommodations to meet course requirements should see me early so that appropriate arrangements can be made. Typical University rules related to documentation apply, and official documentation may be requested depending on what arrangements are requested.