Statistical Physics 2006/7

Synopsis

This is a course on the statistical physics of interacting particles. In part I we review the fundamental assumptions of equilibrium statistical mechanics focussing on the relation between missing information (or entropy) and probability. In part II we consider the statistical mechanics of interacting particles and develop important approximation schemes. In part III we consider phase transitions. We review well known phase transitions and the unifying phenomenology. We study in detail a simple, microscopic model: the Ising model. We then consider a general theoretical framework known as Landau Theory. In part IV we discuss the issue of dynamics: how does a system approach and explore the state of thermal equilibrium? How does one reconcile microscopic time reversibility with the macroscopic arrow of time?

Syllabus

I: Derivation of Statistical Ensembles

- Maximising the missing information
- Derivation of the principal ensembles: microcanonical; canonical; grand canonical
- Quantum systems: Fermi-Dirac, Bose-Einstein, classical limit
- Bose-Einstein Condensation
- Phonons and the Debye theory of specific heat of solids

II: The Many-Body Problem

- Interacting systems
- Perturbation theory
- Cluster expansion
- Breakdown of perturbation theory
- Non-perturbative ideas: Debye-Hückel Theory

III: Phase Transitions

- Phenomenolgy
- The Ising Model
- Solution in one dimension
- Correlation functions and correlation length
- Mean-field theory
- long range order in two dimensions, lack of in one dimension
- Landau Theory
- Order Parameter

- Critical exponents and Universality

IV: The Arrow of Time

- Hamiltonian dynamics and phase space
- Liouville's theorem
- Coarse graining
- The master equation
- Random walks and the diffusion equation
- Detailed balance
- Brownian motion and the Langevin equation
- Dynamics of fluctuations
- Fluctuation-dissipation relations and Linear Response

Textbooks

There is no perfect text book at this level— we will outgrow the introductory books you might have used in P3 but many thorough 'graduate level' texts are just a bit too scary.

R Baierlein *Thermal Physics* (CUP). An excellent book for basics but not advanced enough for many parts of the course

F Mandl *Statistical Physics* (Wiley). Well established book. Does not cover latter parts of course.

F Reif *Fundamental of Statistical and Thermal Physics* (McGraw Hill). Classic book now a little dated. Very broad coverage

K Huang *Statistical Mechanics* (Wiley). A thorough and rigorous book. A bit too advanced generally but excellent for mathematical detail of e.g. Bose-Einstein Condensation and Ising models

J P Sethna *Statistical Mechanics: Entropy, Order Parameters and Complexity*, (OUP). Very recent book specifically designed for this level of course. Minimizes the traditional discussions and instead focusses on modern applications in a variety of contexts. Excellent for supplementary reading but not too close to the course unfortunately

D Chandler *Introduction to Modern Statistical Mechanics* (OUP). This book is probably closest to the course in level and content. But aimed at Physical Chemists so has some notational quirks.

There are several other textbooks at the slightly more advanced level which cover just about everything in the course and more and are worth investing in R. K. Pathria *Statistical Mechanics*, M Plischke and B Bergersen *Equilibrium Statistical Physics*, L. E. Reichl *A Modern Course in Statistical Physics*.

Finally I would like to acknowledge that previous lecturers Professors M.E.Cates and W. D. McComb let me have access to the latex source code for their notes which I have used on occasion in the course notes I have provided.

In particular the source code for Professor McComb's notes contains material included in his book *Renormalization Methods: A Guide for Beginners* OUP This book would be a recommended text for the Physics 5 course *Advanced Statistical Physics*

MRE, September 2006