

Advanced Statistical Physics

WS 2007/2008

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I. Microscopic and macroscopic degrees of freedom

1. Thermodynamics and entropy

- 1.1 Boltzmann entropy
- 1.2 Ensembles and fluctuations
- 1.3 Entropy and information

2. Diffusion

- 2.1 Simple random walks
- 2.2 Other universality classes
 - a) Lévy flights
 - b) The self-avoiding walk
- 2.3 Collective diffusion
- 2.4 Driven diffusion

II. Phase transitions and critical phenomena

1. Phenomenology of phase transitions

- 1.1 Simple fluids
- 1.2 The van der Waals gas
- 1.3 Lattice models of ferromagnetism

2. Critical behavior of the Ising model

- 2.1 Mean field approximation
- 2.2 The Ising chain
- 2.3 Energy barriers and domain walls
- 2.4 The two-dimensional Ising model

3. Landau theory and Gaussian fluctuations

- 3.1 The Landau free energy

- 3.2 The Ginzburg-Landau functional
- 3.3 Gaussian fluctuations
- 3.4 The Ginzburg criterion
- 3.5 Order parameters with continuous symmetry
- 3.6 Thermal roughening

4. Scaling and renormalization

- 4.1 Block spins and scaling relations
- 4.2 Renormalization of the Ising chain
- 4.3 Structure of the RG flow
- 4.4 Real space RG of the triangular Ising model
- 4.5 ϵ -expansion and power counting

5. Kinetics of first order phase transitions

- 5.1 Basic phenomenology
- 5.2 Nucleation theory
- 5.3 Conserved and nonconserved dynamics
 - a) Kinetic Ising models
 - b) Time-dependent Ginzburg-Landau theory
- 5.4 Spinodal decomposition
 - a) Linear stability analysis
 - b) The scaling hypothesis
 - c) Growth law for non-conserved dynamics
 - d) Growth law for conserved dynamics
 - e) Porod's law
 - f) Coarsening laws in one dimension

III. Scale invariance at large

1. Scale invariance, self-similarity and power laws

2. Fractal geometry

3. Diffusion-limited aggregation

- 3.1 Basic phenomena
- 3.2 Bounds on the fractal dimension

- a) Opacity bound
- b) Causality bound
- c) Tip growth

3.3 Laplacian fractals and Laplacian instabilities

- a) The continuum limit of DLA
- b) The Mullins-Sekerka instability
- c) The Saffman-Taylor instability
- d) Dielectric breakdown

4. Self-affine growth processes

4.1 Self-affinity

4.2 Stochastic growth models with local rules

- a) The Eden model
- b) The single step model

4.3 The Kardar-Parisi-Zhang equation

- a) Normal growth
- b) Langevin equations for kinetic roughening
- c) Solution of the Edwards-Wilkinson equation
- d) Relevance of the nonlinear term
- e) Galilean invariance

Recommended reading:

- J.P. Sethna: *Entropy, Order Parameters, and Complexity*
(Oxford University Press 2006)
- N. Goldenfeld: *Lectures on Phase Transitions and the Renormalization Group*
(Westview Press 1992)
- M. Plischke and B. Bergersen: *Equilibrium Statistical Physics*
(3rd edition, World Scientific 2006)
- D. Sornette: *Critical Phenomena in Natural Sciences*
(2nd edition, Springer 2004)

Problem sheets and supplementary information:

<http://www.thp.uni-koeln.de/krug/> ⇒ Teaching