# Advanced Statistical Physics

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## Course Material; Michaelmas 2011

This course will focus on the statistical physics of phase transitions and the renormalization group (RG) theory of critical phenomena. It will be based entirely on the following textbook:

M. Kardar, *Statistical Physics of Fields* (Cambridge Univ Press, Cambridge England, 2007).

There will be two Homeworks for this course, which will be assessed, with the following timetable:

- Homework 1: 23 November 2011; due date 30 November 2011
- Homework 2: 7 December 2011; due date 14 December 2011

There will be two problem classes, taught by Dr Abhishek Chaudhuri; one after each Homework is handed in. You will be contacted soon to schedule these problem classes.
The outline of the material, which will be covered in 16 lectures, is as follows:

### I. COLLECTIVE BEHAVIOR, FROM PARTICLES TO FIELDS

1. Introduction
2. Phonons and elasticity
3. Phase transitions
4. Critical behavior

### II. STATISTICAL FIELDS

1. Introduction
2. The Landau-Ginzburg Hamiltonian
3. Saddle point approximation, and mean-field theory
4. Continuous symmetry breaking and Goldstone modes
5. Discrete symmetry breaking and domain walls

### III. FLUCTUATIONS

1. Scattering and fluctuations
2. Correlation functions and susceptibilities
3. Lower critical dimension
4. Comparison to experiments
5. Gaussian integrals
6. Fluctuation corrections to the saddle point
7. The Ginzburg criterion

## IV. THE SCALING HYPOTHESIS

1. The homogeneity assumption
2. Divergence of the correlation length
3. Critical correlation functions and self-similarity
4. The renormalization group (conceptual)
5. The renormalization group (formal)
6. The Gaussian model (direct solution)
7. The Gaussian model (renormalization group)

## V. PERTURBATIVE RENORMALIZATION GROUP

1. Expectation values in the Gaussian model
2. Expectation values in perturbation theory
3. Diagrammatic representation of perturbation theory
4. Susceptibility
5. Perturbative RG (first order)
6. Perturbative RG (second order)
7. The $\epsilon$-expansion
8. Irrelevance of other interactions
9. Comments on the $\epsilon$-expansion

## VI. BEYOND SPIN WAVES

1. The nonlinear $\sigma$ model
2. Topological defects in the XY model
3. Renormalization group for the Coulomb gas
4. Two-dimensional solids
5. Two-dimensional melting