

Broader applications (Potential group project topics)

(0) Epsilon expansions

- Feynman diagrams
- Ising: mean-field above 4 dimensions
- $4-\epsilon$ expansion
- $6-\epsilon$ for disordered systems, $2+\epsilon$, ...

(1) Lower critical dimension

- Kosterlitz-Thouless transition
- Inverse-square Ising model
- Two-dimensional superfluids
- Kondo problem?
- Macroscopic quantum tunneling?

(2) Disordered systems

- Random field Ising model focus
- Diverging energy barriers
- Dangerous irrelevant variables
- Deep connections to glasses?
- Metal – insulator transition, localization
- Griffith phases
- Other disordered systems
- Barrier divergence exercise?

(3) Flocking

- Nonlinear hydrodynamics
- Birds, wildebeests. hard rockers moving in concert
- “Violation” of Mermin-Wagner theorem
- Focus on phase? Experiments? Exercise?

(4) Fermi liquid theory

- RG replaces Green's functions!
- Coarse graining in energy
- Fermi liquid as noninteracting fixed point
- Superconductivity as quadratically relevant perturbation
- Fermi surface as “order parameter”?
- Quasiparticles as Goldstone analogues?

(5) Quantum phase transitions

- High T_c (Eun-Ah Kim)
- Macroscopic quantum tunneling?

(6) Conformal field theory and Stochastic Loewner evolution

- 2D (or 1+1 D quantum) critical points
- Solve all exponents, scaling correlation functions, ...
- Invariant under any complex analytic map
- Representations of conformal group

(7) Glasses and models of glasses

- Jamming
- Mode coupling
- Curved space
- Kinetically constrained models

(8) Networks

- Small worlds, Percolation, Disease Spreading
- Zombies
- Scale-free vs. Grown networks

(9) Chaos and turbulence

- Onset of chaos: period doubling, quasiperiodic
- Strange attractors
- Kolmogorov theory of fully developed turbulence
- Recent fully developed turbulence & strings?

(10) Depinning transitions

- Avalanches and self-organized criticality
- Earthquakes, Barkhausen noise, raindrops on windshields

(11) Surface growth

- MBE and surface roughness
- Random deposition noise vs. diffusive flattening
- Uphill currents and Ehrlich-Schwoebel barrier
- KPZ and other universality classes

(12) Spin glasses and NP-complete problems

- P and NP, NP Complete
- Number partitioning
- Random energy model
- Replicas and replica symmetry breaking, cavity methods, ultrametricity ...
- Neuroscience
- Long-range order in time
- Diverging nonlinear susceptibility
- Replicas vs. clusters
- New algorithms for computationally challenging problems

(13) Wetting

- Surface transitions near bulk transitions
- Water drop contact angle on surface

(14) Equilibrium Crystal Shapes

- Faceting (not cleaving!)
- Wulff construction
- Roughening transition (Kosterlitz-Thouless)
- Critical exponents and facet edge rounding
- Coarsening and scaling

(15) Asymptotic analysis of partial differential equations

- Multiscale analysis, asymptotics
- Bender and Orszag using Renormalization Group

(16) Bifurcation theory

- Dynamical systems, qualitative change in behavior
- Universality classes = Normal forms
- Theory of analytic corrections to scaling

(17) Droplet Breakup

- Dripping faucet: topology change
- Scaling of droplet pinchoff shape (Itai Cohen)