Program midterm 2004

1
Equilibrium ensembles. N-particle distribution function, reduced distribution functions.
Statistical independence. Self-averaging.
Liouville equation; and coarse graining. Microcanonical ensemble.
Gibbs entropy; maximum entropy principle.
Canonical distribution. Partition function and free energy.
Ideal gas; Maxwell and Boltzmann distributions.

2
Exploration of vicinity of equilibrium.
Local equilibrium; non-equilibrium entropy.
Equilibrium fluctuations; Gaussian distribution. Correlation functions for several Gaussian variables.
Non-equilibrium thermodynamics, thermodynamic flows and forces, kinetic coefficients, Onsager relations.

3
Stochastic variables, stochastic processes.
Joint probabilities, conditional probabilities, moments, cumulants, characteristic function.
Stationary process. Markov process. Smolukhovsky equation.
Random walk.Binomial distribution. First and second moments.

4
Continuous random walk: Poissonian distribution. Shot noise.
Central limit theorem Gaussian distribution.
Random walk model for diffusion.
Continuous Markov process: master equation.
Application of master equation. Binary chemical reaction – exponential relaxation.
Birth-death problem: master equation, stationary solution for constant rates, relaxation to stationary state.

5
Boltzmann equation for ideal gas with impurities.
Derivation of collision term from master equation. Microscopic scattering properties: detailed balance and conservation laws.
Validity: scattering time /length << evolution (relaxation) time /length.
Derivation of convection term (Liouville equation).
Stationary state (isotropic distribution). Relaxation process (= isotropization), relaxation time approximation.
H-theorem.
Weak non-equilibrium, linear response, transport coefficients.

6
Boltzmann equation for ideal gas with particle-particle scattering.

Collision term (master equation for two-particle distribution)
Detailed balance and conservation laws.
Statistical independence: from two- to one-particle distribution (coarse graining).
H-theorem.
Stationary state – Maxwell distribution.
Relaxation, relaxation time approximation.
Validity: scattering time << relaxation time.
Local equilibrium; relaxation of mall gradients: new stage of relaxation.
Macroscopic conservation laws; hydrodynamic equations; formulas for flows.

7
Relaxation of. small gradients in ideal gas with impurities: diffusion.
Derivation of diffusion equation from Boltzmann equation.
Binary (AB) ideal gas of light/heavy particles.
Relaxation of B particles, hierarchy of relaxation rates: AA-rate >> AB-rate >> BB-rate: Brownian motion.
Derivation of Fokker-Planck equation: elimination of A-distribution, approximation of small-angle scattering.

8
Langevin equation. White noise.
Calculation of correlation functions and mean square deviations.
Application to electrical circuits. Nyquist theory for current fluctuations
Spectral analysis of noise, spectral function.
Response function, fluctuation-dissipation theorem. Nyquist formula for current noise.
Measuring spectral function, Wiener-Khinchine theorem.

9
Methods of non-equilibrium statistical physics: relation between stochastic equations, thermodynamics and kinetics.
Derivation of Fokker-Planck equation from Langevin equation.
Derivation of Langevin equation from microscopic particle – oscillator-bath model

Recitations and Home Problems

1
Derivation of Liouville equation.
Calculation of correlation functions for thermodynamic variables.

2
Rubber band problem (1D walk).

3
Transport coefficients and linear response.
Current flow and calculation of ac conductivity.

Energy flow and derivation of thermal conductivity.
Calculation of magnetoresistance and Hall coefficient

4
Tourist-mosquitoes problem.
Generalized Langevin equation.
Fluctuation of a rotor (Fokker-Planck equation).

5
Fluctuation of harmonic oscillator without damping (Langevin equation).
Calculation of spectral function.