TENTATIVE COURSE OUTLINE
PY542: NON-EQUILIBRIUM STATISTICAL PHYSICS

I. TRANSPORT THEORY (3 lectures)

1) Elementary Kinetic Theory (1.5 lectures)
   - (a) The Maxwell-Boltzmann Distribution
   - (b) Molecular Collisions and Flux
   - (c) Linear Transport Processes
     - –electrical, heat, particle conductivity, & viscosity

2) Boltzmann Transport Equation (1.5 lectures)
   - (a) Basic Derivation
   - (b) Boltzmann's H Theorem
     - –nature of the equilibrium state
   - (c) The Lorentz Gas

II. HYDRODYNAMICS (3 lectures)

1) Connection Between Microscopic and Macroscopic Approaches (1.5 lectures)
   - (a) Approach to Equilibrium
   - (b) The Hydrodynamic Conservation Laws
   - (c) Zeroth-Order Approximation and Its Consequences
     - –"dry" hydrodynamics
   - (d) First-Order Approximation and Its Consequences
     - –transport coefficients in the relaxation-time approximation

2) The Navier-Stokes Equation (1.5 lectures)
   - (a) Basic Properties of Viscid Flows
     - –turbulence and the Kolmogorov spectrum
     - –instabilities — flow, surface, & thermal

III. FLUCTUATIONS AND IRREVERSIBLE PROCESSES (9 lectures)

1) The Master Equation Description (4 lectures)
   - (a) Evolution in Closed Systems
   - (b) Random Walk Processes
     - –Poisson process
     - –homogeneous random walk & central limit theorem
     - –random walk in a disordered environment
   - (c) The Detailed Balance Condition and Applications
   - (d) The Ising-Glauber Model
     - –exact solution for the evolution of the correlation functions
     - –the "voter" model

2) The Langevin and the Fokker-Planck Equation (3.5 lectures)
   - (a) Basic Properties of Random Noise
   - (b) Solution to the Langevin Equation
     - –white and colored noise
     - –connection between random force and damping
     - –Brownian motion

(c) Derivation of the Fokker-Planck Equation
(d) Connection Between the Langevin and Fokker-Planck Descriptions
(e) Applications of the Fokker-Planck Equation
–position and velocity distribution of a Brownian particle
–the central limit theorem

3) Spectral Analysis of Stochastic Processes (1.5 lectures)

(a) Fourier Analysis of Random Functions
–spectral properties of white, Brownian, and 1/f noise
(b) Basic Properties of Correlation Functions
(c) Nyquist Theorem

IV. APPLICATIONS (12 lectures)

1) First-Passage Phenomena (4 lectures)

(a) Recurrence and Transience in Random Walks
(b) Absorption at Boundaries and Connection to Harmonic Analysis
(c) Mean First-Passage Time
–adjoint equation for time-integrated properties
(d) Applications
–first passage in semi-infinite systems
–Smoluchowski theory of chemical kinetics
(e) First Passage in Confined Geometries
–survival probability in an expanding interval
–survival probability in a wedge

2) Fundamental Non-Equilibrium Processes (8 lectures)

(a) Aggregation
–solution to the rate equations for the constant, sum, and product kernels
–role of fluctations
(b) Fragmentation
–rate equation solutions and the scaling approach
(c) Irreversible Adsorption
–jamming phenomena
(d) Phase Ordering Kinetics
–metastability vs. instability
–non-conserved order parameter — interface dynamics
–conserved order-parameter — coarsening
(e) Reaction Kinetics
–trapping, coalesence, aggregation, 2-species annihilation
(f) Growing Complex Networks