Highly ambitious outlines for Physics 211ABC sequence
SOLID STATE PHYSICS

211A (this will be offered as section C of 239 during F19)

1. Phases of matter
a. the mother of all Hamiltonians (H)
b. classical and quantum phase transitions

2. Spontaneous symmetry breaking
a. Landau theory
b. generalized rigidity
c. lower critical dimension
d. Goldstone and Hohenberg-Mermin-Wagner theorems

3. Crystals
a. crystallography
b. Landau theory of weak crystallization
c. phonons: dispersion, Debye-Waller factor, $S(\mathbf{q},\omega)$
d. elasticity
e. exotica: quasicrystals, defects

4. Metals and insulators
a. electrons in a periodic potential generated by SSB (Bloch's thm and consequences)
b. band gaps; metals and insulators in the simple band picture of solids
c. semiconductors and band insulators
d. thermodynamic consequences: Pauli susceptibility, heat capacity, compressibility
e. Boltzmann transport theory
f. Hartree-Fock and density functional theory
g. screening, RPA, Lindhard function, $S(\mathbf{q},\omega)$
h. linear response and optical properties
i. interactions can change the picture: Hubbard model, Mott insulators

5. Mesoscopia and localization
a. Landauer formula and its multichannel generalization; Pichard's formula
b. Interference effects; universal conductance fluctuations
c. weak localization
d. Anderson localization: localized vs. extended states, models of disorder, scaling theory

211B

1. Fermi liquid theory
a. adiabatic continuity
b. free energy as a functional of distribution n($\mathbf{k}\sigma$); interactions f($\mathbf{k}\sigma$,$\mathbf{k}'\sigma'$)
c. quasiparticles
d. equilibrium properties and thermodynamic stability
e. Landau-Boltzmann equation

2. Second quantization
a. Green's functions for fermionic systems
b. diagrammatic perturbation theory
c. theory of the electron gas

3. Instabilities of the Fermi liquid : mean field theory and gap equation
a. charge density wave
b. spin density wave
c. superconductivity
d. exciton condensate

4. Superconductivity
a. Ginzburg-Landau theory
b. effective attraction mediated by phonons
c. BCS theory
d. electromagnetic response for BCS superconductors
e. Josephson effect and Josephson junctions
f. vortices and duality; KT transition

5. Quantum magnetism of insulators
a. Heisenberg model; superexchange
b. spin wave theory and Schwinger boson formulation
c. quantum disordered states below the LCD; Néel vs. VBS vs. spin liquid states
d. spin chains: Bethe Ansatz (S=1/2), Haldane gap and VBS (S=1), continuum field theory

211C

1. Interacting bosonic systems
a. Bose-Hubbard model
b. mean field analysis: superfluidity and Mott lobes; the Mott-SF transition
c. superfluids, Gross-Pitaevskii model (NLSE)
d. vortices

2. Kondo effect and heavy fermion liquids
a. single impurity Kondo effect, mean field approach, poor man's scaling
b. two channel Kondo problem
c. Kondo lattice Hamiltonian and its phases (heavy fermion metal, Kondo insulator)

3. Bosonization and Luttinger liquid theory
a. 1D interacting Fermi systems, "g"-ology
b. abelian bosonization and the Luttinger model
c. spin-charge separation
d. sine-Gordon theory, Coulomb gas description
e. KT transition and RG, spin and charge gaps

4. Quantum Hall effect
a. Landau levels for ballistic and Dirac dispersions
b. lowest Landau level plus disorder: the integer quantum Hall effect
c. TKNN formula and Chern numbers
d. Laughlin's wavefunctions (abelian case); quasiparticles (charge, statistics), Chern insulators
e. Hierarchy of abelian FQH states; composite fermions
f. CSGL theory of the FQHE (K-matrices)
g. exotica: skyrmions, half-filled LL, nonabelions, QH ferromagnetism

5. Quantum spin liquids
a. confinement / deconfinement (Fradkin-Shenker)
b. Kitaev's toric code and honeycomb lattice models
c. long-ranged entanglement
d. spin ice and quantum spin ice
e. emergent gauge theories