Harvard University

Applied Physics 295b: Quantum Theory of Solids

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Tentative Course Outline

1. Electrons in a periodic crystal lattice. Quasimomentum. Strong and weak binding approximations.
2. Landau's theory of Fermi liquids. Interaction between quasiparticles. Collective modes: zero sound, first sound, spin waves.
3. Response and correlations. Dynamic form factor. Response function. Sum rules.
4. Screening and plasma oscillations in electron liquid.
5. Microscopic Hamiltonian for interacting electrons. Second quantization.
6. Hartree-Fock approximation for Fermi systems with short and long range interactions.
7. Dielectric constant for electron liquid. Random Phase Approximation.
8. Macroscopic and microscopic instabilties of the Fermi liquids. Stoner instability. Instabilities of one dimensional systems to CDW and SDW ordering.
9. Ferromagnetic and antiferromagnetic spin exchange interactions for localized electrons.
10. Quantum magnets (ferro and antiferro).
11. The electron Hubbard model for d-band electrons. Antiferromagnetic instability at half-filling.
12. Anderson and s-d models.
13. RKKY interaction between impurity spins.

14. Kondo effect. Perturbation theory for the electron scattering at high temperature. Poor man's scaling. Low temperature Fermi liquid behavior.

15. Field-theoretic methods in the many-body problem. Green's funcions for non-interacting fermions and bosons. Perturbation series for interacting particles. RPA for the coupled electron-phonon system.

16. Superconductivity. General properties: resistance, Meissner effect, thermodynamics. Intermediate state of superconductors in the magnetic field.

17. Superconductivity. Electron-electron interaction mediated by phonons.

18. Cooper problem. Bardeen-Cooper-Schrieffer wavefunction.

19. Bogolyubov quasiparticles. Sound attenuation and nuclear spin relaxation rate in superconductors. Coherence factors.

20. Effect of Coulomb interaction on Tc.

21. Bogolyubov de Gennes equations for inhomogenious superconductors. Anderson's theorem.

22. Unconventional superconductors: high Tc cuprates, triplet superconductors.

23. Phenomenological Ginzburg-Landau theory of superconductivity. Two types of superconductors. Mixed state of type II superconductors.

24. Electron gas in a magnetic field. Integer and fractional quantum Hall effects in two dimensional electron systems.

Primary references

1. A. Abrikosov. *Fundamentals of the theory of metals.*
2. A. Abrikosov, L. Gorkov, and I. Dzyaloshinski. *Methods of quantum field theory in statistical physics.*
3. N. Ashcroft and N. Mermin. *Solid State Physics.*
4. A. Auerbach. *Interacting Electrons and Quantum Magnetism.*
5. S. Doniach and E. Sondheimer, *Green's functions for solid state physicists.*
6. de Gennes. *Superconductivity of Metals and Alloys.*
7. C. Kittel. *Quantum theory of solids.*
8. G. Mahan. *Many-Particle Physics.*
9. M. Marder. *Condensed matter physics.*
10. P. Nozieres and D. Pines *The theory of quantum liquids.*
11. Landau and Lifshitz course on theoretical physics. *Statistical physics*, part 2.
12. J. Schrieffer, *Theory of Superconductivity.*
13. M. Tinkham, *Introduction to Superconductivity.*