

Solid State Physics 601 Fall 2019

with Jak Chakhalian

Here is the course content which I would like to cover during this semester. Unlike two years this semester the emphasis will be on the enhancements to help grad. students to get acquainted with modern terminology and whenever possible illustrate advanced concepts related to topology and quantum materials.

Grading: Homeworks (30%), mid-term (30%), final (40%). Final grade is determined by averaging over all the components. Also read “*How to get A in my class*”, the basic principles are very relevant to our course – posted on our web site.

<http://physics.rutgers.edu/~chakhalian/CM2019/>

Office hours: Monday 9:30-10:30 am, room 109 Physics & Astronomy

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Topics (tentatively) to be covered:

0. Introduction to condensed matter.
1. Ginzburg Landau theory of **phase transitions**
 - a. 2d order phase transitions
 - b. 1st order phase transitions
 - c. Inhomogeneous cases
 - d. Quantum phase transitions
2. Generalization of order parameter and Goldstone theorem
3. Broken symmetry from field theory point of view (OPTIONAL)

4. What are **quasiparticles** and **excitations**?
5. Main characteristics of QPs.

6. Ground state of a crystal. Zero energy oscillations.
7. Methods for description of thermal oscillations. **Phonons** in 1D and 2D
 - a. Standing waves
 - b. Running waves
 - c. Dispersion
 - d. Acoustic waves with nn interactions

- e. Acoustic waves with nnn interactions

- 8. Acoustic phonons in 3D
- 9. Energy spectrum of acoustic phonons
- 10. Spectral density of acoustic phonons
- 11. Van Hove singularity in 3D and 2D
- 12. Optical phonons
 - a. Dispersion of optical phonons
 - b. Optical phonons in 3D
 - c. Spectral density of optical phonons
- 13. Interaction of phonons (OPTIONAL)
 - a. Anharmonic effects
- 14. Phonon-phonon scattering (OPTIONAL)
- 15. Heat capacity – Debye theory
- 16. Heat capacity in 2D
- 17. Thermal conductivity
- 18. Surface phonons (OPTIONAL)

19. Fermi liquid theory

- a. Non-interacting electrons
 - b. Fermi energy and momentum
 - c. How to describe excitations
 - d. A model of fermi liquid
- 20. Quasiparticles on the hole like Fermi surface
 - 21. Lifetime of quasiparticles
 - 22. Electrons in a periodic potential
 - 23. Bloch theorem
 - a. Fermi momentum
 - 24. Brillouin zones
 - a. 2D and 3D
 - b. Examples
 - 25. Fermi surface
 - 26. How to build Fermi surface?
 - 27. Examples of standard Fermi surfaces.
 - 28. Fermi surface and extended Br. zones.
 - 29. Topology of fermi surface
 - 30. Singularities of Fermi surface
 - 31. Dynamics of quasiparticles
 - 32. Effective mass
 - 33. Quasiparticle scattering.
 - 34. Electrical conductivity

35. Electronic contribution to thermal conductivity.
36. Electrons in a constant magnetic field
37. Energy spectrum of quasiparticles in magnetic field for the case of ideal fermi gas
38. Landau quantization
39. Density of electrons in magnetic field

40. Quantum Hall effect
41. Berry phase and Berry connection
42. Chern **topological insulator**

Other issues:

I will use several texts including journal papers, other people lecture notes, my personal notes etc. to make the topics are clear as possible. Again, all the class notes and extra material will be posted on our web site:

<http://physics.rutgers.edu/~chakhalian/CM2019/>

The main source which roughly covers our class material can be found in the first 9 chapters of **Modern Condensed Matter Physics by Kun Yang and Steven Girvin, Cambridge U. press 2019.**

4 other texts will be extensively used:

1. **Daniel Khomskii, Basic Aspects of the Quantum Theory of Solids (superb!)**
2. Marvin Cohen and Steven Louie, Fundamentals of Condensed Matter Physics
3. **Tom Lancaster and Stephen Blundell, Quantum field theory for the gifted amateur (superb!)**
4. A. Zee, Quantum field theory in nutshell.

You cannot learn how to play piano by only listening music. Practice is the only way to acquire real knowledge of the subject. Every week or every other week (depending on the topic) you will receive a problem set.

Midterm and final exams will be administered to develop your confidence.

A 100% class attendance is expected, however, in a case you really must miss the class please notify me via email. And finally, if you already know all the topics for the class, please, see me ☺.

Also,

- **We will follow the University increment weather policy.**
- **We will follow the University integrity and ethics policies.**