Physics 880.06 (Autumn 2009)
Condensed Matter Physics I
Instructor: Professor Nandini Trivedi

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Office hours: Wednesdays 5:30 pm-6:30 pm [Note: HWs due on Thursdays]; and also by appointment

Physics 880.06 Condensed Matter Physics is a three-quarter sequence of graduate-level courses taught from a modern perspective. I will emphasize how in a system of many interacting particles new phases of matter emerge, their spontaneously broken symmetries, collective modes and phase transitions.

Lecture schedule:
Tuesdays and Thursdays 1 pm -2:18 pm Room: Scot E0103
Wednesdays 4-5:30pm SO E0241
(to accommodate travel during the quarter)

Who should take this course? If you want to do research in condensed matter physics--either theory or experiment, you will make extensive use of ideas developed in this course. This course can also be useful for students in materials science, chemistry and also high energy and nuclear physics given that the concepts and techniques that you will encounter in this course are sufficiently general and worth understanding. Please see the detailed course contents.

Course structure: I will start by motivating each topic through experiments, develop the theoretical framework and then return to a more detailed comparison with experiments to understand the successes, limitations and open questions. Computer simulations have emerged as an important tool for visualization and active engagement of students. When appropriate I will use mathematica to demonstrate some of the important concepts.
Students will be encouraged to participate actively in the class. There will be 5-6 homeworks that could involve the use of mathematica and/or matlab for plotting and writing small programs in order to get a better grip on the material. In most cases a mathematica template program will be provided. There will also be one independent small project.

Grades: Grades will be determined by a combination of HWs (60%); project (20%) ; Discussions (20%)

Prerequisites: The present course is a beginning level self-contained condensed matter course aimed at both experimentalists and theorists.
I will not assume any prior knowledge of solid state physics. A background in undergraduate statistical physics and quantum physics is necessary.

Course Contents

Quarter I

(1) Crystal Structure
(2) Reciprocal Space
(3) Electron Bands

Quarter II

(4) Phonons
(5) Semiconductors
(6) Electron-Electron Interactions
(7) Superconductivity

Quarter III [under construction]

(8) Boltzmann Transport theory
(9) Landauer Transport

(10) Magnetotransport
(11) Quantum Hall Effect
(12) Metal-insulator transitions

Detailed Course Contents (I Quarter):

1. Core ideas of condensed matter physics

2. Crystal Structure
   - X-Ray diffraction and Structure Function
   - Spontaneously broken translational symmetry, order parameter
   - Symmetry and Bravais Lattices
   - Reciprocal Lattice, Brillouin zones, Lattice planes
   - Crystal with basis
   - Effects of temperature and disorder on diffraction
   - Landau theory for first order and continuous transitions

3. Fermi Liquids
   - Drude Theory ; transport, magnetotransport
   - Free Electron Gas; Fermi surface ; density of states
   - Thermodynamics (specific heat and spin susceptibility) of free electrons ; Sommerfeld expansion
   - Photoemission spectroscopy and band structure
   - Signatures of interactions

4. Electron in a Periodic Potential;
   - Energy bands; Metals vs Band Insulators
   - Wannier functions; Tight binding approach
   - Bloch's Theorem
   - Cuprates- tight binding on square lattice; density of states

Graphene- tight binding with 2-atom basis
Silicon- tight binding with 4 atom basis
Failure of band theory

Textbook:

1. N. W. Ashcroft and N. D. Mermin, Solid State Physics, W.B. Saunders, Philadelpha, 1976.

Other References:

Other References you may find useful: They have been placed on reserve in the Science and Engineering Library.

2. H. Ibach and H. Luth, Solid-State Physics, An Introduction to Theory and Experiment, Springer-Verlag, Berlin, 1991.
3. C. Kittel, Introduction to Solid State Physics, 7th edition, John Wiley and Sons, New York, 1996.
4. M. P. Marder, Condensed Matter Physics, Wiley, 2000.
5. L. Mihaly and M. C. Martin, Solid State Physics: Problems and Solutions, Wiley, 1996.
6. W. A. Harrison, Solid State Theory, McGraw-Hill, New York, 1970.

Seminars and Colloquia: We are fortunate to have a large number of high caliber seminar and colloquia series, and you should try to attend at least some of them regularly. Especially while you are in the process of making the crucial decision of what research field to enter it is very important to hear something about a broad range of fields. The seminars and colloquia are listed in the weekly Physics Department calendar. You may wish to make a note of the following regular events:

Seminar	When	Where
Condensed Matter Physics Theory	Mon 11:30	Smith Seminar Room
Condensed Matter Physics Experiment	Thurs 11:30	Smith Seminar Room
Physics Colloquium	Tues 4:00	Smith Seminar Room