Applied Physics 114c: Solid-State Physics

(Dated: Spring, 2016)

Instructor:
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Lectures:
M,W,Fr 9:00-9:55AM, Rm. 104 Watson

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Course Website:
`http://copilot.caltech.edu/classes/aph114`

Course work:
1 HW/week ($\sim$ 7 HWs). HW will be given out at the end of Friday lecture, and due the following Friday. HWs should be handed in to the "INBOX" box outside Watson 268. You can pick up graded HWs and exams from the "OUTBOX". There will be a mid-term exam (1 hour, in class) and a final "HW" exam. With regard to grading, HW will make up 70% of your grade, mid-term exam 10%, and final exam 20%. Please talk to me if you feel you want to take the course pass/fail.

Policies:
Homework: Limited collaboration allowed; make sure to work out the details of solutions on your own. Use of any texts, any notes, computers, etc. is fine. For MATLAB and Mathematica output please provide brief (but comprehensible) commentary.

Textbooks and References:
I plan to follow a number of textbooks, which I list below as recommended reading. I will make (electronically) available the relevant sections.

Main source material:
"Solid State Physics," by Neil W. Ashcroft and N. David Mermain [AM]
"Introduction to Superconductivity," Michael Tinkham [MT]
"Electronic Transport in Mesoscopic Systems," by Supriyo Datta [SD]

Recommended reading:
"Introduction to Solid State Physics," Charles Kittel
"Superconductivity," J. B. Ketterson and S. N. Song
"Quantum Hall Effects: Field Theeoretical Approaches and Related Topics," by Zyun F. Ezawa
"Superconductivity of Metals and Alloys," by P. G. de Gennes

Course Outline: The class is intended as an *introduction* to Solid State Physics, and will be taught accordingly (i.e., very little prior knowledge expected). The third term of APh 114 has historically been somewhat of a special topics class, where we have the opportunity to pick and choose topics of interest that build on our knowledge gained in the first two terms, although in recent years it has focused on magnetism and superconductivity. Below is a proposed syllabus which focuses a little more on superconductivity, and also introduces concepts of electronic transport in mesoscopic systems.

1. **Diamagnetism and Paramagnetism [Ch. 31 AM]**

2. **Magnetic Interactions and Magnetic Ordering [Ch. 32, 33 AM]**
   Heisenberg spin models, exchange interactions, Hubbard model, types of magnetic structure, thermodynamic properties

near the onset of magnetic ordering, ground state and low-lying excitation of the Heisenberg ferromagnet, mean field theory of the ferromagnetic transition.

3. **Superconductivity: historical overview [Ch. 1 MT, Ch. 34 AM]**
   perfect conductivity and perfect diamagnetism, London's equations, Pippard nonlocal electrodynamics, energy gap and BCS theory, Ginzburg-Landau theory, Type II superconductors, Josephson tunneling.

4. **Electrodynamics of Superconductors [Ch. 2 MT]**
   The London equations, the intermediate state of a Type I superconductor, high frequency electrodynamics.

5. **The BCS Theory of Superconductivity [Ch. 3 MT]**

6. **Ginzburg-Landau Theory of Superconductivity [Ch. 4 MT]**

7. **Josephson Effect [Ch. 4, Ch. 5 MT]**
   basic phenomena and applications, SQUID devices, small junctions effects, superconducting qubits (transmon).

8. **Mesoscopic Transport: Preliminaries [Ch. 2 SD]**
   Landauer formula, "contacts", "resistance", "voltage probes", Buttiker formula, three and four terminal devices, reciprocity, non-zero temperature effects, scattering states, non-coherent transport, Landauer-Buttiker formalism.

9. **Mesoscopic Transport: Transmission Functions, Green's Functions, and the S-matrix [Ch. 3 SD]**

10. **Mesoscopic Transport: Quantum Hall Effect [Ch. 4 SD]**
    integer quantum Hall effect, "zero" resistance, introduction to fractional quantum Hall effect.

11. **Mesoscopic Transport: Localization and Fluctuations [Ch. 5 SD]**
    localization length, weak localization, conductance fluctuations, diagramatic perturbation theory (graphical analysis and Goldstone diagrams again).