Physics 7304: Condensed Matter Physics

Spring 2008

Instructor: R.L. Lichti roger.lichti@ttu.edu **Office**: Rm 19 Sc 742-3697 **Hours**: 10:00-12:00 MWF Open Door in general

Meeting Time: 11:00-12:30 TTh Rm: 112 Sc

Course Goal: This course will examine a few of the many complex phenomena that occur in solids and quantum liquids, and will expose the student to some of the theoretical tools used to describe the basic interactions that are behind these phenomena.

Text: A specific text is not required; however, much of the material will come from a CM theory text, PL Taylor and O Heinonen, *A Quantum Approach to Condensed Matter Physics*, Cambridge, 2002, which uses the "second quantization" approach and focuses on elementary excitations and interactions. Some additional treatments will most likely be taken from an older text that uses a similar approach:
O Madelung, *Introduction to Solid State Theory*, Springer-Verlag, 1978.
The second aspect of CMP covered in this course extends traditional solid state physics to non-crystalline materials, including quasi-periodic and amorphous systems, liquid crystals, photonic crystals, etc.
D Feng and G Jin, *Introduction to Condensed Matter Physics*, Vol 1, World Scientific, 2005, covers these aspects to some degree as well a number of topics included in the other two sources.

Learning Goals: In this course a student will have the opportunity to
1) Identify the fundamental excitations which occur in solids.
2) Formulate (and solve) problems using the so-called second quantization approach.
3) Model interacting electron and phonon systems to go beyond the typical introductory SS level.
4) Examine various cooperative phenomena such as magnetism, superconductivity, and superfluidity.
5) Explore the basic features of large scale periodic structures, superlattices, photonic crystals, etc.
6) Look at experimental methods and results that are specifically relevant to the studied phenomena.

By the end of this course a student who expects to do research in the field of condensed matter should have developed a basic understanding some of the important current problems in this field and have some idea of the theoretical approaches used in treating these problems. The student should also have obtained sufficient background by the end of this course to be able to extract the basic ideas from much of recent scientific literature in this field.

Assessment: Because this course is aimed mostly at advanced MS or PhD level students who are actively pursuing research in some form of condensed matter physics and because the amount of work required for any meaningful problem is fairly lengthy, there will not be any exams. The degree to which a student has mastered the basic ideas of this course will be judged from their participation in discussion of the presented topics and performance on a few sets of assigned problems. Students will be asked to present some topics and lead the discussion, especially in areas where they are actually working, as a way of gauging how far they have progressed. Each student will choose an advanced topic which they will explore in more detail, drawing on the basic research literature. A paper and presentation of this topic will then be given to the full class near the end of the semester.

The **course grade** will be based mostly on the problem sets and the final paper and presentation on a specialized topic. However, a portion of the grade will be reserved for regular participation in the discussions during class meetings and quality of work on any smaller topics assigned for student presentation during this course.

Weighting: Problem sets 40% Project paper and presentation 40% Participation 20%

Topics Expected to be Covered
(Not necessarily complete or in order)

Elementary Excitations
Second Quantization (Quantum Field Theory) Approach
Interacting electron systems, Fermi liquids, Heavy Fermions, etc
Materials with amorphous or only quasi-periodic structure
Large-scale periodic structures, Photonic Crystals, Superlattices, etc
Defects, Impurities, Dislocations, etc
Magnetism and various types of coupling interactions
Magnetic impurities and the Kondo problem
Superconductivity and Superfluidity

Some General Comments: This is the first time I have taught this course, and I will be developing it as we go for the most part, so thus do not wish to lay down a definitive topic schedule up front. Also, I hope to be able to structure the course to spend some of the time on topics that are of particular interest to students, especially topics relevant to your research projects.

We will emphasize the approaches to modeling various phenomena in Condensed Matter Theory, as well as attempting to understand the phenomena themselves, rather than the math details of model calculations. There are a number of sources for those types of details if students are interested in pursuing the math development in a more rigorous fashion. I can help find relevant sources if requested, but do not expect to use much class time on such details.

I hope to have much of this course structured as student discussion of these topics rather than mostly lectures, so be prepared to hunt down sources and study topics independently so we can discuss the treatments that you have found and what parts you understand – or more likely, the aspects that you do not fully understand, or are completely confused about. It has been a long time since I looked at some of these topics in any detail, so I may have questions as well.

For this approach to work well, everyone needs to be willing to actively participate and be willing to ask questions and be open about what you are struggling to understand. And most importantly, to put effort into finding useful sources and into reading and studying, and working out some simplified problems to demonstrate important ideas, methods, and results. Lots of feedback and open discussion is crucial.
At this level and in this course structure, I see my role more as a guide for your/our study of covered topics rather than as an expert handing down knowledge.

Special Topic Project: Each student will select a significant topic to research and study in detail. This can overlap with your research: itt should specifically *not* be your main degree project – but could be relevant background or a side topic. A written paper / report based on the primary literature (rather than textbook sources) and an oral presentation of this topic is required of each student. Start early, these special topic projects need to have some real substance. We will use the last two weeks of the course for presentation of these project topics.

The usual ADA statement follows – if relevant, stop by to discuss what we can do to help.

Any student who, because of a disabling condition, may require some special arrangement to meet the course requirements should contact the instructor as soon as possible so that appropriate accommodations can be made. Proper documentation must be presented from the Dean of Students Office.