A Special Topics Graduate Course:  
Correlated Electrons in Reduced Dimensions  
PHYS 392T  
Unique Number 59080  
(Spring Semester, 2009)

**Instructor:** Prof. Greg Fiete.  
Office: RLM 13.316.  232-8084.  fiete@physics.utexas.edu

**TA:** Not sure

**Classes:**  
MWF 11:00 am-12:00 noon,  RLM 5.120.

**Office hours:** Monday 12:00 noon-1:00 pm and by appointment.

**Textbook:** *Condensed Matter Field Theory* (Cambridge) by Altland and Simons.  This is a very good textbook on the modern approach to many-body theory in solid state physics.

**References:** We will refer to more than 10 books and many original research articles throughout the course.  The helpful references will be given at the time of the lecture.

**Prerequisite:** PHY393K (Solid State Physics),  
or permission of instructor (come see me if you aren’t sure).

**Course Requirements:**  
CLASS ATTENDANCE.  We will not be following any particular text, but pulling ideas and results from a wide variety of sources.  If you miss a class you will likely miss the material for that day so attendance is very important.

5-6 Homework sets (roughly due every 2 weeks) to emphasize most important ideas from class.  There will be NO final exam.  Instead, each student will choose a topic with consent of instructor to write a short paper on at the end of the term.  Each student will give a brief (~30 minutes) presentation to the class at the end of the semester on the topic he or she chose.

**Material to be Covered:**  
While this course is nominally on “Correlated Electrons in Reduced Dimensions” it is really much broader in scope.  We will occasionally discuss bosons and systems in three dimensions when there are particular features of interest, such as topological aspects.  In fact, the topological aspects of many-particle systems will form a common thread through almost all of the topics covered in this course.  We will begin by motivating how topological features arise in condensed matter through a discussion of adiabatic motion and the so-called “adiabatic
invariant” which is intimately related to all topological properties of matter. Along the way, we will see many examples of Berry phase effects, topological invariants, and topological defects. We will learn why topological properties can lead to a remarkable robustness of the quantum mechanics, even when disorder and other “non-idealities” are present. We will develop the path-integral formulation of quantum mechanics which is essential to capturing some topological features in a mathematically transparent way. After laying the basic groundwork of path integral techniques, we will investigate physical systems by working our way through important problems in one dimension, two dimensions, and eventually three dimensions. In one dimension we will focus much attention on magnetic systems (spin-chains) and strongly interacting electrons. We will discuss the idea of a “quantum phase transition” occurring at zero temperature and develop the important renormalization group methods necessary for describing “critical” behavior and the phase diagram itself. In two dimensions, we’ll discuss the unusual topological Berezinskii-Kosterlitz-Thouless phase transition which appears in many contexts, and the classification of topological defects using homotopy theory. We will also touch on the gauge theory of strongly correlated electrons and the $CP^1$ formulation here. To develop a general framework for quantum critical phenomena in 3 dimensions, we’ll jump to 4 dimension to develop the important technique of the epsilon expansion using momentum shell renormalization group applied to $\phi^4$ theory. Next, we will develop the basic elements of Conformal Field Theory (CFT) which is exceptionally powerful in the analysis of certain $(1+1)$ and $(2+0)$ dimensional systems. We will then move to the paradigm of topologically ordered states, the Quantum Hall state. We will discuss integer topological classifications, and fractional classifications. We will separately consider Abelian and non-Abelian fractional quantum Hall states and demonstrate how CFT plays an integral role in our understanding of the non-Abelian ones. We will discuss the connection between Chern-Simons theory, CFT, and the wavefunctions of fractional quantum Hall states. Throughout the course connections will be drawn between many apparently different systems to help illustrate the unifying principles in operation. Finally, we will finish up with topological superconductivity and topological band insulators, a topic for which there is no textbook in existence. (It’s impossible. Topological band insulators were only discovered about 3 ½ years ago and a book can’t be written and published in that time frame.) In all of the topics presented in this course, it will be emphasized that symmetry plays a key role in determining the ultimate physical behavior.

**Perspective of instructor:**

I have designed this course to fill in many of the gaps I see in the graduate curriculum for the education of a modern condensed matter/many-body theorist. While the course is aimed mostly at theorists, I hope the ideas will be presented clearly and simply enough that experimentalists and undergraduates attending the course will learn a great deal. Assuming you have completed the other standard graduate and undergraduate courses in solid state physics, there should be few research articles with terminology and concepts unfamiliar after this course. You will be “dressed” to begin research in a wide variety of areas in modern many-body condensed matter physics.
Required University Notices and Policies

University of Texas Honor Code
The core values of The University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the university is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community.

Use of E-Mail for Official Correspondence to Students
Email is recognized as an official mode of university correspondence; therefore, you are responsible for reading your email for university and course-related information and announcements. You are responsible to keep the university informed about changes to your e-mail address. You should check your e-mail regularly and frequently—I recommend daily, but at minimum twice a week—to stay current with university-related communications, some of which may be time-critical. You can find UT Austin’s policies and instructions for updating your e-mail address at http://www.utexas.edu/its/policies/emailnotify.php.

Documented Disability Statement
If you require special accommodations, you must obtain a letter that documents your disability from the Services for Students with Disabilities area of the Division of Diversity and Community Engagement (471-6259 voice or 471-4641 TTY for users who are deaf or hard of hearing). Present the letter to me at the beginning of the semester so we can discuss the accommodations you need. No later than five business days before an exam, you should remind me of any testing accommodations you will need. For more information, visit http://www.utexas.edu/diversity/ddce/ssd/.

Religious Holidays
By UT Austin policy, you must notify me of your pending absence at least fourteen days prior to the date of observance of a religious holy day. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, I will give you an opportunity to complete the missed work within a reasonable time after the absence.

Behavior Concerns Advice Line (BCAL)
If you are worried about someone who is acting differently, you may use the Behavior Concerns Advice Line to discuss by phone your concerns about another individual’s behavior. This service is provided through a partnership among the Office of the Dean of Students, the Counseling and Mental Health Center (CMHC), the Employee Assistance Program (EAP), and The University of Texas Police Department (UTPD). Call 512-232-5050 or visit http://www.utexas.edu/safety/bcal.

Emergency Evacuation Policy
Occupants of buildings on the UT Austin campus are required to evacuate and assemble outside when a fire alarm is activated or an announcement is made. Please be aware of the following policies regarding evacuation:
- Familiarize yourself with all exit doors of the classroom and the building. Remember that the nearest exit door may not be the one you used when you entered the building.
- If you require assistance to evacuate, inform me in writing during the first week of class.
- In the event of an evacuation, follow my instructions or those of class instructors.
- Do not re-enter a building unless you’re given instructions by the Austin Fire Department, the UT Austin Police Department, or the Fire Prevention Services office.