Physics 262 : Topological phases and aspects of localization

The focus of this course will be topological phases. If we have the time, towards the end, we will also dwell on some aspects on the physics of localization especially in the context of topological phases.

This is an advanced course: a basic background in condensed matter and some familiarity with the relevant topological ideas (fibre bundles, etc.) is expected. This is also a seminar course: Students will be expected to make presentations on some set of papers which are agreed upon in advance in consultation with the instructor.

Topological phases and the physics of localization are both very rich fields. In this course, we will barely scratch the surface. The aim of this course is not to provide a comprehensive treatment of disorder and topological phases, which would be difficult if not impossible in the short space of a quarter, but to provide a foundation for doing research in some of the hottest current topics of theoretical condensed matter. Students will get both an overview of the field and a detailed introduction to at least one topic.

I will present a set of introductory lectures whose topics are listed below in the sequence in which we will approach them. It is an ambitious list and we might not get to the last two or three topics. The emphasis will be on presenting theoretical pictures, heuristics and rationalizations of results, rather than rigorous derivations in class. These lectures will be interspersed by a set of student seminars.

The way I hope the seminars will work is as follows: I will make a set of suggestions (individually to the students whose backgrounds I am familiar with) for the set of presentation topics. Students will have at least three weeks to prepare for their presentations. The preparation for the presentations are intended to be a crucial part of the learning process. A student should work on a paper which presents a challenge for him/her (but not an unsurmountable one). The aim should be to have a thorough understanding of this work. (I strongly recommend original works over review papers for this course). The student should therefore try to work through this paper rigorously, and in detail. He/She should meet with me regularly to discuss progress and especially when he is stuck.

The actual presentations are also not unimportant - if done well, they will also really help the rest of the class, but I want to emphasize the preparation that goes towards it.

Physics 262 Special Topics Seminar on Topological Phases and aspects of Localization.

I Introduction :-

- topology in physics - brief historical overview
  - Dirac Monopoles
  - Solitons, Instantons, etc.
  - Berry curvature.
  - Anomalies & index theorems.
- topological phases - brief overview.

II Integer Quantum Hall. Effect

IQHE

→ basic phenomenon.

→ theory
  - const B field Hamiltonian
    - Landau levels
  - quantization of Hall conductivity in insulators.
    - Laughlin argument.
  - role of disorder.
  - Chern insulators.

III Fractional Quantum Hall Effect. (FQHE):-

- Role of interactions & projection to LLL
- Trial wavefns.
- Elementary excitations
  - quasiparticles & quasiholes.
  - collective excitations

Topological field theory & Chern Simons description.

IV Topological Insulators & Superconductors

- Altland-Zirnbauer symmetry classes.
- K-theoretic classification
- Non-linear σ model based classification.

V. Disorder in electronic systems *

- Disorder in Metals.
- Replica Field Theory approach to impurity scattering
- Diffusion
- RG analysis of the nonlinear σ model
- Scaling theory of the Anderson transition

VI. Topology & quantum field theory. *

- θ terms & spin chains
- Pruisken's field theory description of the quantum Hall transition
- Chern Simons terms & Wess Zumino Witten terms.

* – if time permits