

DESCRIPTION: PHYSICS 683 QUANTUM HALL MODULE (Feb-Mar 2006)

Chris Henley, 531 Clark, 5-5056, clh@ccmr.cornell.edu,

Office hour TBA (Tu 2/14/06 3:30-4:30 PM)

please send your email address to be mailing list, if you didn't write it already

website: people.ccmr.cornell.edu/~clh/p683/683.html

Grader: Sourish Basu

CONTENT

Goal: in this portion, the emphasis is not techniques so much as phenomena.

“Prerequisites”: these are not required, mostly not even expected, but every bit of past exposure helps. I'll summarize what I need, but since I surely won't have time to present them in context.

transport: Anderson localization, Landauer conductance in 1D channels

interacting electrons: Luttinger liquid ($d = 1$ analog of Landau's Fermi liquid)

statistical physics: percolation transition, fractal dimension

superconductivity (?)

magnetism: spin stiffness, spin waves (?)

electron hopping on lattice models (very little)

NO field theory. NO Feynman diagrams.

Philosophy

Focus on the simplest nontrivial examples, and introduce only those formalisms that lead to calculations you can do. Variety of topics, sometimes at the expense of depth.

“The most intelligent question is the one that most precisely reveals your ignorance.”

Note – my lectures are chunked into an outline form, not a continuous stream. Please don't ignore the headings: they're signals that a result has been obtained, and I'm heading on to a new subtopic.

Every Weds. lecture, a “**Teaser question**” (or “thought question”) will come out due on Fri. It's designed to take just 10 minutes, and to involve mostly qualitative or back-of-the-envelope thinking, or locating relevant passages, not calculations. **Marked for participation, not correctness!** Sometimes there IS no “right” or “wrong” answer! On the next lecture day, I'll give my answer (use the space on the right hand side of the sheet to take your own notes). Then you **hand them in to me**, and they'll be returned the next lecture day.

Texts

Later I'll give a separate handout on books and other resources (part this is in the books list on the main P683 website). The main text is “The Quantum Hall Effect: Novel Excitations and Broken Symmetries” by Steven M. Girvin, see www.arxiv.org/paper/cond-mat/9907002. I'll be handing out copies of this; it corresponds well with my lectures, except that it omits anyons, edge tunneling, and composite fermions. (I also plan to hand out my own written lecture notes, but only the day *after* each lecture.)

Topics (subject to change!!)

I. Integer quantum Hall

- 1.1 Introduction: inversion layers and Landau levels (1 day +)
 - Inversion layers: energy and length scales.
 - The phenomena; conductivity tensor; why 2D special.
 - Classical motion
 - Landau levels (Landau gauge); harm. osc. (review); density of states eigenfunctions in $V(x)$ potential
 - Landau levels (symmetric gauge)
- 1.2 Localization in IQHE (1.5-2 days)
 - Anderson localization (NOT); IQHE and localized states
 - Landauer-like 1D conductance; why quantization
 - percolation picture; localization exponents
 - Chalker network model (for simulations)

II. Fractional quantum Hall

- 2.1 Laughlin's wavefunction (≤ 1 day)
 - Wavefc'n as complex polynomial
 - Laughlin's ansatz
 - Mapping to stat. mech. (plasma)
 - Why electron density \leftrightarrow B field
- 2.2 Laughlin Quasiparticles (1 day))
 - fractional charge
- 2.3 Fractional statistics: anyons (> 0.75 day)
 - topological order (?)
- 2.4 Composite fermion approach [missing in Girvin] (> 0.75 day)
 - hierarchy of Hall fractions
 - Chern-Simons approach
 - the $\nu = 1/2$ case: map to Fermi sea
- 2.5 Edge excitations (1 day)
 - "chiral Luttinger liquid"
 - shot noise in excitation tunneling

III. Ordered QHE phases

Time permitting; this may be done "seminar style" on the last day. Girvin's notes go into considerable detail on (some of) these topics, in case I miss them.

Ferromagnetism; bilayers; stripes; Wigner crystal.