Course Announcement : Physics 230, Spring 2019
Quantum Hall Effect
Instructor: D. Arovas

Tentative outline:

1. Preliminaries
   (a) Drude transport, conductance *vs.* conductivity
   (b) Semiclassical equations of motion
   (c) Magnetic translation operators, Landau levels, and wavefunctions
   (d) LL projection and LL mixing
   (e) Landau levels for Dirac materials
   (f) Lattice models: Hofstadter's model and Landau subbands
   (g) Math stuff
      i. Fiber bundles: connection and curvature
      ii. TKNN formula and Chern numbers
2. Integer Quantum Hall Effect
   (a) Continuum percolation in the classical and quantum limits
   (b) The integer quantum Hall transition
      i. Network models of quantum percolation
      ii. Charge pumping and Laughlin's gauge argument
      iii. Numerical simulations
      iv. Scaling theory
   (c) Lattice systems: Chern insulators
   (d) Hall conductance and edge states
   (e) Skyrmions
3. Fractional quantum Hall effect
   (a) Laughlin's wavefunctions at $\nu = 1/m$
      i. Haldane pseudopotentials
      ii. The two-dimensional one-component plasma
      iii. Quasielectrons and quasiholes
      iv. Fractional charge and statistics
      v. Collective excitations: magnetophonons and magnetorotons
   (b) Hierarchical constructions for $\nu \neq 1/m$
      i. Halperin-Haldane hierarchy: quasiparticle condensates
      ii. Jain's construction: composite fermions
   (c) Competing states
      i. Wigner crystallization
      ii. Stripes and bubble phases in higher LLs
   (d) Continuum field theories

i. Chern-Simons Ginzburg-Landau theory
ii. Vortex excitations and fractional statistics
iii. Hierarchical states: the Wen-Zee K-matrix construction
iv. Chiral Luttinger liquid theory of edge excitations

4. Exotica
   (a) Multilayer systems and QHE ferromagnetism
   (b) Coupled wire constructions
   (c) The half-filled Landau level
      i. Halperin-Lee-Read theory of the $\nu = \frac{1}{2}$ Fermi liquid
      ii. Son's model: Dirac fermions
      iii. Moore-Read Pfaffian state and Majorana quasiparticles
   (d) Read-Rezayi states and parafermions

Suggested resources:

Z. F. Ezawa, *Quantum Hall Effects* (3^{rd} edition, World Scientific, 2013)

E. Fradkin, *Field Theories of Condensed Matter Physics* (Cambridge, 2013)

A. H. MacDonald, Introduction to the Physics of the Quantum Hall Regime, `arXiv:cond-mat/9410047`

S. M. Girvin, The Quantum Hall Effect: Novel Excitations and Broken Symmetries, `arXiv:cond-mat/9907002`

D. Tong, Lectures on the Quantum Hall Effect `arXiv:1606.06687`

A. Stern, Anyons and the quantum Hall effect – A pedagogical review *Ann. Phys.* **33**, 204 (2008)