Syllabus for Physics 230
Advanced Condensed Matter Physics

Spring 2016-2017, Physics Department, UCSD

INSTRUCTOR: Congjun Wu (5430 MH)

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Time/Place: 9:30am - 10:50am, TUTH, Mayer Hall 5301

Instructor Office hour: 10:50pm - 12:00pm, TU

Text Books:

1. Shun-Qing Shen, *Topological Insulators – Dirac equation in condensed matter physics*, Springer-Verlag Berlin Heidelberg 2012.

2. B. Anderei Bernevig with Taylor L. Hughes, *Topological insulators and topological superconductors*, Princeton University Press (2013).

Class Schedule

1. One dimension

   Lecture 1: Jackiw-Rebbi modes (domain wall fermion) and Su-Schrieffer-Heeger model,

   Lecture 2: AKLT spin chain - Schwinger boson representation and edge modes
   Lecture 3: Kitaev model (1D) – Majorana edge modes

2. Two dimensions

   Lecture 4: Integer Quantum Hall effect (symmetric gauge, Landau gauge), Hatsugai's solution to edge states

   Lecture 5: Laughlin gauge argument, Application to electric polarization, charge pumping

   Lecture 6: Quantum Anomalous Hall insulator – Haldane model, Chern (TKNN) number, Berry phase

   Lecture 7: Quantum Spin Hall (2D topological insulator) – Kramers' degeneracy, Kane-Mele model, HgTe-CdHgTe, the Z_2 index

   Lecture 8: Valley Hall effects, TMD, and orbital-active honeycomb lattice

   Lecture 9: QHE for 2D Dirac fermion - parity anomaly

   Lecture 10: 2D topological insulators $p \pm ip$ – Read and Green, Ivanov

3. Three dimensions

   Lecture 11: 3D Landau levels – symmetric gauge and quaternionic analyticity, Landau gauge and helical surface states –

   Lecture 12: 3D Landau levels for Dirac fermions

   Lecture 13: 3D topological insulators with Bloch band structure

   Lecture 14: 3D topological superconductor/superfluidity – ^{3}He-B, surface Dirac modes

   Lecture 15: Weyl semi-metal and Weyl superconductor –^{3}He-A

4. Interacting systems

   Lecture 16: Non-linear σ-model for quantum spin chain, Haldane conjecture

   Lecture 17: 2D XY-model and Coulomb gas

   Lecture 18: K-T phase transition and RG analysis