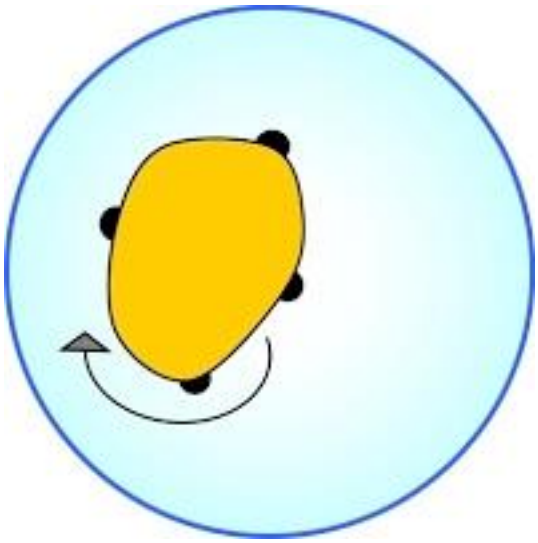
Phys 268R: Special Topics in Quantum Matter



Location & Time: Lyman 425; Wednesday 01:30 PM - 02:45 PM; Friday 01:30 PM - 02:45 PM . **Exam Group:** FAS03_G

- **Course Description:** This is a special topics course on quantum systems of many particles, i.e. quantum matter. Primarily, we will be interested in condensed matter systems - eg. electrons in solids or ultra-cold atoms in optical lattices - although the concepts invoked will be more generally applicable. Mostly, we will study well defined microscopic models, involving a finite number of degrees of freedom per unit volume, such as spins on a lattice. Our aim will be to understand the physics at much longer scales, where rich phenomena described by universal laws emerge.
- Simple spin models will be shown, at long distances, to give rise to remarkable new excitations, from `sound' and `light', to fermions and even more exotic excitations. Often, (but not always) we will use quantum field theory to describe this physics, which may also help demystify the origin of quantum field theory in a physical setting free of 'infinities".
- Two criteria are applied when selecting topics. First, that they be of experimental relevance and, second, that they illustrate a central concept of quantum many body physics such as
- (i) the importance of locality in many body systems (ii) symmetry and its spontaneous breaking (iii) origin of gauge theories (iv) finding the right variables to describe the physics (a.k.a. dualities) (v) topological order (vi) scale invariance.
- **Planned Topics:**
    - 1.The 1+1D transverse field Ising model - duality, fermionization, chiral symmetry. Experimental realization in CoNb2O6.

- 2. Continuous symmetry breaking in 2+1D. Goldstone modes and the Anderson Tower. Non-perturbative approaches such as dualities and large N expansions. The Mott-superfluid transition in optical lattices.
- 3. Emergent Gauge Theories and topological order. Confinement and topological order. Chern Simons theories. Fractional quantum Hall states and gapped quantum spin liquids. Emergent electromagnetism in quantum magnets and "Spin-ice".
- 4. Special Topics: Quantum entanglement in many body systems. Scale invariance.

- **Evaluation**: Assignments (roughly biweekly) and a final reading/small research project in groups of 2-3 based on enrollment. There will be no examinations.
- **Prerequisites:** Previous offerings of this course have been taken mainly by condensed matter/AMO and high energy theory graduate students, although the only real requirement is a strong background in basic quantum and statistical mechanics. No previous exposure to quantum field theory is assumed.
- Suggested Books & Lecture Notes of Related Courses:

1. Gauge Fields and Strings: A. Polyakov

2. Quantum Field Theory of Many Body Systems: X. G. Wen

3. Quantum Phase Transitions. Subir Sachdev

4. John McGreevy's Lecture Notes [UCSD]

5. Leon Balents' Lecture Notes [UCSB]

6. Sid Parameswaran's Lecture Notes [Oxford]

7. A previous offering of this course