Harvard University Physics 144 Fall 2011

Symmetries and geometry in quantum mechanics

Course Meetings	MW 1:00 - 2:30 pm in Jefferson 256
Instructor	**Eugene Demler**
Office:	Lyman 322
Email:	demler@physics.harvard.edu
Teaching Fellow	**David Benjamin**
Email:	benjamin@physics.harvard.edu
Course Grade	Grading will be based on homeworks (50%) and final presentations (50%).

Office hours to be arranged

Tentative Course Outline

1. Introduction. Symmetry in physics.
2. Definition of a group. Simple examples. General properties of groups and mappings.
3. Group representations. Properties of irreducible representations.
4. Physical applications of group theory. Crystal field splitting of atomic energy levels. Molecular vibrations.
5. Physical applications of group theory. Crystal symmetry operations. Bloch theorem and band theory of solids.
6. Continuous groups. Full rotation group. Clebsch-Gordan coefficients. Wigner-Eckart theorem.
7. 'Accidental' degeneracy of Hydrogen atom.
8. Spontaneous symmetry breaking. Landau theory of phase transitions.
9. Aspects of the theory of homotopy groups and the topological theory of defects in states with broken symmetry.
10. Berry phase in quantum mechanics.
11. Topological states of noninteracting electrons. The quantum Hall effect and the Chern numbers.
12*. Group theory in particle physics.

Primary references

- *Groups, representations and physics*, H. Jones, Taylor & Francis Group (1998)
- *Group theory and quantum mechanics*, M. Tinkham, McGraw Hill Book Company (1992)
- *The topological theory of defects in ordered media*, N. Mermin, Reviews of Modern Physics, 51:591(1979)
- *Statistical Physics of Fields*, M. Kardar, Cambridge University Press (2007)

Other useful references

- *Group Theory: The Application To Quantum Mechanics* , P. Meijer, E. Bauer, Dover publications (2004)
- *Applications of Group Theory in Quantum Mechanics*, M. I. Petrashen, J. L. Trifonov, Dover Books on Physics
- *Principles of condensed matter physics*, P. Chaikin, T. Lubensky, Oxford science publishing, Cambridge University press (1995)
- *Topological insulators and topological superconductors*, B. A. Bernevig, T. L. Huse, Princeton University Press (2013)
- *Lie algebras in particle physics*, H. Georgi, Addison-Wesley publishing company (1996)

Possible topics for final presentations

The icosahedral group and phonon modes of the C_{60} buckyball.

Quasicrystals.

Quantum Spin Hall Effect.

3D topological insulators.

Onsager's reciprocity relations for transport coefficients.

Fractional quantum Hall states.

Non-Abelian Berry phases.

Topological quantum computing.

Random matrix theory. Applications in nuclear and/or condensed matter physics.

SU(N) groups in particles physics and/or quantum magnetism.

Poincare group.

The gauge groups.