Physics 251 **Group Theory and Modern Physics** **Spring 2026**

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COURSE TEXTBOOK:

From Finite Groups to Lie Groups and Lie Algebras: A Guide for the Perplexed Physicist, by Howard E. Haber and John Terning

Latest draft copy available from the course website.

Textbooks used in previous Physics 251 classes:

Theory of Groups and Symmetries–Finite Groups, Lie Groups, and Lie Algebras, by Alexey P. Isaev and Valery A. Rubakov

Theory of Groups and Symmetries–Representations of Groups and Lie Algebras, Applications, by Alexey P. Isaev and Valery A. Rubakov

Group Theory in Physics: A Practitioner's Guide, by Rutwig Campoamor-Stursberg and Michel Rausch de Traubenberg

Group Theory in Physics, by Wu-Ki Tung

Groups, Representations and Physics (2nd edition), by H.F. Jones

Group Theory: A Physicist's Survey, by Pierre Ramond

Group Theory for Physicists, by Zhong-Qi Ma

Lie Groups, Lie Algebras, and Some of Their Applications, by Robert Gilmore

Lie Algebras in Particle Physics (2nd edition), by Howard Georgi

Group Theory in a Nutshell for Physicists, by Anthony Zee

Additional outside reading:

Group Theory in Physics, Volume 1, by J.F. Cornwell

Group Theory in Physics, Volume 2, by J.F. Cornwell

Lie Groups and Lie Algebras for Physicists, by Ashok Das and Susumu Okubo

Symmetries, Lie Algebras and Representations, by Jürgen Fuchs and Christoph Schweigert

Semi-Simple Lie Algebras and Their Representations, by Robert N. Cahn

A Physicist's Introduction to Algebraic Structures, by Palash B. Pal

Continuous Groups for Physicists, by Narasimhaiengar Mukunda and Subhash Chaturvedi

Course Outline

1. Introduction to Abstract Group Theory
2. Fundamentals of Finite Groups
3. Group Representation Theory
4. The Symmetric Group and Young Tableaux
5. Introduction to Topological Groups and Lie Groups
6. SU(2) and SO(3)
7. Global and Local Properties of Lie Groups
8. Lie Algebras
9. Representations of SU(2) and SU(3)
10. Complex Semisimple Lie Algebras and their Representations

Course Requirements

The basic course requirements consist of four problem sets, which will be handed out during the quarter, and a term project. (There will be no exams.) Due to the limited time in an academic quarter, it will be impossible to do more than sketch some of the most basic applications of group theory to modern physics. To encourage students to delve deeper, all students will be required to complete a term project based on their reading of a particular topic in group theory and its applications to physics. The project may be presented orally or in written form at the end of the term. Oral presentations are strongly encouraged since they will benefit all members of the class. Please follow the following schedule:

Initial choice of topic for term	April 28
Short written proposal for term	May 5
Oral Presentation of term project	June 9
Written version of term project	June 11

All projects should include a one page bibliography (containing references pertinent to the project). Copies of this bibliography should be made available to all students in the class. For those projects presented orally, an electronic copy of the transparencies (which will be posted on the course website) and a brief set of notes will be acceptable in lieu of a full written version.

I will be available during my office hours for suggestions and consultation on your choice for the term project. If you need some suggestions, you might consider choosing from the following list of possible topics for term projects.

Suggestions of topics for the term project

1. The Crystallographic Point Groups and Space Groups
2. Lattices, Bloch's Theorem and Band Theory
3. Group Theoretical Treatment of Vibrational Problems
4. Group Theory and Molecular Spectra
5. Group Theory and the Periodic Table
6. Group Theory in Classical Mechanics
7. Group Theoretic Methods in Quantum Mechanics
8. Group Theory in Condensed Matter Physics
9. Group Theory in General Relativity
10. Group Theory and the Shell Model in Nuclear Physics
11. Group Theory and the Quark Model in Particle Physics
12. Nonabelian Discrete Symmetries in Particle Physics
13. Group Structure of Spontaneously Broken Gauge Theories
14. Group Theory and Grand Unification
15. Group Theory and Monopoles
16. The Lorentz and Poincaré Groups in Relativistic Field Theory
17. Applications of Clifford Algebras (and spinors) in physics
18. Boson and Fermion Realizations of Lie algebras
19. Spectrum generating groups (a.k.a. noninvariance groups)
20. Group theory of coherent states

For inspiration, in addition to the recommended outside reading and the many references on group theory for physicists provided in the bibliography that follows, have a look at:

Symmetry, Broken Symmetry, and Topology in Modern Physics–A First Course, by Mike Guidry and Yang Sun

Quantum Theory, Groups and Representations: An Introduction, by Peter Woit (Revised and expanded version, under construction: `https://www.math.columbia.edu/~woit/QM/qmbook.pdf`)

Algebraic Quantum Physics—Volume 1: Quantum Mechanics via Lie algebras, by Arnold Neumaier and Dennis Westra (draft version available: `https://arxiv.org/pdf/0810.1019v2.pdf`)

Classical and Quantum Mechanics with Lie Algebras, by Yair Shapira