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Office Hours: Mondays 2–4 pm  
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**TEXTBOOKS:**

*Group Theory in a Nutshell for Physicists*, by Anthony Zee

Recommended outside reading:

*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 in Physics: An Introduction*, by J.F. Cornwell

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

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

*Group Theory for Physicists*, by Zhong-Qi Ma

*Problems and Solutions in Group Theory for Physicists*, by Zhong-Qi Ma and Xiao-Yan Gu

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

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

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

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

*Symmetry Groups and Their Applications*, by Willard Miller Jr.

*Group Theory: Birdtracks, Lie's, and Exceptional Groups*, by Predrag Cvitanović

(available for free from: <http://www.nbi.dk/GroupTheory/version9.0/index.html>)

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

(available for free from: <http://phyweb.lbl.gov/~rncahn/www/liealgebras/book.html>)

*Lie Groups, Lie Algebras, and Representations (2nd edition)*, by Brian C. Hall

(preliminary version available from: <http://arxiv.org/abs/math-ph/0005032>)

*Group Theory for Unified Model Building, Physics Reports* **79** (1981) 1–128, by Richard Slansky

*Mathematics of Classical and Quantum Physics*, Chapter 10: Introduction to Group Theory,

by Frederick W. Byron Jr. and Robert W. Fuller

## 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 a 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 encouraged since they will benefit all members of the class. Please follow the following schedule:

Initial choice of topic for term .....	May 2
Short written proposal for term .....	May 9
Oral Presentation of term project .....	June 14
Written version of term project.....	June 15

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, a xerox of transparencies 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. Non-Abelian 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. Graded Lie Algebras and Supersymmetry
17. The Lorentz and Poincare Groups in Relativistic Field Theory
18. Applications of Clifford Algebras (and spinors) in physics
19. Boson and Fermion Realizations of Lie algebras
20. Spectrum generating groups (a.k.a. noninvariance groups)
21. Coherent states as a problem in group theory

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:

*Quantum Theory, Groups and Representations: An Introduction*, by Peter Woit  
(final draft version available from: <https://www.math.columbia.edu/~woit/QM/qmbook.pdf>)

*Classical and Quantum Mechanics via Lie algebras*, by Arnold Neumaier and Dennis Westra  
(draft version available from: <https://arxiv.org/pdf/0810.1019v2.pdf>)

## Bibliography

### Other selected references in group theory for physicists:

- Lectures on Group Theory and Particle Theory*, by H. Bacry
- Lectures on Group Theory for Physicists*, by A.P. Balachandran and C.G. Trahern
- Group Theory for the Standard Model of Particle Physics and Beyond*, by Ken J. Barnes
- Lie Algebras Part 1: Finite and Infinite Dimensional Lie Algebras and Applications in Physics*, by G.G.A. Bäuerle and E.A. de Kerf
- Lie Groups and Lie Algebras: A Physicist's Perspective*, by Adam M. Bincer
- Group Theory and General Relativity*, by Moshe Carmeli
- Symmetries in Quantum Mechanics: From Angular Momentum to Supersymmetry*, by M. Chaichian and R. Hagedorn
- Group Theory: Application to the Physics of Condensed Matter*, by Mildred S. Dresselhaus, Gene Dresselhaus and Ado Jorio
- Symmetries and Condensed Matter Physics*, by Michael El-Batanouny and Frederick Wooten
- Group Theoretical Methods and Their Applications*, by A. Fässler and E. Stiefel
- Lie Groups, Physics and Geometry*, by Robert Gilmore
- Symmetries and Curvature Structure in General Relativity*, by G.S. Hall
- Group Theory and its Application to Physical Problems*, by Morton Hamermesh
- Group Theory in Quantum Mechanics*, by Volker Heine
- Lie Algebras and Applications (Lecture Notes in Physics)*, by Francesco Iachello
- An Introduction to Non-Abelian Discrete Symmetries for Particle Physicists*, by H. Ishimori et al.
- Lectures on Groups and Vector Spaces for Physicists*, by Chris J. Isham
- An Introduction to Tensors and Group Theory for Physicists (2nd edition)*, by Nadir Jeevanjee
- Theory of Groups in Classical and Quantum Physics*, by Théo Kahan
- Primer for Point and Space Groups*, by Richard L. Liboff
- Symmetries in Physics: Group Theory Applied to Physical Problems*, by W. Ludwig and C. Falter
- Lectures on Advanced Mathematical Methods for Physicists*, by Sunil Mukhi and N. Mukunda
- Group Structure of Gauge Theories*, by L. O'Raiheartaigh
- Generalized Coherent States and their Applications*, by A. Perelomov
- Lie Groups and Algebras with Applications to Physics, Geometry and Mechanics*, by D.H. Sattinger and O.L. Weaver
- A Course in the Application of Group Theory to Quantum Mechanics*, by I.V. Schensted
- Relativity, Groups, Particles*, by Roman U. Sexl and Helmuth K. Urbantke
- Group Theory in Subnuclear Physics*, by Fl. Stancu
- Group Theory and Physics*, by S. Sternberg
- Shattered Symmetry*, by Pieter Thyssen and Arnout Ceulemans
- Group Theory and Quantum Mechanics*, by Michael Tinkham
- Group Theory and its Applications to the Quantum Mechanics of Atomic Spectra*, by E. Wigner
- Classical Groups for Physicists*, by Brian G. Wybourne

Selected references in topology and differential geometry for physicists:

*An Introduction to Spinors and Geometry*, by A.M. Benn and R.W. Tucker  
*Differential Geometry and Lie Groups for Physicists*, by Marián Fecko  
*The Geometry of Physics: An Introduction (3rd edition)*, by Theodore Frankel  
*Differential Geometry for Physicists*, by Bo-Yu Hou and Bo-Yuan Hou  
*Fundamental Groups and Covering Spaces*, by Elon Lages Lima  
*Topology: An Introduction with Application to Topological Groups*, by George McCarty  
*A First Course in Topology: Continuity and Dimension*, by John McCleary  
*Geometry, Topology and Physics (2nd edition)*, by M. Nakahara  
*Geometry and Topology*, by Miles Reid and Balázs Szendrői  
*Geometrical Methods of Mathematical Physics*, by Bernard Schutz

Other selected mathematical references:

*Basic Lie Theory*, by Hossein Abbaspur and Martin Moskowitz  
*Conformal Groups in Geometry and Spin Structures*, by Pierre Anglès  
*An Introduction to Lie Groups and the Geometry of Homogeneous Spaces*, by A. Arvanitoyeorgos  
*Matrix Groups: An introduction to Lie group theory*, by Andrew Baker  
*Theory of Group Representations and Applications*, by A.O. Barut and R. Raczka  
*Representations of Linear Groups*, by Rolf Berndt  
*Representations of Compact Lie Groups*, by Theodor Bröcker and Tammo tom Dieck  
*Lie Groups (2nd edition)*, by Daniel Bump  
*Lectures on Lie Groups and Lie Algebras*, by R..W. Carter, G. Segal and I.G. Macdonald  
*Lie Groups*, by P.M. Cohn  
*Matrix Groups*, by Morton L. Curtis  
*The Geometry of Octonians*, by Tevian Dray and Corinne A. Manogue  
*Transformation Groups for Beginners*, by S.V. Duzhin and B.D. Chebotarevsky  
*Clifford Algebras: An Introduction*, by D.J.H. Garling  
*Representations of the Rotation and Lorentz Groups and their Applications*, by I.M. Gel'fand, R.A. Minlos and Z. Ya. Shapiro  
*Basics of Lie Groups*, by Michel Gourdin  
*Lie Algebras: Theory and Algorithms*, by W.A. De Graaf  
*Continuous Groups of Transformations*, by Luther Eisenhart  
*Introduction to Lie Algebras*, by Karin Erdmann and Mark Wildon  
*Spinors and Calibrations*, by F. Reese Harvey  
*Lie Groups, Lie Algebras*, by Melvin Hausner and Jacob Schwartz  
*The Structure and Geometry of Lie Groups*, by Joachim Hilgert and Karl-Hermann Neeb  
*Lectures on Representation Theory*, by Jing-Song Huang

*Introduction to Lie Algebras and Representation Theory*, by James E. Humphreys  
*Lie Algebras*, by Nathan Jacobson  
*An Introduction to Lie Groups and Lie Algebras*, by Alexander Kirillov, Jr.  
*Lie Groups Beyond an Introduction* (2nd Edition), by Anthony W. Knap  
*Groups and Symmetries*, by Yvette Kosmann-Schwarzbach  
*Theory of Continuous Groups*, by Charles Loewner  
*Clifford Algebras and Spinors*, by Pertti Lounesto  
*Topological Groups: An Introduction*, by Nelson G. Markley  
*Lie Theory and Special Functions*, by Willard Miller, Jr.  
*The Unitary and Rotation Groups*, by Frank Murnaghan  
*Linear Representations of the Lorentz Group*, by M.A. Naimark  
*Theory of Group Representations*, by M.A. Naimark and A.I. Stern  
*Lectures on Real Semisimple Lie Algebras and Their Representations*, by Arkady L. Onishchik  
*Lie Groups and Algebraic Groups*, by Arkady L. Onishchik and Ernest B. Vinberg  
*The Lie Algebras  $su(N)$ —An Introduction*, by Walter Pfeifer  
*Topological Groups*, by L.S. Pontryagin  
*Clifford Algebras and the Classical Groups*, by Ian R. Porteous  
*Lie Groups: A Problem-Oriented Introduction via Matrix Groups*, by Harriet Pollatsek  
*Topological Groups*, by L.S. Pontryagin  
*Lectures in Geometry, Semester V: Lie Groups and Lie Algebras*, by M. Postnikov  
*Lie Groups: An Approach through Invariants and Representations*, by Claudio Procesi  
*Geometry of Lie Groups*, by Boris Rosenfeld  
*Lie Groups, An Introduction Through Linear Groups*, by Wulf Rossmann  
*An Introduction to the Theory of Groups* (4th Edition), by Joseph J. Rotman  
*The Symmetric Group*, by Bruce E. Sagan  
*Introduction to Lie Groups and Lie Algebras*, by Arthur A. Sagle and Ralph E. Walde  
*Representing Finite Groups—A Semisimple Introduction*, by Ambar N. Sengupta  
*Compact Lie Groups*, by Mark R. Sepanski  
*Representations of Finite and Compact Groups*, by Barry Simon  
*Naive Lie Theory*, by John Stillwell  
*Special Functions: A Group Theoretical Approach*, by James D. Talman  
*Matrix Groups for Undergraduates* (2nd edition), by Kristopher Tapp  
*Lie Groups, Lie Algebras, and Their Representations*, by V.S. Varadarajan  
*An Introduction to Clifford Algebras and Spinors*, by Jayme Vaz, Jr. and Roldão Da Rocha, Jr.  
*Linear Representations of Groups*, by Ernest B. Vinberg  
*Group and Representation Theory*, by J.D. Vergados  
*Lie Algebras*, by Zhe-Xian Wan  
*Compact Lie Groups and their Representations*, by D.P. Zelobenko

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