Physics 251 **Group Theory and Modern Physics** **Spring 2013**

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TEXTBOOKS:

Group Theory in Physics, by Wu-Ki Tung

Lectures on Advanced Mathematical Methods for Physicists, by Sunil Mukhi and N. Mukunda

Recommended outside reading:

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

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

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

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

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

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

Classical Groups for Physicists, by Brian G. Wybourne

Group Theory for Physicists, by Zhong-Qi Ma

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

Group Structure of Gauge Theories, by L. O'Raifeartaigh

Symmetry Groups and Their Applications, by Willard Miller Jr.

Lectures on Group Theory for Physicists, by A.P. Balachandran and C.G. Trahern

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, 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

If there is sufficient time, the following topics will also be treated:

- The Lorentz and Poincare Groups
- Supersymmetry

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 ..... April 30
Short written proposal for term ..... May 7
Oral Presentation of term project ..... June 10
Written version of term project ..... June 13

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.

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 Theoretic Methods in Quantum Mechanics
6. Group Theory in Condensed Matter Physics
7. Group Theory in General Relativity
8. Group Theory and the Shell Model in Nuclear Physics
9. Group Theory and the Quark Model in Particle Physics
10. Group Structure of Spontaneously Broken Gauge Theories
11. Group Theory of the Two-Higgs Doublet Model
12. Group Theory and Monopoles
13. Graded Lie Algebras and Supersymmetry
14. The Lorentz and Poincare Groups in Relativistic Field Theory
15. Applications of Clifford Algebras (and spinors) in physics
16. Boson and Fermion Realizations
17. Quantum Groups and their Applications
18. Virasoro and Kac-Moody Algebras
19. Group Theory of Little Higgs Models
20. Coherent States

Bibliography

Other selected references in group theory for physicists:

Lectures on Group Theory and Particle Theory, by H. Bacry

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

Group Theory and General Relativity, by Moshe Carmeli

Symmetries in Quantum Mechanics: From Anglular Momentum to Supersymmetry, by M. Chaichian and R. Hagedorn

Group Theory in Physics: An Introduction, by J.F. Cornwell

Group Theory in Physics, Volume 3, by J.F. Cornwell

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

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

Lie Groups, Physics and Geometry, by Robert Gilmore

Kac-Moody and Virasoro Algebras: A Reprint Volume for Physicists, edited by Peter Goddard and David Olive

Basics of Lie Groups, by Michel Gourdin

Group Theory and its Application to Physical Problems, by Morton Hammermesh

Group Theory in Quantum Mechanics, by Volker Heine

Lie Algebras and Applications (Lecture Notes in Physics), by Francesco Iachello

Lectures on Groups and Vector Spaces for Physicists, by Chris J. Isham

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

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 Quantum Mechanics, by Michael Tinkham

Group Theory and its Applications to the Quantum Mechanics of Atomic Spectra, by Eugene Wigner

Selected references in topology and differential geometry for physicists:

An Introduction to Spinors and Geometry, by A.M. Benn and R.W. Tucker

Analysis, Manifolds and Physics, by Y. Choquet-Bruhat, C. DeWitt-Morette and M. Dillard-Bleick

Differential Geometry and Lie Groups for Physicists, by Marián Fecko

The Geometry of Physics: An Introduction, by Theodore Frankel

Differential Geometry for Physicists, by Bo-Yu Hou and Bo-Yuan Hou

Manifold Theory: An Introduction for Mathematical Physicists, by Daniel Martin

A First Course in Topology: Continuity and Dimension, by John McCleary

Geometry, Topology and Physics, by M. Nakahara

Topology and Geometry for Physicists, by Charles Nash and Siddhartha Sen

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 Andreas 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, by Daniel Bump

Lectures on Lie Groups and Lie Algebras, by Roger W. Carter, Graheme Segal and Ian G. Macdonald

Matrix Groups, by Morton L. Curtis

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

Lie Algebras: Theory and Algorithms, by W.A. De Graaf

Introduction to Lie Algebras, by Karin Erdmann and Mark Wildon

Affine Lie Algebras and Quantum Groups, by Jürgen Fuchs

Spinors and Calibrations, by F. Reese Harvey

Lie Groups, Lie Algebras, by Melvin Hausner and Jacob Schwartz

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. Knapp
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
Topology: An Introduction with Application to Topological Groups, by George McCarty
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
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
Lie Groups, An Introduction Through Linear Groups, by Wulf Rossmann
An Introduction to the Theory of Groups (4th Edition), by Joseph J. Rotman
Introduction to Lie Groups and Lie Algebras, by Arthur A. Sagle and Ralph E. Walde
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, by Kristopher Tapp
Lie Groups, Lie Algebras, and Their Representations, by V.S. Varadarajan
Linear Representations of Groups, by Ernest B. Vinberg
Lie Algebras, by Zhe-Xian Wan
Selected Papers of E.B. Dynkin with Commentary, edited by A.A. Yushkevich, G.M. Seitz and A.L. Onishchik
Compact Lie Groups and their Representations, by D.P. Zelobenko