PHYS 467: Methods of Theoretical Physics II
Spring 2013

Time and Location:
T R 09:30-10:45, Physics and Astronomy Room 184

Instructor:
Rouzbeh Allahverdi
Office: Physics and Astronomy Room 172
E-mail: rouzbeh@unm.edu

Teaching Assistant:
Zhixian Yu
E-mail: zyu@unm.edu

Course Webpage:
http://panda.unm.edu/Courses/Allahverdi/Phys467Sp13/index.html

Description:
This class is a full 3 credit course primarily aimed at graduate students, but can serve as an elective for undergraduates.

My plan is to focus almost entirely on Lie Algebras and Lie Group Theory in this course. The main goal will be to learn about finite-dimensional semi-simple Lie algebras, their associated Lie groups, their representations, their classification, and their many applications to physics. Time permitting, we will also talk about infinite-dimensional algebras particularly Kac-Moody and Virasoro algebras and their applications.

Requisites:
There are not really many prerequisites for this material other than the maturity that one has by being a graduate student or an advanced senior student in physics.

The mathematical material lies somewhat out of the traditional mathematics (calculus, differential equations, etc). It certainly depends a lot on matrix theory and linear algebra, with which you are familiar from studying quantum physics and operators that describe the behavior of physical systems in vector spaces.

Book(s):

Here is a list of books that I will use as references for this course:

Elements of group theory for physicists, A. W. Joshi, J. Wiley, c1982.

Semi-simple lie algebras and their representations, R. N. Cahn, Benjamin/Cummings, 1984.

Lie algebras in particle physics, H. Georgi**,** Perseus Books, Advanced Book Program, c1999.

Quantum Mechanics "Volume 2: Symmetries", W. Greiner, Springer-Verlag, c1994.

I have put these books on reserve at the Centennial Library. The first three books are also available at the Physics and Astronomy Library, and have been put on reserve in the Physics and Astronomy main office. There are several other useful references on the subject, which I will not use.

After introducing the jargon used in group theory, mainly from the book by Joshi, I will use the four books in tandem. The book by Cahn is a particularly nice and useful. It is available from Dover publication for about $11; you can actually obtain electronic versions for free from the right places. I may also distribute handouts on specific topics from time to time.

Grading Policy:

The final grade will consist of equal contributions from the following three things:

a) Homework assignments (approximately 10 sets)

b) A midterm exam almost halfway through

c) A final exam that will cover the remainder of the material discussed

Preliminary outline:

A list of main topics that will be covered in this course includes:

- **Introduction to Group Theory**
  Groups, subgroups, transformations and symmetries, direct product of groups, isomorphism and homomorphism, permutation groups

- **Representation Theory of Finite Groups**
  Invariant subspaces and irreducible representations, Schur's lemmas and orthogonality theorem, representations of a direct product group

- **Continuous Groups and their Representations**
  Topological groups and Lie groups, general structure of Lie groups, Lie algebra of a Lie group, generators and Lie's theorem, rank of a Lie group, invariant subgroups, simple and semi-simple Lie algebras, Casimir's operators and Racha's theorem

- **SU(2)**
  Three-dimensional rotation group SO(3), angular momentum operators and SU(2) algebra, irreducible representations and addition of angular momenta, connectedness and covering groups

- **SU(3)**
  SU(3) and its generators, Lie algebra of SU(3) and its sub-algebras, fundamental representations of SU(3), construction of the irreducible representations, some physical applications

- **Permutation Group and Young Tableaux**
  Permutation group S_N and its irreducible representations, standard form of Young diagrams, the connection between SU(2) and S_N, irreducible representations of SU(n) and their dimension

- **Classification of Simple Lie Algebras**
  Structure of simple Lie algebras, Cartan subalgebra, root vectors and their graphic representation, simple roots and Dynkin diagrams, classical and exceptional Lie algebras, some physical applications

- **Infinite-dimensional Algebras**
  Kac-Moody algebras as a mild generalization of Lie algebras, vertex operators, Virasosro Algebras and conformal symmetry, some physical applications