Fundamental Symmetries

Synopsis

Symmetry principles are now an essential part of our understanding of the underlying structure of physics. The course sets out the mathematical preliminaries - Lie groups, Lie algebras and their representations - and covers various physical applications, in particular the Lorentz group and SU(3), explicit and spontaneous symmetry breaking, gauge symmetries and the Higgs mechanism.
This course unit is intended primarily for Mathematical Physics 5 students but it may be attended - either seriously or on a 'sitting in' basis - by Astrophysics 5 and Physics 5 students, graduate students, and indeed by anyone else who may be interested. Prior attendence at the fourth year courses on Groups and Symmetries, Hamiltonian Dynamics and Particle Physics is recommended. Concurrent attendence at Relativistic Quantum Field Theory is expected. The course should also be helpful to those intending to study General Relativity, the Standard Model, and Modern Quantum Field theory. Students are warned that there will be no printed lecture notes: come to the lectures and make your own!

Syllabus

1. Lie Groups; Unitary and Orthogonal Groups; One Dimensional Groups; Translations and Rotations; Representations; Generators; Lie Algebras; SU(2) and SO(3); Scalars, Vectors and Tensors

2. Lorentz Group; Spinors and Vectors; Poincaré Group

3. Invariant Actions; Spin zero fields; Spin half fields; Chiral Symmetry

4. Noether's Theorem; Conserved Charges; Stress-Energy Tensor

5. Compact Lie algebras; Killing form; Casimir Operators; Cartan subalgebra;
   Roots and weights; Representations of SU(3)

6. Internal Symmetry; Isospin; the Quark Model; the Eight-Fold Way; Mesons and Baryons

7. Broken Symmetry; Soft Breaking; Spontaneous Symmetry Breakdown;
   Goldstone's Theorem

8. Local Symmetry; Maxwell's equations; Yang-Mills Theory; Higgs' mechanism

Recommended Textbooks

Suitable books that may be found on the library shelves are:

Lectures on Physics, Feynman, R.P. (I.52 and II.25)
Inward Bound, Pais, A. (last three chapters)

Lie Algebras and Particle Physics, Georgi, H.
Groups, Representations and Physics, Jones, H.F.
Group Theory and Physics, Cornwell, J.F.
Unitary Symmetry and Particle Physics, Lichtenberg, D.B.
Lie Groups, Lie Algebras and Representations, Hall, B.C.
Semi-Simple Lie Algebras and Their Representations, Cahn, R.N.

Field Theory, a Modern Primer, Ramond, P.
Gauge Theories of the Strong, Weak and Electromagnetic Interactions, Quigg, C.
Aspects of Symmetry, Coleman, S.

An online book of P. Cvitanovic can be found at
http://www.nbi.dk/GroupTheory/

Examples

Problem solving is the best way to learn and understand mathematical physics. For this course there will be eight problems classes at which solutions to the more difficult problems will be presented on the blackboard as required. I will also be available in my office (4421) to answer any remaining questions about the lectures and the associated problem sheets.
Students are warned that no written solutions will be provided to the problems. It is thus essential that each students intending to take the course seriously make a determined attempt to construct their own solutions to the problems BEFORE the appropriate problems class, so that any difficulties he or she finds during the course of solving the problems may be resolved during the class.
As this is an advanced course some of the problems are quite open-ended. Solutions to some of them may be found in the textbooks listed above.
Copies of the example sheets may be found at http://www.ph.ed.ac.uk/∼gheinric/teaching/FuSy.html

Gudrun Heinrich
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