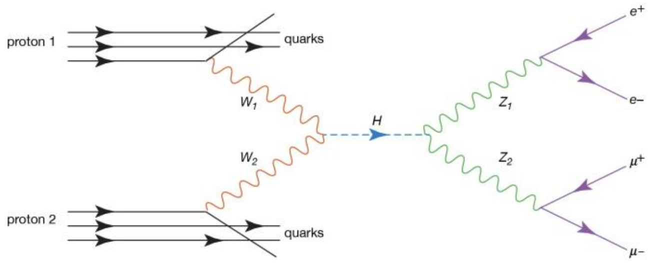


UNIFICATION
Electives Fair Information

Physics Course PHYS70011

Lecturer:- Tim EVANS
Abdus Salam Centre for Theoretical Physics

12th May 2026

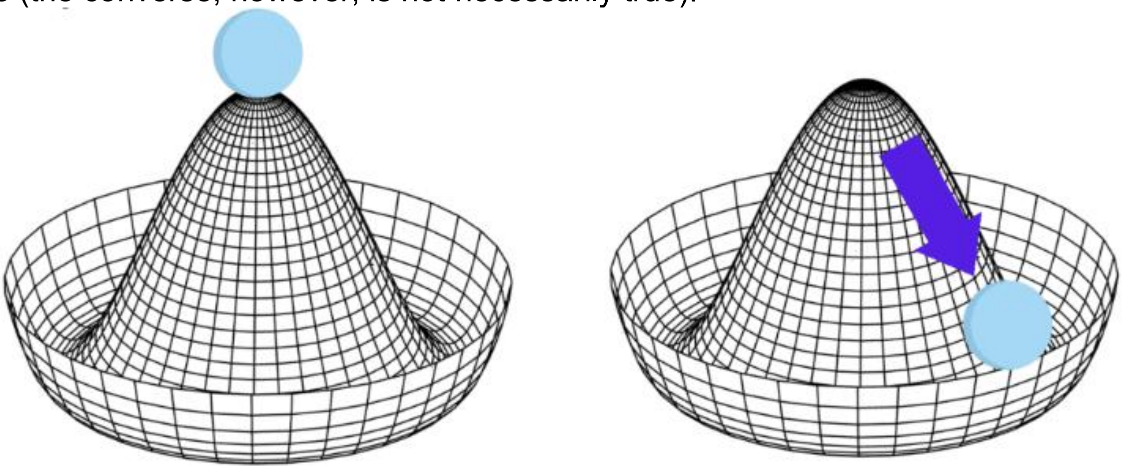
Course Background

This course is a fourth year MSci undergraduate course. It is a core course of the *Quantum Fields and Fundamental Forces* MSc run by the Theoretical Physics group at Imperial.

Course Outline

The objective of the course is to understand the role of symmetry in the Standard Model of elementary particle physics.

This means that we study the implications of symmetry in field theory in the Unification course. Quantum field theory is used to describe the fundamental interactions as probed in the particle accelerators and neutrino experiments at CERN, Fermilab, DESY, etc. However, the discussion is almost entirely classical, although it is motivated by the full quantum theory. Accordingly, this course should only be taken in parallel with the QFT course (the converse, however, is not necessarily true).



The ideas in this course are also the key to understanding phase transitions, whether they took place in the early universe or in superconductors/superfluids. The same ideas about symmetry, but with different symmetry groups, form the backbone of string theory as the same symmetry principles are fundamental to understanding gravity. The heart of the course is an investigation of the mass generating sector of the Standard Model, *i.e.* the Higgs particle.

How the course is taught

This course consists of twenty-six in-person lectures (mostly chalk/blackboard) in the Autumn term. Two sets of complete notes for the course are available. The lectures are supported by eight Problem Sheets to help you understand the material and to show you how to put the ideas into practice. The Problem Sheets are supported by Rapid Feedback sessions led by a teaching assistant where some of the problems are examined in more detail. Written feedback is given on the problems covered by the feedback sessions if scripts are handed in on time, but these do not contribute to the course assessment.

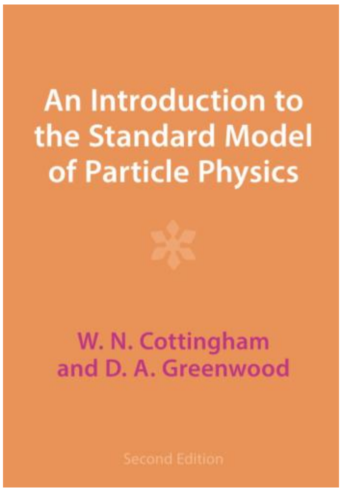
Exam

The course is only assessed by one written exam in May. Past papers are available on the Physics Examinations page, together with solutions for selected years.

Requirements

As background knowledge, you are expected to be familiar with basic particle physics: the basic properties of the forces and particles in the Standard Model. Third year Nuclear & Particle Physics should give you this and it is in many textbooks. You also need to know the Lagrangian formulation of classical mechanics, special relativity in the four vector/tensor notation, and the relativistic formulation of electrodynamics. These three are all covered in the third-year course Advanced Classical Physics. Students coming from other universities can revise this content by reading my copy of notes from the Advanced Classical Physics course which are available in the Supplementary Reading folder.

A general knowledge of group theory and group representations is a prerequisite, including the group axioms and a basic understanding of matrix representations. Lie Groups and Lie Algebras are also prerequisites. The third-year undergraduate group theory course gives sufficient coverage of these topics. The course will not assume a high degree of fluency in Lie Groups and Lie Algebras as I expect this will be the first time most students have applied these ideas. We will use the simplest examples, namely the trivial, fundamental and the adjoint matrix representations for SO(2), SO(3), U(1), SU(2) and U(2) (explicitly) and in generic form for SO(N) and SU(N).



A fluency with vector spaces, matrix algebra and index notation is essential but this should have been encountered in the second year Mathematical Methods course.

I have a comprehensive set of notes (a monograph, not a set of slides) and the excellent notes from the previous lecturer also provided (same topics, sometimes a different order or emphasis). I have not found a good text for the course but you could try Cottingham and Greenwood, “An Introduction to the Standard Model of Particle Physics”. Some QFT books also provide a short introduction at the level required - see the Unification or QFT course bibliographies.

Course Topics

This is not a definitive syllabus. However, based on what was included in previous years I expect the course will cover most of the following material.

- Field Theory.
    - Classical Field Theory.
    - From Classical to Quantum Theory.
    - Typical Lagrangians in Particle Physics.
- Symmetry.
    - Symmetry and Groups in Classical Field Theory.
    - Global and Local Symmetries
- Global Symmetry and Conserved Charges.
    - Noether's theorem.
    - Abelian charges.
    - Charges in Non-Abelian groups
- Breaking Global Symmetry.
    - Spontaneous symmetry breaking.
    - Goldstone's Theorem.
    - Charges and broken symmetry.
    - Scalar fields as matter or Higgs fields
- Local (Gauge) Symmetry.
    - Local Abelian Symmetry.
    - Generalisation to Non-Abelian Gauge Theories.
    - Physical content of the Lagrangian.
    - Product Groups.
    - Multiple matter fields
- Local Symmetry Breaking.
    - Symmetry Breaking of Local Abelian Symmetry.
    - Non-Abelian Spontaneous Symmetry Breaking
- Fermions.
    - Dirac Fermions.
    - Lagrangians for spin 1/2 particles.
    - Chiral Fermions
- Strong interactions and QCD.
    - Early theories and experiments.
    - Gauge theory for strong interactions.
    - Confinement and asymptotic freedom in QCD.
- Electroweak theory.
    - Early theories and experiments.
    - Gauge theory for weak and electromagnetic interactions.
    - The status of Standard model today