PX430-7.5 Gauge Theories for Particle Physics

20/21

Department
    Physics
Level
    Undergraduate Level 4
Module leader
    Bill Murray
Credit value
    7.5
Module duration
    5 weeks
Assessment
    100% exam
Study location
    University of Warwick main campus, Coventry

Description

Introductory description

The electromagnetic field is a gauge field. Gauge changes to the vector potential ($A_\mu \to A_\mu - \partial_\mu \Phi$ with Φ an arbitrary function of position and time), combined with multiplication of the wavefunction of particles with charge q by the phase factor, $\exp(iq\Phi)$, leave all physical properties unchanged. This is called a gauge symmetry. In particle physics, this idea is generalized to (space- and time-dependent) unitary matrix-valued fields multiplying spinor wavefunctions and fields. This generalization of the theory of an electron in an electromagnetic field is the basis for current theories of elementary particles.

The module starts with the theory of the electron in the electromagnetic field making the gauge symmetry explicit. It then discusses the gauge symmetries appropriate for the various theories and approximate theories used to describe other elementary particles and their interactions with their corresponding gauge fields.

Module web page

Module aims

To develop ideas used in gauge theories and apply these to the field of particle physics. To describe the theory underpinning the Standard Model of Particle Physics should and to highlight the symmetry properties of the theory. To consider Quantum Electrodynamics (QED) in some detail, and to illustrate its success by comparison with experiments.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

1. Introduction and revision: relativistic quantum mechanics and notation; the Klein Gordon equation; the Dirac equation and interpretation of negative energy solutions; quantum numbers and spin; revision of matrices, Hermitan, unitary, determinants
2. Group theory: definition of a group, examples of discrete groups; continuous groups, Lie groups, examples: U(1), SU(2), SU(3)
3. Gauge invariance: symmetries and conservation laws; current conservation; Noether's theorem; the gauge principle; examples: Maxwell's equations, quantum electrodynamics
4. Quantum field theories: brief outline of the deeper theory; Feynman rules and diagrams Non Abelian gauge theories: SU(2) and the electroweak interaction; SU(3) and QCD; local nonAbelian gauge theory; gauge fields; self-interaction
5. Quantum electrodynamics: perturbation theory; scattering and cross sections

Learning outcomes

By the end of the module, students should be able to:

- Explain the theoretical framework of the Standard Model
- Explain the symmetry properties associated with gauge invariance
- Calculate amplitudes for simple QED processes
- Discuss qualitatively properties of the strong and weak interactions

Indicative reading list

Gauge Theories in Particle Physics, I.J.R.Aitchison and A.J.G.Hey, IOP Publishing

View reading list on Talis Aspire

Subject specific skills

Knowledge of mathematics and physics. Skills in modelling, reasoning, thinking

Transferable skills

Analytical, communication, problem-solving, self-study

Study

Study time

Type	Required
Lectures	15 sessions of 1 hour (20%)
Private study	60 hours (80%)
Total	75 hours

Private study description

Working through lecture notes, solving problems, wider reading, discussing with others taking the module, revising for exam, practising on past exam papers

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Assessment group B1

	Weighting	Study time	Eligible for self-certification
Assessment component			
Online Examination Answer 2 questions from 3	100%		No
Reassessment component is the same			

Feedback on assessment

Personal tutor, group feedback

Past exam papers for PX430

Availability

Courses

This module is Optional for:

- TMAA-G1PE Master of Advanced Study in Mathematical Sciences
  - Year 1 of G1PE Master of Advanced Study in Mathematical Sciences
  - Year 1 of G1PE Master of Advanced Study in Mathematical Sciences
- Year 1 of TMAA-G1P0 Postgraduate Taught Mathematics
- Year 1 of TMAA-G1PC Postgraduate Taught Mathematics (Diploma plus MSc)
- Year 4 of UPXA-F303 Undergraduate Physics (MPhys)

This module is Option list A for:

- Year 1 of TMAA-G1P0 Postgraduate Taught Mathematics
- Year 3 of UMAA-G100 Undergraduate Mathematics (BSc)
- Year 3 of UMAA-G103 Undergraduate Mathematics (MMath)
- Year 4 of UMAA-G101 Undergraduate Mathematics with Intercalated Year

This module is Option list B for:

- Year 4 of UPXA-FG33 Undergraduate Mathematics and Physics (BSc MMathPhys)
- Year 4 of UPXA-FG31 Undergraduate Mathematics and Physics (MMathPhys)

This module is Option list C for:

- UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
  - Year 3 of G105 Mathematics (MMath) with Intercalated Year
  - Year 5 of G105 Mathematics (MMath) with Intercalated Year
- UMAA-G103 Undergraduate Mathematics (MMath)
  - Year 3 of G103 Mathematics (MMath)
  - Year 4 of G103 Mathematics (MMath)
- UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe
  - Year 3 of G106 Mathematics (MMath) with Study in Europe
  - Year 4 of G106 Mathematics (MMath) with Study in Europe