PX408-7.5 Relativistic Quantum Mechanics

21/22

Department
: Physics

Level
: Undergraduate Level 4

Module leader
: Tom Blake

Credit value
: 7.5

Module duration
: 5 weeks

Assessment
: 100% exam

Study location
: University of Warwick main campus, Coventry

Description

Introductory description

The module sets up the relativistic analogues of the Schrödinger equation and analyses their consequences. Constructing the equations is not trivial - knowing the form of the ordinary Schrödinger equations turns out not to be much help. The correct equation for the electron, due to Dirac, predicts antiparticles, spin and other surprising phenomena. One is the 'Klein Paradox': When a beam of particles is incident on a high potential barrier, more particles can be 'reflected' than are actually incident on the barrier.

Module web page

Module aims

This module should start from the premise that quantum mechanics and relativity need to be mutually consistent. The Klein Gordon and Dirac equations are derived as relativistic generalisations of Schrödinger and Pauli equations respectively. The Dirac equation will be analysed in depth and its successes and limitations will be stressed.

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. Introductory Remarks. Revision of relativity, electromagnetism and quantum mechanics; problems with the non-relativistic Schrödinger equation; unnaturalness of spin in NRQM and the Pauli Hamiltonian; phenomenology of relativistic quantum mechanics, such as pair production
2. Klein Gordon Equation. Derivation of the Klein-Gordon equation; continuity equation and the Klein-Gordon current; problems with the interpretation of the Klein-Gordon Equation
3. The Dirac Equation. Derivation of the Dirac equation; the quantum phenomenon of spin; gamma matrix algebra and equivalence transformations
4. Solutions of the Dirac Equation.
   The helicity operator and spin; normalisation of Dirac spinors; Lorentz transformations of Dirac spinors; interpretation of negative energy states
5. Applications of Relativistic Quantum Mechanics.
   The gyromagnetic ratio of the electron; non-relativistic limit of the Dirac equation; fine structure of the hydrogen atom

Learning outcomes

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

- Discuss the general nature of Relativistic Quantum Mechanics
- Solve the Dirac equation in simple cases, and explain its significance and transformation properties.
- Explain how some physical phenomena including spin and the Lamb shift can be accounted for using relativistic quantum mechanics

Indicative reading list

R.Feynman, Quantum Electrodynamics, Perseus Books 1998;
Bethe and Jackiw “Intermediate Quantum Mechanics”, Perseus Books 1997.

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 B2

	Weighting	Study time	Eligible for self-certification
Assessment component			
In-person Examination Answer 2 questions	100%		No

- Answerbook Green (8 page)

Reassessment component is the same

Feedback on assessment

Personal tutor, group feedback

Past exam papers for PX408

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-G1PD Postgraduate Taught Interdisciplinary Mathematics (Diploma plus MSc)
- 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