PX156-10 Quantum Phenomena

25/26

Department
Physics
Level
Undergraduate Level 1
Module leader
Nicholas d'Ambrumenil
Credit value
10
Module duration
10 weeks
Assessment
100% exam
Study location
University of Warwick main campus, Coventry

Description

Introductory description

This module explains how classical physics is unable to explain the properties of light, electrons and atoms. (Theories in physics, which make no reference to quantum theory, are usually called classical theories.) It covers the most important contributions to the development of quantum theory including: wave-particle 'duality', de Broglie's relation and the Schrodinger equation. The second half looks at applications of quantum theory to describe elementary particles: their classification by symmetry and how this allows us to interpret simple reactions between particles.

Module web page

Module aims

To describe how the discovery of effects, which could not be explained using classical physics, led to the development of quantum theory. The module should cover wave-particle duality and the wave theory of matter based on Schrödinger's equation. It should introduce elementary particle physics including the naming and classification of particles, their detection and their interactions with matter

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.

Waves, particles and thermodynamics before quantum theory

Light:
Thermal radiation and the origin of quantum theory: blackbody radiation, derivation for the case of a `1D black-body', Planck's hypothesis and E=hf . The photoelectric effect - Einstein's interpretation. The Compton effect - direct evidence for the particle nature of radiation.

Matter:
Atoms and atomic spectra a problem for classical mechanics. Bohr's Model of the Atom: quantisation of angular momentum, atomic levels in hydrogen. De Broglie's hypothesis.

Quantum Mechanics:
Correspondence Principle. The Schrödinger wave equation. Relation of the wave function to probability density. Probability distribution, need for normalisation. Superpositions of waves to give standing waves, beats and wave packets. Gaussian wave packet. Use of wave packets to represent localised particles. Group velocity and correspondence principle. Wave-particle duality, Heisenberg's uncertainty principle and its use to make order of magnitude estimates.

Using Schrödinger's equation:
Including the effect of a potential. Stationary states and the time-independent Schrödinger equation. Infinite potential well and energy quantisation. The potential step and the notion of tunnelling. Alpha decay of nuclei.

Principles of Elementary Particle Physics:
Simplicity, Composition, Symmetry, Unification. Quarks and Leptons as basic building blocks: Periodic Table of Quarks and Leptons; Basic composition rules for hadrons. The four forces and their roles: Electromagnetism, Gravity, Strong nuclear force, Weak nuclear force.

Observation and Experiment:
Natural radioactivity, source of geothermal energy, cosmic rays, natural
sources of neutrinos: radioactivity, solar, atmospheric. Charged particles in electric and magnetic fields, e/m for an electron, mass spectrometry, cathode ray tube, particle accelerators. Interactions of particles with matter: Ionisation, Pair creation by photons and Bremsstrahlung, hadronic interactions, probability of interaction: radiation and interaction lengths, particle detectors

The "big questions":
Origin of mass and the Higgs, Grand Unification as a goal, neutrino character and mass

Learning outcomes

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

- Discuss how experimental evidence implied a wave-particle duality for both light and matter
- Discuss the background to and issues surrounding Schrödinger's equation and its solutions
- Work with the time-independent Schrödinger equation for simple 1-dimensional potentials
- Classify the elementary particles giving the correct quantum number assignments to quark and lepton flavours

- Discuss the relationship between symmetries and conservation laws
- Explain the principles of experimental study of elementary particle physics
- Characterise natural radioactivity, cosmic rays, solar and atmospheric neutrinos

Indicative reading list

H. D. Young and R A Freedman, University Physics, Pearson

View reading list on Talis Aspire

Interdisciplinary

Quantum theory has been a joint endeavour between mathematics and physics since its inception. Particle physics is one of the success stories of this interdisciplinary collaboration - the Standard Model of particle physics is heavily based on concepts from algebra and differential geometry.

Quantum theory has applications beyond physics and mathematics. It is important in chemistry and increasingly computer science (quantum computing). One of the founders of the subject, Dirac, was a great interdisciplinarian. He trained as an engineer and is celebrated for his contributions to both mathematics and to physics.

This module is taken by many students from within Mathematical Sciences (mainly Mathematics and Physics).

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	30 sessions of 1 hour (30%)
Private study	70 hours (70%)
Total	100 hours

Private study description

Working through lecture notes, solving problems, wider reading, discussing with others taking the module, revising for the 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
In-person Examination	100%		No
Answer 4 questions			

- Answerbook Pink (12 page)
- Students may use a calculator

Feedback on assessment

Meeting with personal tutor, group feedback

[Past exam papers for PX156](#)

Availability

Courses

This module is Core for:

- UPXA-GF13 Undergraduate Mathematics and Physics (BSc)
  - Year 1 of GF13 Mathematics and Physics
  - Year 1 of GF13 Mathematics and Physics
- UPXA-FG31 Undergraduate Mathematics and Physics (MMathPhys)
  - Year 1 of GF13 Mathematics and Physics
  - Year 1 of GF13 Mathematics and Physics
  - Year 1 of FG31 Mathematics and Physics (MMathPhys)
  - Year 1 of FG31 Mathematics and Physics (MMathPhys)
- UPXA-F300 Undergraduate Physics (BSc)

    - Year 1 of F300 Physics
    - Year 1 of F300 Physics
    - Year 1 of F300 Physics
- UPXA-F303 Undergraduate Physics (MPhys)
    - Year 1 of F300 Physics
    - Year 1 of F303 Physics (MPhys)
    - Year 1 of F303 Physics (MPhys)
    - Year 1 of F303 Physics (MPhys)
- UPXA-F3F5 Undergraduate Physics with Astrophysics (BSc)
    - Year 1 of F3F5 Physics with Astrophysics
    - Year 1 of F3F5 Physics with Astrophysics
- Year 1 of UPXA-F3FA Undergraduate Physics with Astrophysics (MPhys)
- Year 1 of UPXA-F3N2 Undergraduate Physics with Business Studies

This module is Optional for:

- USTA-G302 Undergraduate Data Science
    - Year 1 of G302 Data Science
    - Year 1 of G302 Data Science
- USTA-G300 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics
    - Year 1 of G30A Master of Maths, Op.Res, Stats & Economics (Actuarial and Financial Mathematics Stream)
    - Year 1 of G30J Master of Maths, Op.Res, Stats & Economics (Data Analysis Stream)
    - Year 1 of G30B Master of Maths, Op.Res, Stats & Economics (Econometrics and Mathematical Economics Stream)
    - Year 1 of G30C Master of Maths, Op.Res, Stats & Economics (Operational Research and Statistics Stream)
    - Year 1 of G30C Master of Maths, Op.Res, Stats & Economics (Operational Research and Statistics Stream)
    - Year 1 of G30D Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)
    - Year 1 of G300 Mathematics, Operational Research, Statistics and Economics
    - Year 1 of G300 Mathematics, Operational Research, Statistics and Economics
    - Year 1 of G300 Mathematics, Operational Research, Statistics and Economics
- UMAA-G100 Undergraduate Mathematics (BSc)
    - Year 1 of G100 Mathematics
    - Year 1 of G100 Mathematics
    - Year 1 of G100 Mathematics
- UMAA-G103 Undergraduate Mathematics (MMath)
    - Year 1 of G100 Mathematics
    - Year 1 of G103 Mathematics (MMath)
    - Year 1 of G103 Mathematics (MMath)
- Year 1 of UMAA-G1NC Undergraduate Mathematics and Business Studies
- Year 1 of UMAA-GL11 Undergraduate Mathematics and Economics
- UMAA-GV17 Undergraduate Mathematics and Philosophy
    - Year 1 of GV17 Mathematics and Philosophy

    - Year 1 of GV17 Mathematics and Philosophy
    - Year 1 of GV17 Mathematics and Philosophy
- UMAA-GV18 Undergraduate Mathematics and Philosophy with Intercalated Year
    - Year 1 of GV18 Mathematics and Philosophy with Intercalated Year
    - Year 1 of GV18 Mathematics and Philosophy with Intercalated Year
- Year 1 of USTA-G1G3 Undergraduate Mathematics and Statistics (BSc MMathStat)
- USTA-GG14 Undergraduate Mathematics and Statistics (BSc)
    - Year 1 of GG14 Mathematics and Statistics
    - Year 1 of GG14 Mathematics and Statistics
- USTA-Y602 Undergraduate Mathematics,Operational Research,Statistics and Economics
    - Year 1 of Y602 Mathematics,Operational Research,Stats,Economics
    - Year 1 of Y602 Mathematics,Operational Research,Stats,Economics