PX156-10 Quantum Phenomena

22/23

Department
Physics
Level
Undergraduate Level 1
Module leader
Oleg Petrenko
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 physics including: wave-particle 'duality', de Broglie's relation and the Schrodinger equation. It also looks at applications of quantum theory to describe elementary particles: their classification by symmetry, how this allows us to interpret simple reactions between particles and how elementary particles interact with matter.

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 develop the ideas of wave-particle duality and introduce the wave theory of matter based on Schrödinger's equation. It should provide an introduction to 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', the idea of modes, Wien's law, Rayleigh-Jeans formula, Planck's hypothesis and E=hf . The photoelectric effect - Einstein's interpretation. Waves or Particles? Interference a problem for the particle picture; 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: quantization of angular momentum, atomic levels in hydrogen. De Broglie's hypothesis. Experimental verification of wave-like nature of electrons - electron diffraction

Quantum Mechanics:
Correspondence Principle. The Schrödinger wave equation. Relation of the wavefunction to probability density. Probability distribution, need for normalization. Superpositions of waves to give standing waves, beats and wavepackets. Gaussian wavepacket. Use of wavepackets to represent localized particles. Group velocity and correspondence principle again. 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. Importance of stationary states and time-independent Schrödinger equation. Infinite potential well and energy quantization. The potential step - notion of tunnelling. Alpha decay of nuclei. Status of wave mechanics.

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 of the electron, mass spectrometry, cathode ray tube, particle accelerators. Interactions of particles with matter: Ionisation, Pair creation by photons and Bremsstrahlung, Hadronic interactions, Exponential 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 key pieces of experimental evidence implied a wave-particle duality for both

light and matter
- Discuss the background to and issues surrounding Schrödinger's equation. This includes the interpretation of the wave function and the role of wave packets and stationary states
- Manipulate the time-independent Schrödinger equation for simple 1-dimensional potentials
- Classify the elementary particles giving the correct quantum number assignments to all quark and lepton flavours
- Discuss qualitatively 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

Reading lists can be found in Talis

Specific reading list for the module

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 B

	Weighting	Study time	Eligible for self-certification
Assessment component			
In-person Examination Answer 4 questions	100%		No

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

Reassessment component is the same

Feedback on assessment

Meeting with personal tutor, group feedback

[Past exam papers for PX156](#)

Availability

Courses

This module is Core for:

- Year 1 of UPXA-GF13 Undergraduate Mathematics and Physics (BSc)
- UPXA-FG31 Undergraduate Mathematics and Physics (MMathPhys)
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    - Year 1 of FG31 Mathematics and Physics (MMathPhys)
- Year 1 of UPXA-F300 Undergraduate Physics (BSc)
- UPXA-F303 Undergraduate Physics (MPhys)
    - Year 1 of F300 Physics
    - Year 1 of F303 Physics (MPhys)
- Year 1 of UPXA-F3F5 Undergraduate Physics with Astrophysics (BSc)
- Year 1 of UPXA-F3FA Undergraduate Physics with Astrophysics (MPhys)
- Year 1 of UPXA-F3N2 Undergraduate Physics with Business Studies

This module is Option list B for:

- Year 1 of UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
- Year 1 of UMAA-G100 Undergraduate Mathematics (BSc)
- UMAA-G103 Undergraduate Mathematics (MMath)
    - Year 1 of G100 Mathematics
    - Year 1 of G103 Mathematics (MMath)
- Year 1 of UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe
- Year 1 of UMAA-G1NC Undergraduate Mathematics and Business Studies
- Year 1 of UMAA-G1N2 Undergraduate Mathematics and Business Studies (with Intercalated Year)
- Year 1 of UMAA-GL11 Undergraduate Mathematics and Economics
- Year 1 of UECA-GL12 Undergraduate Mathematics and Economics (with Intercalated Year)
- Year 1 of UMAA-G101 Undergraduate Mathematics with Intercalated Year