PX101-6 Quantum Phenomena

21/22

Department
Physics
Level
Undergraduate Level 1
Module leader
Oleg Petrenko
Credit value
6
Module duration
5 weeks
Assessment
100% exam
Study location
University of Warwick main campus, Coventry

Description

Introductory description

This module starts by explaining 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 then deals with the most important contributions to the development of quantum physics including those of: Planck, who first suggested that the energy in a light wave comes in discrete units or 'quanta'; Einstein, whose theory of the photoelectric effect implied a 'duality' between particles and waves; Bohr, who suggested a theory of the atom that assumed that not only energy but also angular momentum was quantised; and Schrödinger who wrote down the first wave-equations to describe matter.

Module web page

Module aims

The module should 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.

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.

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

Indicative reading list

H. D. Yo.ung 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. It has applications to 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 both for his contributions to 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	15 sessions of 1 hour (25%)
Private study	45 hours (75%)
Total	60 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
In-person Examination	100%	
Answer 2 questions		

Feedback on assessment

Meeting with personal tutor, group feedback

Past exam papers for PX101

Availability

Courses

This module is Core for:

- Year 1 of UPXA-FG33 Undergraduate Mathematics and Physics (BSc MMathPhys)
- 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 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 UPXA-F3N1 Undergraduate Physics and Business Studies
- 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:

- Year 1 of USTA-G300 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics
- 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

This module is Option list B for:

- 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-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)
- 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 UMAA-G101 Undergraduate Mathematics with Intercalated Year