PX262-15 Quantum Mechanics and its Applications

24/25

Department
Physics
Level
Undergraduate Level 2
Module leader
Julie Staunton
Credit value
15
Module duration
20 weeks
Assessment
Multiple
Study location
University of Warwick main campus, Coventry

Description

Introductory description

Quantum theory was developed initially to understand black-body radiation and the emission spectra of atoms. Since then it has become the basis for understanding many phenomena across physics and beyond. Examples include nuclear fusion, which provides all our energy one way or another (fossil fuels are solar energy captured by plants), semiconductor devices (computers, phones, LEDs), the properties of materials (do they conduct, are they transparent), the elementary particles and their interactions.

This module covers the mathematical tools used in quantum mechanics and the fundamental postulates of quantum theory. It applies these to explain the structure of the periodic table, the conductivity and heat capacity of metals, and how semiconductor devices work. Using ideas from quantum mechanics, the module also shows how it is possible to explain a number of aspects of particle physics such as antiparticles and particle oscillations.

[Module web page]

Module aims

To introduce the mathematical structure of quantum mechanics and to explain how to compute expectation values for observable quantities of a system. To show how quantum theory accounts for properties of atoms, elementary particles, nuclei and solids.

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.

Revision of wavefunctions, probability densities and the Schrödinger equation in 1 dimension. The hydrogen atom: orbital angular momentum, quantum numbers, probability distributions. Atomic spectra and Zeeman effect. Electron spin: Stern-Gerlach, spin quantum numbers, spin-orbit coupling, exclusion principle and periodic table. X-ray spectra

Formal Quantum Mechanics:
The first postulate - the wavefunction to describe the state of a system; the principle of superposition of states; Operators and their rôle in quantum mechanics; the correspondence principle; measurement, Hermitian operators and eigenvalue equations; the uncertainty principle - compatibility of measurements and commuting of operators; the time dependent Schrödinger equation

Quantising the harmonic oscillator, creation and annihilation operators

Angular momentum:
The angular momentum operators and their commutators; the eigenvalues of the angular momentum operators, the l and m quantum numbers; the eigenfunctions of the angular momentum operators, the Spherical Harmonics. The hydrogen atom revisited

Models of Matter:
Statement of the many body problem. Why do molecules, nuclei and solids form? The free fermion model model, the Fermi surface, density of states. Fermi-Dirac distribution. Heat capacity, magnetic susceptibility, Pauli paramagnetism, ferromagnetism. Current in quantum mechanics and conductivity in a metal. Fermion degeneracy in white dwarf and neutron stars, gravitational collapse. The liquid drop model of the nucleus, energy release in fission. The crystal lattice: Lattices as repeated cells, unit cell. Lattice types in 3D. Reciprocal lattice vectors, relation to material on Fourier series. Planes and indices. X-ray diffraction. The nearly free electron model, scattering of electron waves by a periodic lattice and band structure. Insulators and semiconductors, doping. Semiconductor devices, e.g. diode, LED

Klein-Gordon and Dirac equations. Solution to Dirac for particle in its rest frame and for particles with zero rest mass. Antiparticles and the origin of spin

Learning outcomes

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

- Explain the origin of the n,l,m and s quantum numbers and their relation to the periodic table
- Explain the significance of Hermitian operators, eigenvalue equations and the correspondence principle
- Use quantum mechanics to find the electronic states of a hydrogen atom
- Explain the free-electron model of a metal

- Discuss the concept of an energy band and how this can be used to explain the properties of metals and semiconductors
- Apply ideas from quantum theory to explain phenomena observed in elementary particles and nuclei

Indicative reading list

H D Young and R A Freedman, University Physics, Pearson
AIM Rae, Quantum Mechanics, IOP
P.C.W. Davies and D.S. Betts, Quantum Mechanics, Chapman and Hall 1994;
F. Mandl, Quantum Mechanics, John Wiley 1992
Steve Simon, The Oxford Solid State Basics, OUP.
RP Feynman, Feynman Lectures on Physics (Vol III), NY Basic Books (Chapters 8-11)
W.N. Cottingham and D.A. Greenwood, An Introduction the Standard Model of Particle Physics, Cambridge 2nd Edition, 2007.

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	40 sessions of 1 hour (27%)
Other activity	20 hours (13%)
Private study	90 hours (60%)
Total	150 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

Other activity description

20 Problem Classes

Costs

No further costs have been identified for this module.

Assessment

You do not need to pass all assessment components to pass the module.

Assessment group D2

	Weighting	Study time
Coursework Class Tests/Computer assessments	15%	
Quantum Mechanics and its Applications Answer 4 questions	85%	

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

Assessment group R1

	Weighting	Study time
Quantum Mechanics and its Applications Answer 4 questions	100%	

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

Feedback on assessment

Personal tutor, group feedback

Past exam papers for PX262

Availability

Courses

This module is Core for:

- Year 2 of UPXA-FG33 Undergraduate Mathematics and Physics (BSc MMathPhys)
- UPXA-GF13 Undergraduate Mathematics and Physics (BSc)
  - Year 2 of GF13 Mathematics and Physics
  - Year 2 of GF13 Mathematics and Physics
- UPXA-FG31 Undergraduate Mathematics and Physics (MMathPhys)
  - Year 2 of FG31 Mathematics and Physics (MMathPhys)
  - Year 2 of FG31 Mathematics and Physics (MMathPhys)
- UPXA-F300 Undergraduate Physics (BSc)
  - Year 2 of F300 Physics
  - Year 2 of F300 Physics
  - Year 2 of F300 Physics
- UPXA-F303 Undergraduate Physics (MPhys)
  - Year 2 of F300 Physics
  - Year 2 of F303 Physics (MPhys)
- Year 2 of UPXA-F3N1 Undergraduate Physics and Business Studies
- UPXA-F3F5 Undergraduate Physics with Astrophysics (BSc)
  - Year 2 of F3F5 Physics with Astrophysics
  - Year 2 of F3F5 Physics with Astrophysics
- Year 2 of UPXA-F3FA Undergraduate Physics with Astrophysics (MPhys)
- Year 2 of UPXA-F3N2 Undergraduate Physics with Business Studies

This module is Option list B for:

- Year 2 of UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
- UMAA-G100 Undergraduate Mathematics (BSc)
  - Year 2 of G100 Mathematics
  - Year 2 of G100 Mathematics
  - Year 2 of G100 Mathematics
- UMAA-G103 Undergraduate Mathematics (MMath)
  - Year 2 of G100 Mathematics
  - Year 2 of G103 Mathematics (MMath)
  - Year 2 of G103 Mathematics (MMath)
- Year 2 of UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe
- Year 2 of UMAA-G1NC Undergraduate Mathematics and Business Studies
- Year 2 of UMAA-G1N2 Undergraduate Mathematics and Business Studies (with Intercalated Year)
- Year 2 of UMAA-GL11 Undergraduate Mathematics and Economics
- Year 2 of UECA-GL12 Undergraduate Mathematics and Economics (with Intercalated Year)
- Year 2 of UMAA-G101 Undergraduate Mathematics with Intercalated Year