10586 - 714 (16) Quantum Mechanics B
(Advanced Formalism and Applications) (3L, 3P)

2022

Course summary

Bra-ket notation, the axioms of quantum mechanics, basis transformations and unitary operators, position and momentum representations, Schrödinger and Heisenberg images, spin, formal theory of angular momentum, time-dependent perturbation theory, scattering theory, identical particles.

Module relevance in programme:

The first half of the module focuses on consolidating the content of the second and third year quantum mechanics modules into a unified mathematical framework. This formalism serves to elucidate the formal structure of quantum mechanics and serves as a basis for the more advanced theory modules that follow, specifically quantum many-body theory and quantum field theory. The second half of the module is dedicated to a detailed development of time-dependent perturbation theory and scattering theory. These topics find application in virtually all areas of physics and are particularly crucial to the understanding of atomic, molecular and nuclear phenomena. In this way the module aims to equip both theory- and experimentally-oriented students with the skills required to master the content of later, more specialised modules.

Outcomes of course:

After introductory courses in quantum mechanics this course equips the student with an understanding and working knowledge of the formal structure of quantum mechanics and its relation to wave mechanics. In particular the student is skilled in operator techniques which are an essential tool in any more advanced application of quantum mechanics.

Lecturer:

Prof FG Scholtz
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Mentor:

The Department of Physics has appointed a staff member as mentor for each year of its physics programme to be available to students for consultation. Students should feel free to discuss general issues related to the physics programme or specific modules in the programme with the relevant mentor, in addition to usual consultations with their individual lecturers of modules.

The mentor for the Honours programme and its modules is Dr P Southey (southey@sun.ac.za)

Course content:

Fundamental concepts
Bra- and ket spaces, state vectors and basis states. Matrix representations and change of basis. Dynamical variables, their operators and the simultaneous measurement of different variables. Continuous bases with application to the position and momentum bases and their mutual transformations. The uncertainty principle.

Quantum dynamics
Time development of states, the time-dependent Schrödinger equation and the energy-time uncertainty relation. The Heisenberg picture, Heisenberg equation of motion and applications.

Angular momentum
The rotation operator in terms of the angular momentum operator J and the characteristic non-commuting property of the components of J. Eigenvalues and eigenvectors. The coupling of angular momenta and the calculations of Clebsch-Gordan coefficients.

Time dependent perturbation theory
Time dependent potentials, the interaction picture and time dependent perturbation theory with applications.

Scattering theory
The Lippmann-Schwinger equation, Born approximation, phase shifts and the optical theorem.

Study material:

A study guide will be made available to students in the Sunlearn portal of the module.

Contact:

Lectures will be face-to face in the slots allocated on the the time table (please consult it). Scheduled tutorials should be used by students to complete the week's homework assignments. Tutorials may also be used for face-to-face feedback sessions as required. Apart from possible face-to-face feedback sessions, the lecturer will also be available during tutorials for consultation in his office (room 1041) or online, depending on the circumstances.

Assignments will be made available on a weekly basis in the Sunlearn portal of the module. It will be graded and the marks will weigh as set out under assessment. The graded assignments will be returned to the students and a memo will be made available for each assignment. It is expected from the student to work through the memo and marked assignment to identify shortcomings in his/her understanding or technical skills.

Assessment:

Evaluation will take place on a continuous basis. Assignments and tests will carry the following weights:

1. Weekly assignments will contribute 50% of the final mark and are compulsory.
2. There will be a mid-semester and a final test at the end of the module, contributing 25 % each to the final mark. These tests will be open book.

This division of marks may be altered in consultation with the students and head of department.