Physical and Chemical Sciences

PHYS411 Advanced Quantum Mechanics 2026
Version: 29 January 2026
0.125 EFTS   15 Points
First Semester Course

Course Coordinator
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Timetable
Classes are scheduled: Monday 9:00, Wednesday 11:00, Thursday 11:00
For rooms, please check your online timetable.

I intend to finish lecture material by the middle of Term 2, to give you time to complete the final assignment.

Tutorials will not be on a fixed schedule but will vary depending on the material.

There will be Test near the beginning of Term 2.

Description
This advanced course in non-relativistic quantum mechanics covers Dirac notation, time evolution, angular momentum, time-dependent perturbation theory, identical particles. This material should be of practical use to students who need to do quantum-mechanical calculations. It also provides background that will be useful in the PHYS416 Quantum Field Theory course.

Assessment
15%   Five Homework Assignments
20%   Test at start of Term 2.
65%   Final Examination

Pre-requisites
Material from PHYS311 (Quantum) is assumed. If you did not take PHYS311 you should obtain a copy of Jenni Adam's notes from the PHYS411 Learn page, since in several places I intend to build on that material.
Some material from PHYS313 (E&M) section will also be assumed (e.g. Maxwell's equations in differential form). Material from PHYS326 (Classical Mechanics) will be helpful for appreciating the material but not essential. Knowledge of multivariate calculus, differential equations, and linear algebra is, of course, assumed.

Textbooks
Much of the course is based on the text: *Modern Quantum Mechanics*, J.J. Sakurai.
The latest version has been considerably expanded by Jim Napolitano. I think that it is a very good book and worth owning. However, there are earlier versions of the book which contain most of the material that I will be using, and you may be able to find one of those. I will

provide some notes and extra materials, but these will not be anywhere as comprehensive as the PHYS311 notes.

Goal of the Course
The aim of this course is to provide a thorough understanding of non-relativistic quantum mechanics, with an emphasis on Dirac notation, time evolution, angular momentum theory, time-dependent perturbation theory and creation and annihilation operator techniques.

Learning Outcomes
Students will be able to:
- Manipulate expressions using Dirac notation.
- Calculate the time-evolution of simple quantum systems.
- Perform calculations using angular-momentum techniques, including the Wigner-Eckart theorem.
- Be able to explain the concept of quantum entanglement and how it might be used for quantum information applications.
- Calculate transition rates using time-dependent perturbation theory.

Summary
In the following "Sa1" and "Sa3" refer to the first and third (and later) editions of Sakurai, *Modern Quantum Mechanics.*
(I have indicated the number of lectures and tutorials we used last year, but this varies.)

FC: Fundamental Concepts:
Bras, kets, operators; Measurement; Position, momentum, translation.
[Sa1 1.1-1.7, Sa3 1.1-1.7]
(5 lectures, 2 tutorials).

DY: Dynamics:
Schrodinger and Heisenberg pictures; Harmonic Oscillator; Potentials.
[Sa1 2.1-2.4, 2.6, Sa3 2.1-2.4, 2.7].
(6 lectures, 2 tutorials).

AM: Angular Momentum and Quantum Information:
Rotations, commutation relations; Eigenvalues and eigenstates; Addition of angular momenta; Bell's theorem, and entanglement; Quantum Information.
Wigner-Eckart theorem.
[Sa1 3.1-3.3, 3.5-3.7, 3.9-3.10, Sa3 3.1-3.6, 3.8, 3.10-3.11, extra material]
(6 lectures, 3 tutorials).

TDPT Time-dependent perturbation theory.
[Sa1 5.1-5.7, Sa3 5.1-5.5, 5.7-5.8]
(3 lectures, 1 tutorial).

General Physics Information
Please consult the document General Information for Physics Students, available on Learn.

Use of AI
The following shall apply for all **assessments** in this course, except where a lecturer has specifically stated otherwise in written instructions for an assessment.
Generative AI Tools Cannot Be Used for This Assessment
In this assessment, you are strictly prohibited from using generative artificial intelligence (AI) to generate any materials or content related to the assessment. This is because students are expected to solve problems and demonstrate knowledge and understanding without the assistance of AI. The use of AI-generated content is not permitted and may be considered a breach of academic integrity. Please ensure that all work submitted is the result of your own human knowledge, skills, and efforts.