Physicals and Chemical Sciences

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

General Course Information

PHYS411 Advanced Quantum Mechanics 2020

Version: 10 February 2020

0.125 EFTS 15 Points
First Semester Course

Course Coordinator
Professor Mike Reid
Beatrice Tinsley 418, Phone (03) 369 4252
mike.reid@canterbury.ac.nz

Timetable
Classes: Monday 10:00, Wednesday 16:00, Friday 10:00
Currently Jack Erksine 121, but please check your MyTimetable!

I will try to run the three slots a week for about 9 weeks, concluding in Mid May,

There will be Test, probably in the last week of Term 1.

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% Three to Four 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, 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 I have is by Sakurai and Jim Napolitano, 2nd ed. Addison-Wesley, 2011, but I understand there is a newer one. 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's 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.
- [*Probably not covered this year, but material will be available for those who are interested:*
  Apply to use second-quantization techniques to simplify calculations involving systems of many fermions and/or bosons.]

Summary
In the following "Sa1" and "Sa2" refer to the first and second editions of Sakurai, *Modern Quantum Mechanics.*

FC: Fundamental Concepts:
Bras, kets, operators; Measurement; Position, momentum, translation.
[Sa1 1.1-1.7, Sa2 1.1-1.7] (4 lectures).

DY: Dynamics:
Schrodinger and Heisenberg pictures; Harmonic Oscillator; Potentials.
[Sa1 2.1-2.4, 2.6, Sa2 2.1-2.4, 2.7]. (4 lectures).

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, Sa2 3.1-3.6, 3.8, 3.10-3.11, extra material] (6 lectures).

TDPT Time-dependent perturbation theory.
[Sa1 5.1-5.7, Sa2 5.1-5.5, 5.7-5.8] (4 lectures).

[*IP Identical particles: Bosons and Fermions; Second quantization.*
[Sa1 6.1–6.4, Sa2 7.1-7.5, extra material].]

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