PHYS 4500: Quantum Mechanics II (fall)

Calendar description: This course is a continuation of PHYS 3500.1(.2), and covers topics such as time-independent perturbation theory, the variation principle, the Werner-Kremer-Boltzmann (WKB) approximation, time-dependent perturbation theory, the adiabatic approximation, and scattering.

Contents

Overview

This is the second of three courses in Quantum Mechanics, with the third (PHYS 4501) being taught only occasionally. It is intended to be a direct follow-on to PHYS 3500 (Quantum Mechanics I).

Prerequisites

PHYS 3201 Mathematical Methods in Physics II

This course provides students with a background in special functions (Laguerre and Legendre polynomials, Bessel and Hankel functions), Hilbert-Schmidt theory, and integro-differential equations. From previous courses, students will also be familiar with Dirac notation, linear algebra, vector calculus, complex numbers and analysis, Greens functions, Sturm-Liouville theory, and methods to solve virtually any second order ODE.

PHYS 3300 Classical Mechanics

Students will have been introduced to the Lagrangian and Hamiltonian formalisms and, in particular, to the Hamiltonian operator.

PHYS 3500 Quantum Mechanics I

If the advice of these notes is followed, PHYS 4500 is a natural follow-on to PHYS 3500, using the second half of the same text. The instructor of PHYS 4500 should be able to rely upon students having covered Schrödinger's model of the one-electron atom, spin and angular momentum, and the concept of identical particles, quantum numbers, *etc.*

Dependent courses

PHYS 4501 Quantum Mechanics III

This is an advanced, special topics course that could cover things like second quantisation, multiple electron atoms, numerical techniques, laser physics, *etc.*, and relies upon students having had a thorough introduction to all the topics in Griffith's text, *Introduction to Quantum Mechanics.*

PHYS 4510 Subatomic Physics

PHYS 4510, also a special topics course, is not an extension of anything specifically covered in PHYS 4500. Rather, it depends upon students having a familiarity with the basic concepts and mathematical techniques covered in an intermediate course in Quantum Mechanics such as PHYS 4500.

Student Outcomes

Students completing PHYS 4500 should have mastered the following skills:

1. Manage different mathematical formalisms
   - select appropriate formalism for the problem
   - change easily between the representations
2. Gain an appreciation of uncertain and probabilistic reality, and that multiple interpretations can exist simultaneously
3. Realise that little is soluble exactly, and thus gain a familiarity with perturbative analysis

Curriculum

1. Time-independent perturbation theory
   - nondegenerate perturbation theory
   - degenerate perturbation theory
   - the fine structure of hydrogen
   - the Zeeman effect
   - hyperfine splitting
2. The variational principle

  - ground state of helium
  - the hydrogen molecule ion

3. The WKB approximation
   - the "classical" region
   - tunneling
   - connection formulae

4. Time-dependent perturbation theory
   - two-level systems
   - emission and absorption of radiation
   - spontaneous emission, lasing

5. The adiabatic approximation (optional)
   - the adiabatic theorem
   - Berry's phase

6. Scattering
   - partial wave analysis
   - phase shifts
   - the Born approximation

Suggested texts

For the most part, the curriculum committee gives names of texts merely as suggestions. However, in this stream the committee strongly urges the instructor to use *Introduction to Quantum Mechanics* by Griffiths, which can serve both this course and its prerequisite, PHYS 3500. Students and instructors universally praise both of Griffiths' texts (this, and *Introduction to Electrodynamics*) as the most enjoyable and comprehensible treatment of both subjects; there simply is no equal.

Part II of *Introduction to Quantum Mechanics*, by David Griffiths (ISBN 0-131-24405-1)

- universally praised by students and instructors as the best text on the market for a two-semester upper-year course in quantum mechanics.
- first half of the text ideal for PHYS 3500.
- covers all the topics required
- includes many problems of varying degrees of difficulty, with many worked examples

For additional problems or alternate approachs, other commonly used and more"advanced" texts on Quantum Mechanics include:

Quantum Mechanics by L. I. Schiff (ISBN 0-070-55287-8)

Quantum Mechanics by Eugene Merzbacher (ISBN 0-471-88702-1)

Quantum Mechanics by Claude Cohen-Tannoudji (ISBN 0-471-56952-6)

Modern Quantum Mechanics by J. J. Sakurai (ISBN 0-201-53929-2)

If the instructor wishes their students to purchase an additional, more advanced text in Quantum Mechanics, (s)he is encouraged to recommend the text to be used in PHYS 4501 (Quantum Mechanics III), in the years that it is taught, since this course is intended to take the student beyond the material in Griffith.

Notes to the instructor

1. The instructor should spend little, if any, time reviewing ideas in mathematics such as linear algebra, Dirac notation, vector calculus, *etc.*; these should have been adequately covered in the MATH prerequisites. If not, the instructoer is asked to bring this to the attention of the Curriculum Committee, so that we may raise these possible deficiencies with our colleagues in the math department.

2. After collectively trying many texts for PHYS 3500 (Quantum Mechanics I) and PHYS 4500, this faculty has determined that hands down, David Griffiths' text (*Introduction to Quantum Mechanics*) is exactly the right text for our students; a sentiment endorsed enthusiastically by *every* student asked. We have made a similar choice for our E&M stream (PHYS 2400 and PHYS 3400). In both cases, Griffiths has just the right amount of material for two courses—one introductory, one intermediate—at exactly the right level for a complete undergraduate curriculum in each subject.

3. The instructor is encouraged to consult with the instructor for PHYS 3500 (Quantum Mechanics I) from the previous year to determine exactly where (s)he left off and what, if any, areas were problematic for the students.