

PHYS 371 – Quantum Theory

Stefan Meinel

Contents

1 Introduction

- 1.1 Particle behavior of electromagnetic waves
 - 1.1.1 Thermal electromagnetic radiation
 - 1.1.2 Photoelectric effect
 - 1.1.3 Compton scattering
- 1.2 Wave behavior of matter particles
 - 1.2.1 Electron diffraction on crystals
 - 1.2.2 Double-slit experiments

2 The Schrödinger equation for a single nonrelativistic particle

- 2.1 Free particle
 - 2.1.1 Phase and group velocity
- 2.2 Particle in a given potential
- 2.3 Conservation of probability
- 2.4 Expectation values and operators
 - 2.4.1 Expectation values of position
 - 2.4.2 The momentum-space wave function
 - 2.4.3 Expectation values of momentum
 - 2.4.4 Momentum and position operators
 - 2.4.5 The uncertainty of an observable
- 2.5 The Hamilton operator
- 2.6 Stationary states

3 One-dimensional problems

- 3.1 Continuity of the wave function
- 3.2 Infinite square well
 - 3.2.1 Orthogonality
 - 3.2.2 Completeness
 - 3.2.3 Measurements of the energy
 - 3.2.4 Note on the integration range
- 3.3 Negative delta-function potential
 - 3.3.1 Bound state ($E < 0$)
 - 3.3.2 Scattering states ($E \geq 0$)
 - 3.3.3 Positive delta-function potential
- 3.4 General properties of one-dimensional potentials
 - 3.4.1 Minimum value of the energy
 - 3.4.2 Bound states vs. scattering states

- 3.4.3 Parity symmetry
- 3.4.4 Adding a constant to the potential
- 3.5 Finite square well
 - 3.5.1 Bound states
 - 3.5.2 Scattering states

4 General formalism

- 4.1 Mathematical preliminaries
 - 4.1.1 Vector spaces
 - 4.1.2 Inner products
 - 4.1.3 Bra vectors
 - 4.1.4 Hilbert spaces
 - 4.1.5 Linear operators
 - 4.1.6 Eigenvectors and eigenvalues of linear operators
 - 4.1.7 The matrix elements of a linear operator
 - 4.1.8 Linear combinations of linear operators
 - 4.1.9 Products of operators; the commutator of two operators
 - 4.1.10 The adjoint of a linear operator
 - 4.1.11 Bra vectors and the adjoint of an operator
 - 4.1.12 Hermitian operators; spectral theorem
 - 4.1.13 Operators with a continuous spectrum
- 4.2 The quantum state vector for a nonrelativistic particle
- 4.3 The general postulates of quantum mechanics
- 4.4 The expectation value of an observable
- 4.5 The general uncertainty principle
- 4.6 The time dependence of an expectation value
- 4.7 Neutrino oscillations

5 The harmonic oscillator

- 5.1 The harmonic oscillator in classical mechanics
- 5.2 The Hamilton operator of the quantum harmonic oscillator
- 5.3 Finding the energy eigenstates using ladder operators
- 5.4 Time dependence
 - 5.4.1 Coherent states

6 Orbital angular momentum

- 6.1 Translations and Rotations
 - 6.1.1 Momentum operators as generators of translations
 - 6.1.2 Angular momentum operators as generators of rotations
- 6.2 Commutation relations for the the angular momentum operators
- 6.3 Rotationally symmetric operators
- 6.4 Eigenvalues of the angular momentum operators
- 6.5 Eigenfunctions of the (orbital) angular momentum operators

7 Spherically symmetric potentials in three dimensions

- 7.1 The radial equation for a general spherically symmetric potential
- 7.2 The hydrogen atom
 - 7.2.1 Electron wave functions in the infinitely-heavy-proton approximation

7.2.2 Treatment as a two-particle system

8 Spin

8.1 Spin 1/2

8.1.1 Wave function with spin and Pauli equation

8.1.2 Larmor precession