Advanced Quantum Physics Notes

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Contents

Abstract

Abstract of this course

1 Revision

2 Perturbation Theory

2.1 Time-Independent Perturbation Theory

2.2 First-order Perturbation Theory

2.3 Second-order Perturbation Theory

Example: Infinite square well with central bump

...

Example: Infinite square well in an electric field

...

Example: Harmonic Oscillator + Linear perturbation

...

Example: Van der Waals Interaction

...

2.4 Degenerate Perturbation Theory

Example: Perturbed 2D infinite square well

...

2.5 Variation Method

Example: Hydrogen atom ground state energy

...

2.5.1 Rayleigh-Ritz Method

Example: Hydrogen atom with finite proton mass

...

3 Electromagnetism

Definition cyclotron frequency:

$$\omega_c = \frac{qB}{m}$$

This is the frequency with which particles moving transverse to a magnetic filed B undergo circular orbit.
ω_c should be really close to the spin precesssion frequency ω_s.

3.1 Aharanov-Bohm Effect

3.2 Gauge Invariance

3.2.1 Couloumb Gauge

3.2.2 Symmetric Gauge

3.3 Orbital Magnetic moment

In Hamiltonian, the $L \cdot B$ term can be written as: $\hat{H} = -\hat{\mu}_L \cdot B$ *Definition Orbital magnetic moment operator:*

$$-\hat{\mu}_L = \frac{q}{2m}\hat{L}\gamma_L$$

...
Definition Gyromagnetic ratio, γ_L:

$$\gamma_L = \frac{q}{2m}$$

...
For an electron (q=-e), the orbital magnetic moment operator is

3.4 Magnetic Moments

3.4.1 Electron

3.4.2 Muon

3.4.3 p, n, nuclei

3.5 Spin

3.5.1 Particle magnetic moment: spin-half

3.5.2 Spin Precession

3.5.3 Spin-half

3.5.4 Energy Eigenstates

3.5.5 Wave-function Evolution

3.6 Stern-Gerlach

3.7 Landau Levels

3.7.1 Landau Gauge

Example: 2D Electron Gas

4 Real Hydrogen Atom

4.1 Relativistic Corrections

4.2 Fine Structure

4.3 Hyperfine Structure

5 Symmetries

5.1 Symmetry Transformation

5.1.1 Time translation

Take way: The time-dependent Shrodinger equation is a consequence of the invariance under time transformation

5.2 The Wigner-Eckart Theorem(selection rule)

Wigner-Eckart Theorem: $\langle \alpha'' j'' m'' | \hat{K} | \alpha' j' m' \rangle = \langle \alpha'' j'' | |\hat{K}| | \alpha' j' \rangle$
A particular case is that $\langle \alpha j m | \hat{K} | \alpha j m \rangle = \langle \alpha j | |\hat{K}| | \alpha j \rangle$
i.e. the expectation values of a scalr opertator are independent of m and are given by the appropriate reduced matrix element of K

5.3 Combining magnetic moment

6 Identical Particles

6.1 Spin and statistics(fermions and bosons)

6.2 Exchange forces

6.3 The Helium atom

7 Multi-electron atoms

7.1 Periodic table

7.2 LS coupling(Hund's rule)

7.3 jj coupling

8 Zeeman effect/Stark effect/Molecules: H_2^+ and H_2