Review for FINAL Exam
Phys 402

Background

Modern Physics Concepts
The Postulates of Quantum Mechanics

The infinite square well potential
The harmonic oscillator

Hydrogen

The Hydrogen Atom (Lecture 1)
- Quantum numbers n, ℓ, m_ℓ
- Eigen-energies $E_n = -13.6\, eV/n^2$, degeneracy $p = 2n^2$ (including spin)
- Eigen-functions (Spherical Harmonics, radial solution)
- Orbital angular momentum as a ladder of states
  - Raising and lowering operators ($\hat{a}_\pm, \hat{L}_\pm, \hat{S}_\pm, \hat{J}_\pm$)
  - Top and bottom of the ladder
  - Symmetric about 0
- Internal field, spin-magnetic field interaction potential $\mathcal{H}^1 = -\vec{\mu}\cdot\vec{B}$

Spin-1/2 (Lecture 2)
- "A two-valudeness not describable classically"
- Spinor Kets $|s\ m_s\rangle$, Pauli spin matrices

Important Skills and Concepts

Adding Vector Operators $\vec{J} = \vec{L} + \vec{S}$ (Spin-orbit, Lecture 5), $\vec{L} + \overrightarrow{2S}$ (Zeeman, Lecture 9), $\vec{S} = \vec{S}_1 + \vec{S}_2$ (Hyperfine, Lecture 7)

Going back and forth between the Coupled and Un-Coupled Representations

$$\left| j\ m_j \right\rangle = \sum_{m_\ell + m_s = m_j} C^{\ell\ \ s\ \ j}_{m_\ell\ m_s\ m_j} \left| \ell\ m_\ell \right\rangle \left| s\ m_s \right\rangle \qquad \text{(Lecture 6)}$$

Spin-triplet and spin-singlet states for two spin-1/2 particles

Perturbation Theory
- Time-Independent, Non-Degenerate, 1st-order, 2nd-order (Lecture 3, Lecture 4)
- Time-Independent, Degenerate (Lecture 8)

Multi-Identical Particle Wavefunctions

- Bosons and Fermions [anti-symmetry constraint], Pauli Exclusion Principle, He atom (Lecture 10)
- Exchange energy, Helium ground and excited states (Lecture 11)
- H_2 molecule (Lecture 12)

Time-Dependent Perturbation Theory

Transition probability from time-dependent perturbation, two-level systems (Lecture 13)

Sinusoidal perturbations, Rabi oscillations (Lecture 14)

Selection rules (Lecture 15)

Incoherent absorption of light, LASERs (Lecture 16)

Approximation Methods

WKB for classically-allowed potentials, eigen-energies and eigen-functions (Lecture 18)

WKB for classically-forbidden regions – Tunneling (Lecture 19)

The Variational method for finding ground state energies (Lecture 20)

Quantum Scattering Theory

Classical and quantum scattering overview (Lecture 21)

Solving the Schrodinger equation for scattering, scattering phase shift (Lecture 22)

Scattering Green's function, Lippmann-Schwinger equation, Born series (Lecture 24)

Applications of Quantum Mechanics

Free Electrons in a Metal – Many identical Fermions, Pauli Exclusion Principle (Lecture 25)

The Cooper Pairing problem of two electrons outside a filled Fermi sea (Lecture 26)

Kronig-Penney periodic potential – electron-ion interactions and band structure (Lecture 27)

Superfluidity in a gas of many identical Bosons: ^{4}He and Bose-Einstein condensation (Lecture 28)

Best way to study for the exam?

Quantum Mechanics is not a subject that we understand based on everyday experience. It must be learned by doing a large number of homework problems to help create an intuition for the subject.

Do all the homework, quiz and discussion problems "cold turkey"

Solutions posted on ELMS!

Understand the concepts (combining vector spins, employing the postulates, respecting indistinguishability, building wavefunctions that are anti-symmetric under exchange of particles, breaking a problem into un-perturbed and perturbed pieces, constructing variational wavefunctions, thinking in terms of operators and waves rather than trajectories, …)

Be proficient at the technical skills (integrals, expectation values, perturbation theory, finding eigenvalues and eigenfunctions, …)