Midterm Examination 1: Topics and Concepts

Course: PHYS 234: Introduction to Quantum Mechanics
Date: February 26, 2026
Coverage: Chapters 1, 2, 3, 4, 5, 6

This midterm covers the fundamental mathematical formalism of quantum mechanics, its application to discrete (spin) systems, and the introduction to wave mechanics through canonical 1D potential problems.

Chapter 1: Stern-Gerlach Experiments & Quantum State Vectors

- **Classical vs. Quantum Results:** Understanding the outcome of Stern-Gerlach experiments (quantization of spin).
- **Observables and Constraints:** Spin up and spin down values, spin-1/2 systems.
- **Quantum States (Kets and Bras):** Definition, notation, and physical meaning of the state vector.
- **Basis Sets:** Orthonormality (normalization and orthogonality) and completeness.
- **Probability Postulate:** Calculating the probability of measurement outcomes from amplitudes.
- **Superposition States:** Understanding coherent superposition versus mixed states.

Chapter 2: Operators and Measurement

- **Operators:** Definition and representation of physical observables.
- **Eigenvalues and Eigenvectors:** Definition and the characteristic equation.
- **Matrix Representation:** Representing kets (column vectors) and operators (matrices) in a chosen basis
- **Diagonalization:** Finding eigenvalues and eigenvectors of a matrix.
- **New Operators:** Spin component in a general direction.
- **Hermitian Operators:** Properties and significance for observables.
- **Measurement and Projection:** The Projection Postulate (state collapse/reduction).
- **Commuting Observables:** Simultaneous measurement and common eigenstates.
- **Expectation Value:** Calculation of the average outcome and the uncertainty.
- **Uncertainty Principle:** Application to spin components.

Chapter 3: Schrödinger Time Evolution

- **Schrödinger Equation:** The fundamental differential equation governing time evolution.
- **Hamiltonian (Energy Operator):** Definition and its role in dynamics.
- **Energy Eigenstates:** Definition of stationary states (states whose measurable properties do not change over time).
- **Time Evolution Recipe:** Calculating the time-evolved state vector for time-independent Hamiltonians.
- **Spin Precession:** Application of the recipe to a spin-1/2 particle in a uniform magnetic field (Larmor precession, Rabi oscillations).

Chapter 4: Quantum Spookiness

- **The EPR Paradox:** Concepts of locality and elements of reality (hidden variables).
- **Entanglement:** Description of entangled states and their non-local correlations.
- **Schrödinger's Cat Paradox:** Conceptual discussion of macroscopic superposition and wave function collapse (decoherence).

Chapter 5: Quantized Energies: Particle in a Box

- **The Wave Function:** Position representation, understanding the wave function as a probability amplitude.
- **Probability Density:** Calculating the spatial probability distribution.
- **Normalization:** Integrating probability density over all space.
- **Translating Formalism:** Rules for moving between bra-ket notation and wave function notation (position and momentum operators).
- **Energy Eigenvalue Equation:** The differential equation form of the energy eigenvalue problem.
- **Infinite Square Well:** Solving the 1D model (allowed energy values, quantization, wave functions, and nodes).
- **Finite Square Well:** Key differences from the infinite well (exponential decay outside the well, barrier penetration).
- **Wave Function Curvature and Energy:** Qualitative relation between the total energy, the potential energy, and the curvature of the wave function.

Chapter 6: Unbound States

- **Free Particle Eigenstates:** Allowed energy and momentum values for a particle with zero potential energy.

- **Momentum Eigenstates:** Relationship to the de Broglie wavelength; wave nature.
- **Momentum Space Wave Function:** Fourier transform relationship with the position space wave function.
- **Wave Packets:** Localized superposition of momentum states, understanding particle-wave duality.
- **Group and Phase Velocity:** Distinction and calculation for free particles, agreement of group velocity with classical velocity.
- **Heisenberg Uncertainty Principle:** The inverse relation between position uncertainty and momentum uncertainty, minimum uncertainty states.