Quantum Mechanics 1

Syllabus

1. Historical and experimental foundations (1). The wave function and its probability interpretation (2.1). The Schrödinger equation for free particles (2.2). Time dependent and stationary Schrödinger equation for general potential (2.5.1,2.8.1). Continuity equation, the probability current density (2.7). Ehrenfest theorem, relation to classical mechanics (2.6).

2. One dimensional problems: Wave function at discontinuity of the potential (3.2.1). Potential well (3.4). Harmonic oscillator: algebraic method (3.1.1), Hermite polynomials (3.1.2), zero point energy (3.1.3). Scattering in one dimension: transmission and reflection coefficients. Potential step (3.2.2), potential barrier (3.3.1), the tunneling effect (3.3.3).
3. Vector spaces, scalar product, Hilbert space. Linear operators, adjoint operator, Hermitian operators. Eigenvalues and eigenfunctions of Hermitian operators. Commutator of operators, common eigenbasis of commuting Hermitian operator. Spectrum of the coordinate and momentum operators. Discrete (matrix) and continuous representations, unitary transformations (2.4.3, 8.1, 8.2, 8.3, 4.3).
4. Measurement in quantum mechanics, density matrix (20.1, 20.2.1, 20.3.4). Average value and uncertainty of a measurement. Heisenberg's uncertainty principle (4.1, 4.2). Axioms of quantum mechanics (2.9.4, 8.3).
5. The angular momentum operators, commutation relations (5.1). Eigenvalues of the $\boldsymbol{L}^2$ and L_z operators (5.2). The $\boldsymbol{L}^2$ and L_z operators in spherical coordinates (5.3). Separation of the kinetic energy into radial and tangential components: the radial momentum operator (6.1).
6. Central potential, the radial Schrödinger equation (6.1). The Coulomb potential, eigenvalues and eigenfunctions of the hydrogen atom, radial probability distribution (6.2, 6.3, *Lenz-vector not needed*).
7. Experimental evidences for the spin of electron: magnetic moment of the electron, normal and anomalous Zeeman effect, Stern–Gerlach experiment, Einstein – de Haas experiment. Mathematical formulation for 1/2-spin, spinor states, the Pauli matrices. The Pauli equation, time evolution of the spin. (9)
8. Time independent perturbation theory, non-degenerate and degenerate first order perturbation theory (11.1). The first order Stark effect: splitting of the n=2 level of the hydrogen atom in homogeneous electric field (14.3).
9. Time dependent perturbation theory. First order transition probability. Transition probability in radiation field, absorption and induced emission. Fermi's golden rule, transition rate. Selection rules in dipole approximation (16.3).
10. Dynamical pictures of quantum mechanics: Schrödinger picture, Heisenberg picture and conservation laws. Dirac (interaction) picture. (8.5)

11. Identical particles, the permutation operator, the Hamilton operator. Symmetry of the wave function: bosons and fermions. Slater determinant. (13.1) He atom: singlet and triplet states, Coulomb and exchange integrals (13.2.1, 13.2.2.1, 23.2.2.2).

12. Potential scattering in three dimension: scattering amplitudes and differential cross section. Method of partial waves, partial scattering amplitudes and phase shifts. The Born approximation. The optical theorem. (18.1-18.5, 18.7)

The numbers in the parentheses refer to the corresponding sections in the texbook:

Franz Schwabl: Quantum Mechanics (Springer, second edition 1990)