

## MINIMUM TO KNOW

- Numerical Data:  $m_e$ ,  $m_p$ ,  $\hbar c$ ,  $\alpha$ ,  $a_B$ , Ry,  $\mu_B$ .
- Simple commutators. Uncertainty relations
- Coordinate and momentum representation, Gaussian wave packet.
- Bohr-Sommerfeld quantization
- Time-dependent evolution in terms of the initial wave function
- Probability density and probability current
- Boundary conditions, discrete and continuum spectrum
- Simple problems with rectangular potentials, infinitely deep and finite box; how to handle the delta-function potential
- Direct variational approach
- Harmonic oscillator, spectrum and wave functions. Operator construction, coherent states of the harmonic oscillator
- Heisenberg operator equations of motion. Conservation laws and relation to symmetry properties
- Orbital momentum operator. Spherical functions (at least up to  $l = 2$  inclusive), relation to vectors, parity
- Reduction of the two-body problem to one-body problem
- Reduction of the three-dimensional Schrödinger equation to the radial equation for a spherically symmetric potential
- Spherical potential box
- Hydrogen atom, spectrum, ground state and excited wave functions (at least  $n = 2$ )
- Two- and three-dimensional harmonic oscillator, classification of states in Cartesian and spherical coordinates
- Creation and annihilation operators, application to the harmonic oscillator
- Landau levels in the magnetic field
- Angular momentum as generator of rotations
- Spin 1/2, spinors, algebra of Pauli matrices, polarization
- Dynamics of spin in static and rotating magnetic field
- Vector coupling of angular momenta, Clebsch-Gordan coefficients

- Selection rules for scalars and vectors
- Classification of states for two particles of spin  $1/2$
- Classification of states in spin-orbit coupling, estimate of fine structure spectrum in the hydrogen atom
- Classification of states and estimate of hyperfine structure
- Static electric and magnetic field (Stark and Zeeman effects), polarizability and Lande factor
- Stationary perturbation theory (up to the second order inclusive)
- Time-dependent perturbations
- Sudden perturbations
- Golden rule
- Density of states in the continuum
- Dipole radiation, transition rate and lifetime, selection rules
- Permutational symmetry for bosons and fermions
- Scattering in the Born approximation, criteria of validity
- Phase shifts, scattering amplitude and cross section