Exam questions.

1. Physical interpretation of wave function in quantum mechanics. Basic properties of wave function (finite, unique , continuous and superposition). Density of probability. Normalizing the wave function ant its physical interpretation.
2. Schrödinger equation. Gradient and Laplas operators. Operator of momentum.
3. Continuity equation for wave function. Probability current density (derive formulas for 1d case). Probability current density and density of current (relation).
4. Stationary Schrödinger equation (derive). Total (time dependent) wave function. Hamilton operator.
5. Operator, linear operator, eigenvalue problem. Hermitian operator. Show that momentum operator is hermitian.
6. Eigenvalues and eigenfunctions of Hermitean operators (definition and formulas). Show that eigenvalues of Hermitian operators are real numbers.
7. Show that the wave function of hermitian operators forms the system of orthonormal functions.
8. Calculate the eigenvalue problem for one dimensional motion of free particle (practical task). Energy, momentum, wavefunction normalized on unit.
9. Completeness of eigenfunctions of Hermitean operators. Calculation of coefficient of linear expation of arbitrary wave function $\psi = \sum_n c_n \phi_n$. Normalizing of ψ and physical meaning of c_n coefficients.
10. Mean values of physical quantities. Calculation of the average value of the system energy for an arbitrary wave function $\psi = \sum_n c_n \phi_n$.
11.Commutative and noncommutative operators and condition for simultaneous measurement of physical quantities. Show that if operators ($\hat{A}$ and $\hat{B}$) of two physical quantities *A* and *B* are commute so the physical quantities *A* and *B* are simultaneously exactly measureable and vice versa.
12. Uncertainty relations (Heisenberg uncertainty principle) (derive).
13.Potential barrier (E > U).
Schrodinger equation. Wave function. Eigenvalues. Transmission and reflection coefficients.
14.Potential barrier (E < U).Wave function. Eigenvalues. Transmission and reflection coefficients.
15.Tunnel effect (tunneling).Wave function. Eigenvalues. Transmission and reflection coefficients.
16. Infinite potential well. Wave function. Eigenvalues.
17. Finite potential well. Wave function. Eigenvalues.
18.Harmonic oscillator. Schrodinger equation. Dimensionless parameters. Asymptotic solution. Nonasymptotic part of the total wave function. Total wave function.
19.Harmonic oscillator. Energy calculation. Eigenfunction. Hermite polynomials. Normalizing of wave function.
20. Harmonic oscillator. Calculation of $\langle x \rangle, \langle U_{pot} \rangle, \langle E_{kin} \rangle, \langle E_{total} \rangle$
21.Creation and annihilation operators. Commutation relation. Hamilton operator for harmonic oscillator in creation-annihilation operators approaches.

22. Calculation of specific heat for chain of identical atoms.
23. Angular momentum operator. Commutation relations.
24. Square of angular momentum operator $\hat{L}^2$. Commutation relations between $\hat{L}^2$ and $\hat{L}_z$.
25. Representation of $\hat{L}^2, \hat{L}_x, \hat{L}_y, \hat{L}_z$ operators in spherical coordinates. Eigenvalue problem for $\hat{L}_z$ operator. Magnetic quantum number. Normalizing the wave function.
26. Eigenvalue problem for $\hat{L}^2$ operator. Spherical function. Legendre polynomial. Orbital quantum number. Relation between orbital and magnetic quantum numbers. Normalizing the spherical wave function.
27. Schrodinger equation for Hydrogen atom. Representation of general solution (wave function).
28. Equation for the radial part of wave function for Hydrogen atom. Method of solution. Laquerre polynomial.
29. Normalizing of radial part of total wave function. Energy of electron. Spectral series of Hydrogen atoms (Lyman, Balmer, Paschen,…). Calculation of wave length for different spectral lines.
30. Bohr radius. Calculation by semiempirical Bohr theory and by quantum mechanics.
31. Degenerate of levels. Order of degeneration of energy levels for Hydrogen atoms. A simple model that includes the influence of internal electrons of alkali metals on a valence electron. Elimination of degeneracy. Periodic table of elements.
32. Time independent perturbation theory(non degenerate case). First order approximation. Corrections for energy and wave function.
33. Time independent perturbation theory. (non degenerate case). Second order approximation. Corrections for energy and wave function.
34. Harmonic oscillator in the field of constant external force. Correction of energy by perturbation theory. Anharmonic oscillator. Correction of energy for cubic perturbation of potential energy($\alpha \cdot x^3$).
35. Time independent perturbation theory(degenerate case). First order approximation. Secular equation. Corrections for energy. Calculation of wave functions.
36. Stark effect and simple Zeeman (electron with zero spin) effect for Hydrogen atom.
37. Time dependent theory. Schrodinger equations for non perturbed stationary task and after the applying the time-dependent perturbation. Representation of wave functions.
38. The equation for the time-dependent expansion coefficients of the wave function. Physical interpretation of this coefficients.
39. The solution of time-dependent perturbation theory for small perturbation. First order approximation. Physical interpretation of results.
40. The time-dependent perturbation theory for small harmonic perturbation. Transition probability for long time and per time unit.
41. The time-dependent perturbation theory for an atom in an external harmonic electromagnetic wave. Perturbation Hamiltonian. Transition probability for dipole moment of electron. Induced and spontaneous transitions and their probabilities. Einstein theory of radiation.
42. Selection rules for transition in dipole approximation for harmonic oscillator and hydrogen like atoms.

43. Orbital magnetic moment of electron. Spin and total magnet moment of electron. Bose and Fermi particles and distributions. Pauli exclusion principle.
44. Fine structure of atomic levels. Spin-orbital (L-S) interaction and it energy.