Lectures

1-3 **Mathematical background**. *Basic linear algebra*: finite dimensional linear spaces. *Probability theory*: basic concepts, probability density function, characteristic function, moments of a distribution. *Fourier transform theory*: basic concepts and application to Gaussian functions.

4-5 **Introduction to quantum mechanics**. Comparison between classical mechanics and quantum mechanics. Classical mechanics: particle OR wave mechanics. Examples: one-dimensional Newton and wave equations. Quantum mechanics: particle AND wave mechanics. Position vector versus wave function. Fundamental concepts of quantum mechanics: superposition principle, operators with discrete spectrum, sum and product of operators.

6-7 **Linear momentum**. Operators with continuous spectrum. Linear momentum operator as the generator of spatial translations. Wave function in momentum space. Uncertainty relations.

8 **Energy**. The Hamiltonian operator. Derivation of expectation values with respect to time. Stationary states.

9 **Schrödinger's equation**. Matrices and unitary operators. The Ammonia molecule as a two level systems.

10 **One-dimensional systems**. Probability current density and continuity equation. The particle in a box. The Ehrenfest theorem.

11 **More about one-dimensional systems**. The potential step. The potential well. Scattering from a potential barrier.

12 **One dimensional Harmonic Oscillator**. Solutions of the wave and matrix problems. Fock states, coherent states and squeezed states.

13 **From the wave function $\Psi(q)$ to the state vector $|\Psi\rangle$**. Evolution of the formalism of quantum mechanics. Functions as vectors. The continuum limit of the norm of a vector. Wave function in position and momentum representations. Complement: The matrix representation.

14 **Angular momentum I**. Orbital angular momentum as generator of spatial rotations. Eigenvalues and eigenfunctions of the angular momentum operators: algebraic treatment.

15 **Angular momentum II**. Eigenvalues and eigenfunctions of the orbital angular momentum operators. Spherical harmonics and their properties.

16 **Photon polarization I**. Single-photon polarization as a two-level quantum systems.

17 **Photon polarization II**. Polarization states invariant under rotations. The "spin" of the photon. Pure states versus statistical mixtures. The density matrix operator.

18-19 **Motion in a centrally symmetric field**. General properties. The Coulomb field: discrete spectrum and degeneracy. Two particle systems and the Hydrogen atom.

20 **Spin**. Intrinsic angular momentum of a particle. Spin operators and Pauli matrices. Sum of angular momenta.

21 **Stationary state perturbation theory I**. Definition of the problem. Non degenerate case. Examples.

22 **Stationary state perturbation theory II**. Degenerate case. Examples.

23 **Time dependent perturbation theory**. Interaction picture. Interaction of an atom with a classical radiation field.

24 **Identical particles**. Permutational symmetry. Bosons and Fermions. The Helium atom and the singlet/triplet states.

25 **Measurements and interpretation of quantum mechanics**. Measurement and collapse of the wave function. Entanglement and nonlocality. Bell's inequality.