Typical oral exam questions

The questions are intended to test understanding of the basic theoretical principles and concepts. At the oral exam it is expected that you prove your statements by showing the respective formulas and by providing a sketch of derivations and proofs.

- Explain the virtual displacement, the principle of virtual work and the D'Alembert's principle.
- Define inertial frames, Galilean principle of relativity (non)conservative forces, (non)holonomic constraints and forces of constraint.
- Derive the equations of motion from the D'Alembert's principle. Define a generalized velocity-dependent potential.
- Explain the properties of Lagrangian, define the cyclic coordinates, show a relation between dynamical invariants and properties of space and time (with examples).
- Define the monogenic systems and explain the Hamilton's principle and its advantages.
- Derive the Lagrange equations from the Hamilton's principle.
- Explain the method of Lagrange multipliers in the case of holonomic and semiholonomic constraints.
- Define the energy function and Jacobi's integral. Show under which circumstances the energy function is the total energy.
- Relate the two-body problem of motion on the central force field with the equivalent one-dimentional problem.
- Identify all the independent constants of motion of the two-body problem with potential $V(r)$. Prove the second Kepler's law.
- Derive and classify the possible types of orbits in the Kepler's and isotropic oscillator's problems. The orbit equation.
- Derive the equation of motion and the period of elliptic motion for the inverse square law. Prove the third Kepler's law.
- Explain the virial theorem and the Bertrand's theorem.
- Define the differential scattering cross section and the scattering angle as a function of the impact parameter.
- Sketch the derivation of the Rutherford cross section of the Coulomb scattering.
- Define an orthogonal transformation, the Euler angles and angle of finite rotations.
- Prove the Euler's theorem. Relate the rotation vector with infinitesimal rotations.
- Show the rate of change of a vector in body and space coordinates. Derive the Coriolis effect.

- Define the total angular momentum, the inertia tensor and the moment of inertia about the rotation axis of the Rigid Body.
- Show how the inertia tensor changes under a change of origin. Define the principal axes and the principal moments of inertia.
- Derive Euler equations of motion. Explain basic properties of the torque-free motion of the axially-symmetric Rigid Body.
- Describe properties of small oscillations. Explain the resonant frequencies, normal coordinates and principal axes.
- Define the relativistic Lagrangian for a point particle. Show a roadmap towards the covariant formulation of Lagrangian mechanics.
- Explain the route from the Lagrangian to the Hamiltonian formalism, their differences. Derive the Hamilton's equations.
- Explain a connection between the cyclic canonical variables and the conservation laws. Describe the Routh's procedure.
- Formulate the modified Hamilton's principle. Explain and derive the principle of least action in various forms.
- Define and classify different types of the canonical transformations. Show a connection between old and new Hamiltonians.
- Define the Poisson bracket and its properties, equations of motion in the Poisson bracket form. Explain when a transformation is a canonical transformation.
- Prove the Poisson theorem. Derive the generation function of the infinitesimal canonical transformation when it corresponds to the physical motion.
- Prove the Liouville's theorem. Give examples of the infinitesimal canonical transformations that leave the Hamiltonian invariant.
- Explain the Hamilton-Jacobi method and its advantages. Describe the physical meaning of the Hamilton's principal and charateristic functions.
- Explain the reason for using Staekel conditions, and give an example. Obtain the form of the Hamilton's principal function in the case of conserved Hamiltonian and separable variables.
- Explain the Action-Angle variables method and its advantages (with examples).
- Formulate the time-dependent Perturbation Theory method.
- Explain the time-independent Perturbation Theory and when it is useful.
- Describe the adiabatic invariance (with examples).
- Describe a transition to the Lagrangian formulation of continuous systems. Derive the energy-momentum tensor, its conservation.
- Prove the Noether's theorem for relativistic fields.