List of subjects for Mechanics 2 oral exam, 2022

1. **Basics of special relativity theory**
   Galilei transformation, Galilei's and Einstein's principle of relativity, event, four-interval. Lorentz transformation, simultaneity, proper time, time dilation, Lorentz contraction. Minkowski space: future, past, causality.
2. **Four-vectors**
   Properties of the Lorentz matrix and the Lorentz group, dependence on relative velocity of the inertial frames, rapidity, addition of velocities. Contravariant and covariant four-vectors, metric tensor, requirements with respect to Lorentz transformation, relativistic Doppler effect, Compton scattering.
3. **Relativistic dynamics**
   Four-velocity, rest mass, four-momentum, relativistic equation of motion, transverse and longitudinal mass, energy-momentum four-vector, particle with zero rest mass, four-force, energy-mass equivalence, mass deficiency.
4. **Relativistic particle in electromagnetic field**
   Lorentz force, relativistic vector potential, electromagnetic four-tensor, equation of motion. Lagrangian and Hamiltonian of a free relativistic particle and a particle in electromagnetic field. Relativistically invariant equation of motion of a charged particle.
5. **Lagrange formalism of elastic media**
   Displacement field, deformation tensor, kinetic energy and potential energy, Lagrange density. Lagrange density of isotropic material.
6. **Dynamics of elastic media**
   Hamilton's principle, Euler-Lagrange equation. Equation of motion of the displacement field in isotropic and anisotropic materials, elastic waves in isotropic elastic medium: transverse and longitudinal sound waves.
7. **Hamilton formalism of field theories**
   Energy and energy current density, equation of continuity, energy conservation. Canonical momentum density, ~~Hamiltonian formalism~~.
8. **Field theories**
   Lagrangian density and action for quantum mechanics, derivation of Schrödinger equation, energy, ~~conservation of charge and Noether-current~~. Relativistic action for a real scalar field, Klein-Gordon equation, its solution in Fourier space, relativistic dispersion. ~~Energy-momentum four-tensor and its continuity equation~~.
9. ~~**Symmetries in the Lagrange formalism, Noether's theorem**~~
   ~~Consequences of the invariance with respect to temporal and spatial translation and rotation, conservation laws, general coordinate transformations, invariance of the Lagrangian with respect to point transformations, Noether theorem~~.
10. **Conserved quantities in the Hamilton formalism**
    Time dependence of physical quantities, properties of Poisson brackets, Poisson theorem, notable Poisson brackets, generators of transformations, symmetry transformations and conserved quantities.
11. **Canonical transformations**
    Mapping the phase space onto itself, definition of the canonical transformation, it's necessary and sufficient condition, it's properties, derivative matrix of the transformation, symplectic structure.
12. **Generating functions**
    Modified Hamilton's principle and Hamilton equations, introduction of the generating function, it's types and relation to the canonical transformation, old and new coordinates, momenta and Hamiltonian.

13. **Hamilton-Jacobi equation**
    The action as ~~a function of coordinates and time, it's use~~ as a type II generating function, and Hamilton-Jacobi equation. Conservative system and reduced action. Motion of a free particle, separation of variables.
14. **Integrable systems**
    The notion of Liouville's integrability, choice of basis in the explorable subspace of the phase space, invariant torus. Action-angle variables, discussion of general integrable motion, discussion of a spherical billiard. Chaotic vs. integrable systems.
15. **Relation to quantum mechanics**

    Interference, Feynman's path integral and relation to the principle of least action. Semiclassical wave function, and quantization conditions: examples of a harmonic oscillator, motion in a hard wall potential, discussion of the Coulomb problem.
16. **Chaotic behavior of dynamical systems**
    ~~The driven damped harmonic oscillator and the attractor of it's motion, dependence on initial conditions, the driven damped pendulum as a nonlinear problem, period doubling, Poincare section, bifurcation diagram, strange attractor, sensitivity to initial conditions, Liapunov exponent.~~