Physical Foundations of Natural Science

1. Introduction to General Relativity. Limitations of the classical theory of gravity. Group properties for rotations. The invariance of the electrodynamic equations under Lorentz transformations.

2. Tensors in physics. The metric tensor in different coordinates. Energy-momentum tensor.

3. Curvature. The triangles and circles. The Gaussian curvature. Curvatureof a sphere in different coordinates.

4. Einstein's equation. Heuristic arguments. Gravity is the curvature. Definition of the curvature through the acceleration of free fall. Limiting transition tononrelativistic case.

5. Cosmology. Friedmann model. Friedmann solution for a flat metric

6. The Einstein equations in a weak gravitational field. The analogy with the equationsMaxwell. Geodetic and Lense-Thirring precession as an analogy of the Larmor precession.

7. Black Holes. Schwarzschild metric. The gravitational radius. Equation of motionof the light. The radius of the marginally stable orbit. Kerr metric, ergosphere.

8. Quantum mechanics. Introduction. The revolutionary character of the development of quantum mechanics in the first quarter of the twentieth century. The discreteness of the energy (photoelectric effect, the spectrum). Planck constant. Determination of Planck length, time, and mass.

9. Wave as a particle. Thomson cross section, the classical electron radius. Compton effect.

10. Particle as a wave. The uncertainty principle for the waves. The group velocity. Wave path of a moving ship, the definition of the angle. Lower levels as a consequence of the uncertainty relation. Phase and group velocity for particles.

11. Dualism. Passage of the light through a polarizer. The interference of the electron. The Bohr's levels as a consequence of the wave nature of electrons. Bohr radius. The size of Rydberg atoms with n= 700

12. Why are incompatible classical gravity and quantum theory. Matvei Bronstein breakthrough – with the derivation in a weak gravitational field. As supersymmetry solves this problem.
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13. Fundamentals of quantum mechanical formalism. Probability, ensemble, measurement, and collapse of the wave function.

14. Spin. Stern-Gerlach experiment. Rotations in three dimensions.

15. The decay of a spinless particle into two particles with spin 1/2. Einstein-Podolsky-Rosen paradox. Hidden variables. Their experimental violation. Bell's inequalities.

16. The identity of the particles. Connection between spin and statistics. The quantum limit of detection of gravitational waves. The density of states. Casimir effect. Chandrasekhar limit.