Exam topics

1. Special relativity, inertial frames, Lorentz transform, Minkowski spacetime, Lorentz contration, time dilatation. Principle of general covariance, rotating coordinate system, curved coordinates.

2. Principle of equivalence, Eötvös experiment, metric tensor, curved spacetime, covariant and contravariant four vectors. Invariant spacetime volume, proper time and distance, simultaneity, synchronizing clocks. Properties of metric tensor.

3. Parallel displacement in curved spacetime, covariant derivatives, Christoffel symbols. Four divergence of vectors and antisyymmetric tensors.

4. Application of parallel displacement: precession of the spherically symmetric top. Connection to Thomas precession and the Gravity Probe B experiment.

5. Motion in curved spacetime, principle of least action, geodetic motion, Hamilton-Jacobi equation. Light propagation. Weak gravitationnal field. Static gravitational field, gravitational redshift. Maxwell's equations in curved spacetime.

6. Parallel translation of a vector along a loop, Riemannian and its properties. Bianchi identity, Ricci tewnsor, Ricci scalar.

7. Action integral of gravity. Energy momentum tensor, divergence equation. Examples.

8. Einstein's equations, derivation, properties. Conservation laws. Energy momentum pseudotensor of gravity.

9. Spherically symmetric vacuum solution of Einstein's equations: Schwarzschild metric. Gravitational mass defect. Motion in a spherically symmetric gravitational field. Gravitational collapse.

10. Experimental evidence of general relativity. Perihelion precession, light deflection. Observation of gravitational redshift.

11. Weak gravitational fields: static fields, stationary fields. Gravitational field of a rotating sphere. Experimental evidence: Gravity Probe B experiment.

12. Weak gravitational fields: gravitational waves. Radiation of gravitational waves. Experimental evidence: Hulse-Taylor pulsar, LIGO experiment.