

Phys 503 / 729: General Relativity and Gravitation Fall 2015 – Checklist of Topics for the Final Exam

Ch.	Subject	Topics
0	Newtonian and Relativistic Gravity	Newtonian gravitational force, gravitational field, gravitational potential and Poisson equation. Gravitomagnetism and its limitations, need for another theory. Inertial and gravitational mass, free fall, equivalence principle, Mach's principle, tidal forces.
1	Minkowski Spacetime and Special Relativity	Spacetime manifold, events, light cones, causality, worldlines, simultaneity, inertial coordinates, interval, timelike / spacelike / null separations; spacetime diagram and transformation under boosts. Postulates of special relativity, Minkowski metric and line element, Poincaré and Lorentz groups. Particle four-velocity U^μ , energy and momentum with respect to an observer t^μ .
2	Differentiable Manifolds	Tangent vectors, dual vectors, tensors, transformation properties, metrics (Riemannian and Lorentzian), operations on tensors (contractions, trace, (anti)symmetrization, index raising and lowering, norm, change of basis), Lie derivative, lengths of curves, tensor densities and integration on manifolds. Symmetries, Killing vector fields and Killing equation.
3	Curvature	Covariant derivative, parallel transport, connection and Christoffel symbols; Geodesic curve, geodesic equation, and acceleration of a worldline; The Riemann tensor and its symmetries, Bianchi identity, Ricci tensor, scalar curvature; Geodesic deviation.
4	Einstein's Theory	Einstein's equation, energy-momentum tensor, cosmological constant and their interpretation, weak-field limit and correspondence with Newtonian gravity, coupling to matter (minimal and non-minimal coupling).
5	Schwarzschild Solution	Form of the Schwarzschild metric, Birkhoff theorem, event horizon, singularities, structure of the maximally extended spacetime and white holes. Effective radial potential and types of particle orbits; Tests of general relativity, gravitational redshift, precession of the perihelion.
7	Gravitational Waves	Linearized gravity, gauge transformations (concept, and consequence for a metric perturbation), form of a plane-wave solution in the transverse traceless gauge, number of independent solutions and their physical effects.
8	Cosmology	Maximally symmetric spacetimes; de Sitter metric and de Sitter space as a solution of Einstein's equation. FLRW spacetimes, scale factor, types of spatial metrics, Friedmann equation, Hubble parameter, deceleration parameter, equation of state parameter w , expansion rate for spatially flat metrics with "matter" and radiation, Big Bang.