General relativity

(Thematic of the complex exam)

1. Einstein equation from variational principle. Einstein—Hilbert and Gibbons—Hawking—York action. Matter energy-momentum tensor. Energy conditions.
2. Geodesic motion and geodesic deviation equation. Kinematic quantities, optical scalars. Raychaudhuri equation, focusing theorem. Weak and strong gravitational lensing.
3. Israel junction conditions on spacelike hypersurfaces. The Lanczos equation.
4. The Arnowitt—Deser—Misner 3+1 decomposition of spacetime, the Hamiltonian formalism of gravity.
5. Spherically symmetric black holes: Schwarzschild, Reissner-Nordström and Vaidya spacetimes, Penrose—Carter diagrams.
6. Rotating black holes, Kerr spacetime. Boyer—Lindquist and Kerr—Schild coordinates. Accretion disk and jet. The Penrose process.
7. Symmetries in general relativity. Killing vectors, conformal Killing vectors, Killing tensors. The Carter constant in Kerr spacetime.
8. Black hole formation in the Oppenheimer-Snyder collapse. Black hole mechanics, black hole thermodynamics.
9. Relativistic cosmology, the Standard Cosmological Model, cosmological observations, and tensions.
10. Gravitational radiation, detection of gravitational waves.

Bibliography:

1. C. W. Misner, K. S. Thorne, J. A. Wheeler – Gravitation, Freeman (1973)
2. S. W. Hawking, G. F. R. Ellis, The large scale structure of space-time, Cambridge University Press (1973)
3. R. M. Wald: General Relativity, The University of Chicago Press, Chicago (1984)
4. N. Straumann - General Relativity and Relativistic Astrophysics, Springer (1984)
5. H. Stephani et al - Exact Solutions of Einstein's Field Equations, Second Edition, Cambridge Monographs on Mathematical Physics (2003)
6. E. Poisson - A Relativist's Toolkit. The Mathematics of Black-Hole Mechanics (2004)
7. M. Hobson, G. Efstathiou, A. Lasenby - General Relativity, An Introduction for Physicists, Cambridge University Press (2006)
8. J. B. Griffiths, J. Podolský - Exact Space-Times in Einstein’s General Relativity, Cambridge Monographs on Mathematical Physics (2009)
9. G. F. R. Ellis, R. Maartens, M. A. H. MacCallum - Relativistic Cosmology, Cambridge University Press (2012)
10. E. Poisson, C. M. Will - Gravity. Newtonian, Post-Newtonian, Relativistic, Cambridge University Press (2014)