

Gravitation

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45 hours: 15 Lectures (30 hours) and 15x1 hours of practical training

1. **Introduction** (Overview of the course; Models of space and time in classical physics; Models of space-time after Einstein).
2. **Fields in Minkowski space-time** (Review of Special Theory of Relativity; Four-Vectors and tensors; A review of Elementary Particles in flat space-time).
3. **Energy-momentum tensors** (Energy of particles; Stress-energy tensors of classical fields; Canonical and Metrical Energy-Momentum Tensors).
4. **Mathematical foundations of GR** (Covariant derivatives and Christoffel symbols; Parallel transport; Riemann tensor).
5. **Physical foundations of GR** (Equivalence Principle; Metrics and Potential; Newton's Law).
6. **Einstein's theory for gravitation** (Einstein Equations; Action for Gravitational Field; Lovelock's theorem).
7. **Spherically symmetric space-time** (Birkhoff's Theorem; Schwarzschild's Solution; Schwarzschild singularities).
8. **Effects of GR** (Motion of test particles; Experimental verification of GR; Post-Newtonian approximation).
9. **The initial-value problem and singularities** (Penrose Conformal Diagrams; Initial-value problem in GR; Exploring Schwarzschild singularities).
10. **Black holes** (Types of Black Holes; Information paradox and no-hair theorem; BH thermodynamics).
11. **Gravitational waves** (Weak field approximation of Einstein equations; Plane wave solutions; Generation of gravitational waves).
12. **Gravitational lensing**(Description and history of gravitational lensing; Basics of gravitational lensing; Microlensing).
13. **Alternatives to GR** (Why to modify GR; Timeline of models of gravity; Testing of alternatives to GR).
14. **Higher dimensional theories of gravity** (Kaluza-Klein theory; Braneworld paradigm; Higher dimension braneworlds).
15. **Overview of course.**

Literature:

- [1]. C.W. Misner, K.S. Thorne, J. A. Wheeler, *Gravitation* (Freeman, NY 1973).
- [2]. S. Weinberg, *Gravitation and Cosmology* (Wiley, NY 1972).
- [3]. Л.Д. Ландау, Е.М. Лифшиц, *Теория Поля* (Наука, Москва 1988).
- [4]. Ta-Pei Cheng, *Relativity, Gravitation, and Cosmology: a Basic Introduction* (Oxford University Press, Oxford and NY 2005).

- [5]. **S.M. Carroll**, *Spacetime and Geometry: An Introduction to General Relativity* (Addison-Wesley, 2004), arXiv: gr-qc/9712019.
- [6]. **D. Gorbunov, V. Rubakov**, *Introduction to the Theory of the Early Universe: Hot Big Bang Theory* (World Sci. Hackensack, NJ, 2011).
- [7]. **A. Riotto**, *Particle Cosmology*, arXiv: 1010.2642.
- [8]. **D.H. Perkins**, *Particle Astrophysics* (Oxford Univ. Press, N.Y. 2009).
- [9]. **J. Allday**, *Quarks, Leptons and the Big Bang* (IOP, London, 2002).
- [10]. *Living Reviews in Relativity* (Max Planck Society), a collection of online reviews which cover any topic related to GR at a high level.
- [11]. **M. Gogberashvili**, *Gravitation and Cosmology* (Electronic course).

Literature for practical studies:

A. P. Lightman, W.H. Press, R.H. Price, S.A. Teukolsky, *Problem Book in Relativity and Gravitation* (Princeton University Press, Princeton 1975).