# General relativity resources

## Books

### Popular

- Geroch, Robert (1981). *General Relativity from A to B*. Chicago: University of Chicago Press. ISBN 0-226-28864-1. Leisurely pace, provides superb intuition for Schwarzschild geometry.
- Lieber, Lillian (2008). *The Einstein Theory of Relativity: A Trip to the Fourth Dimension*. Philadelphia: Paul Dry Books, Inc.. ISBN 978-1-58988-044-3. Updated edition of the 1945 cult classic. Covers both Special and General Relativity using only high school algebra. Introduces tensors as gently and readably as possible.
- Wald, Robert M. (1992). *Space, Time, and Gravity: the Theory of the Big Bang and Black Holes*. Chicago: University of Chicago Press. ISBN 0-226-87029-4. Covers much more ground, while remaining concise and readable.
- Thorne, Kip S. (1995). *Black Holes and Time Warps: Einstein's Outrageous Legacy*. New York: W. W. Norton. ISBN 0-393-31276-3. A delightful romp through the physics of black holes. Features many personal anecdotes from the author's distinguished career.

### Textbooks

#### Beginning undergraduate level

- Callahan, James J. (2000). *The Geometry of Spacetime: an Introduction to Special and General Relativity*. New York: Springer. ISBN 0-387-98641-3. Very clear introduction to special relativity using little more than geometrical intuition, some calculus, and first-year linear algebra. Then moves on to a gentle first encounter with the rudiments of differential geometry and tensor calculus. Concludes with the Einstein equations and some well-known consequences.
- Rindler, Wolfgang (2001). *Relativity: Special, General, and Cosmological*. Oxford University Press. ISBN 0-19-850836-0. This book is an expanded version of an earlier book by the same author, *Essential Relativity*, but covers more topics in greater detail. The physics of general relativity is developed with great care, followed by an introduction to the usual formalism and some more advanced topics.
- Schutz, Bernard F. (2003). *Gravity from the ground up*. Cambridge University Press. ISBN 0-521-45506-5. A more elementary treatment than Rindler's, this book uses no more than a little algebra and trigonometry to explore Einstein's theory of gravity. A good book to develop an intuitive understanding of general relativity, underpinned by helpful back-of-the-envelope type calculations.

**Advanced undergraduate level**

- Cheng, Ta-Pei (2005). *Relativity, Gravitation and Cosmology: a Basic Introduction*. Oxford and New York: Oxford University Press. ISBN 0198529570. Full tensor formulation of GR is postponed till the last of the three parts of the book. Particularly suitable for an introductory GR course with an emphasis on cosmology.
- P.A.M.Dirac, *General Theory of Relativity* (1975), Princeton University Press, quick presentation of the bare essentials of GTR. ISBN 0-691-01146-X
- Gron, O.; Hervik, S. (2007), *Einstein's General theory of Relativity*, Springer, ISBN 978-0-387-69199-2
- Hartle, James B. (2003). *Gravity: an Introduction to Einstein's General Relativity*. San Francisco: Addison-Wesley. ISBN 0-8053-8662-9. One feature of this textbook not found in its competitors is a nice discussion of accretion discs.
- Ohanian, Hans C. & Ruffini, Remo (1994). *Gravitation and Spacetime (3rd ed.)*. New York: W. W. Norton. ISBN 0-393-96501-5. In contrast to other introductions, these authors use an exceptionally clear comparison of linearized general relativity with electromagnetism to motivate Einstein's field equations. Superb treatment of observational tests and of gravitational lensing. Should be useful for students wishing to master the textbook by Weinberg.
- d'Inverno, Ray (1992). *Introducing Einstein's Relativity*. Oxford: Oxford University Press. ISBN 0-19-859686-3. Readable, well illustrated, fairly comprehensive without becoming encyclopedic.
- Hughston, L. & Tod, K. P. (1991). *Introduction to General Relativity*. Cambridge: Cambridge University Press. ISBN 0-521-33943-X. Clearly written, short and sweet; covers less ground than the others but much cheaper.
- Schutz, Bernard F. (1985). *A First Course in General Relativity*. Cambridge: Cambridge University Press. ISBN 0-521-27703-5. Features an outstanding treatment of tensor calculus and the stress-energy tensor, a key topic which beginners often have trouble grasping. The treatment of linearized gravitational waves and stellar models is also outstanding.

**Graduate level**

- Carroll, Sean M. (2004). *Spacetime and Geometry: An Introduction to General Relativity*. San Francisco: Addison-Wesley. ISBN 0-8053-8732-3. Readable, up-to-date book. Features an outstanding treatment of the mass, charge, and spin of isolated objects, plus an elementary introduction to quantum field theory on curved spacetimes and Hawking radiation. Further essential material is concisely explained in valuable appendices. Book website [1].
- Grøn, Øyvind; Hervik, Sigbjørn (2007). *Einstein's General Theory of Relativity*. New York: Springer. ISBN 978-0-387-69199-2.. A chapter on special relativity, five chapters on differential geometry, three on general relativity and three on cosmology, all on a graduate level. Advanced topics contain five chapters including a chapter on anisotropic universe models, Israel's metric junction method, a chapter on Brane-worlds and one on Kaluza-Klein theory. Lots of examples and problems with titles and separate lists of examples and problems.

- Stephani, Hans (1990). *General Relativity: An Introduction to the Theory of the Gravitational Field,*. Cambridge: Cambridge University Press. ISBN 0-521-37941-5. Clear and very well organized. Features excellent treatment of far-field and weak-field expansions and linearized gravitational waves, including multipole moments. Offers more on solution techniques than other introductory textbooks.
- Wald, Robert M. (1984). *General Relativity*. Chicago: University of Chicago Press. ISBN 0-226-87033-2. Often cited as the definitive graduate level textbook. Features an outstanding introduction to tensors (with a clear distinction between *abstract indices* and particular indices, overlooked by most other authors), as well as the basic singularity, stability, and uniqueness theorems, quantum field theory on curved spacetimes, and black hole thermodynamics. Much valuable material is clearly explained in a series of superb appendices. In general, this book focuses more on developing insight into mathematical formalism and techniques than on developing physical insight.
- Landau, Lev D.; Lifshitz, Evgeny F. (1980), *The Classical Theory of Fields (4th ed.)*, London: Butterworth-Heinemann, ISBN 0-7506-2768-9 A unique textbook straddling the modern and pre-modern eras in general relativity, this offers a dual introduction to Maxwell's theory of electromagnetism and Einstein's theory of gravitation. Noteworthy topics include a good treatment of multipole moments and background material needed for the BKL conjecture.
- Misner, Charles; Thorne, Kip S.; Wheeler, John Archibald (1973), *Gravitation*, San Francisco: W. H. Freeman, ISBN 0-7167-0344-0 A classic general relativity textbook. Features a unique two-track organization, with numerous boxes, tables, figures, and citations. In general, this book focuses more on developing physical and geometrical intuition than the textbook by Wald. Generally regarded as the first modern textbook on general relativity.
- Weinberg, Steven (1972). *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity*. New York: John Wiley & Sons. ISBN 0-471-92567-5. Demanding but full of valuable physical insight and techniques. No pictures, in marked contrast to the textbook by Misner, Thorne & Wheeler. Excellent treatment of topics related to PPN formalism, weak field approximations, gravitons, as well as applications of particle physics to cosmology. No exercises.

**Special topics**

- Will, Clifford M. (1993). *Theory and experiment in gravitational physics*. Cambridge: Cambridge University Press. ISBN 0-521-43973-6. A systematic introduction to tests of general relativity - from the theoretical underpinnings (Parameterized post-Newtonian formalism) to the actual observations. Compare the same author's article The Confrontation between General Relativity and Experiment [2] on Living reviews in relativity [3].
- Poisson, Eric (2004). *A Relativist's Toolkit: The Mathematics of Black Hole Mechanics*. Cambridge: Cambridge University Press. ISBN 0-521-83091-5. Don't be fooled by the subtitle; this book explains many key concepts and techniques which are needed by *all* contemporary graduate students, but are not adequately explained elsewhere. Essential topics covered here include congruences (expansion, vorticity, and shear), optical scalars, junction conditions for matching interior solutions to exterior solutions, thin shells (including null shells), spatial hyperslices, and energy conditions.

- Stephani, Hans; Kramer, Dietrich; MacCallum, Malcom; Hoenselaers, Cornelius; Hertl, Eduard (2003). *Exact Solutions to Einstein's Field Equations (2nd ed.)*. Cambridge: Cambridge University Press. ISBN 0-521-46136-7. This awesome monograph attempts to provide an up-to-date survey of many of the tens of thousands of known exact solutions, plus solution techniques and essential background such as Newman-Penrose formalism.
- Stewart, John (1993). *Advanced General Relativity*. Cambridge: Cambridge University Press. ISBN 0-521-44946-4. Not easy to read, but one of the few textbooks to offer an introduction to the important Newman-Penrose formalism. Also features much material on gravitational waves.
- De Felice, F.; and Clarke, C. J. (1992). *Relativity on Curved Manifolds*. Cambridge: Cambridge University Press. ISBN 0-521-42908-0. This book is billed as an introductory textbook, but has no exercises and may be hard to read. Unique features include a chapter on measurement theory for general relativity, plus an introduction to tetrad formalism.
- Lightman, Alan P.; Press, William H.; Price, Richard H.; Teukolsky, Saul A. (1975), *Problem Book in Relativity and Gravitation*, Princeton: Princeton University Press, ISBN 0-691-08162-X A collection of excellent problems, with sketch solutions in the back. Test your skills!
- Hawking, Stephen; Ellis, G. F. R. (1973), *The Large Scale Structure of Spacetime*, Cambridge: Cambridge University Press, ISBN 0-521-09906-4 A classic and highly influentical monograph; features excellent motivation of the field equation and careful discussion of some important exact solutions, especially their causal or conformal structure.
- Grøn, Øyvind; Hervik, Sigbjørn (2007), *Einstein's General Theory of Relativity with Modern Applications in Cosmology*, Springer, ISBN 978-0-387-69199-2

# External links

## Popular

- Einstein Online [4]. Website featuring articles on a variety of aspects of relativistic physics for a general audience, hosted by the Max Planck Institute for Gravitational Physics
- NCSA Spacetime Wrinkles [5]. Website produced by the numerical relativity group at the NCSA, featuring an elementary introduction to general relativity, black holes and gravitational waves

## Online tutorials

- Baez, John & Bunn, Ted; http://math.ucr.edu/home/baez/einstein/|"The Meaning of Einstein's Equation". http://math.ucr.edu/home/baez/einstein/. Retrieved on January 4 2006. This superb expository paper explains the meaning of the field equation in terms of the motion of a cloud of free falling test particles.
- Baez, John; http://math.ucr.edu/home/baez/gr/|"The General Relativity Tutorial". http://math.ucr.edu/home/baez/gr/. Retrieved on 1997.
- Carroll, Sean M.; http://preposterousuniverse.com/grnotes/grtinypdf.pdf|"A No-Nonsense Introduction to General Relativity" (PDF). http://preposterousuniverse.com/grnotes/grtinypdf.pdf. Retrieved on November 26 2006. A concise but very readable overview.

## Webcourses

- Brown, Kevin. http://www.mathpages.com/rr/rrtoc.htm|"Reflections on relativity". *Mathpages.com*. http://www.mathpages.com/rr/rrtoc.htm. Retrieved on May 29 2005. An online book providing extensive discussion of various aspects of special and general relativity.
- Carroll, Sean M.. http://preposterousuniverse.com/grnotes/|"Lecture Notes on General Relativity". http://preposterousuniverse.com/grnotes/. Retrieved on November 26 2006. Extensive (227 pages) lecture notes for an introductory course on general relativity. Readable, largely self-contained material.
- Waner, Stefan. http://people.hofstra.edu/faculty/Stefan_Waner/RealWorld/pdfs/DiffGeom.pdf|"Introduction to Differential Geometry and General Relativity" (PDF). http://people.hofstra.edu/faculty/Stefan_Waner/RealWorld/pdfs/DiffGeom.pdf. Retrieved on January 31 2006. Another set of readable, largely self-contained lecture notes.
- Moor, Rafi. http://www.rafimoor.com/english/GRE.htm|"Understanding General Relativity". http://www.rafimoor.com/english/GRE.htm. Retrieved on July 11 2006. - The theory of general relativity in an easily understandable way.

## Collection of review articles

- Living Reviews in Relativity [6]. Electronic journal which features about 50 review articles (and counting) about various subjects of relativistic physics, which are regularly updated by their authors.

## Special topics

- John D Norton [7];
  What was Einstein's principle of equivalence? [8] [PDF-file, 376 KB] Discussion of the difference between what Einstein introduced and the 'infinitisimal principle of equivalence' (which Einstein objected against) that is encountered in virtually all textbooks.
- John D Norton [7];
  General Covariance and the Foundations of General Relativity: Eight Decades of Dispute [9] (PDF-file, 460 KB) Discussion of the question whether the General Covariance of GTR is physically significant. John Norton documents that on this issue there is fundamental dissent in the physics community.

- Michel Janssen [10];
  Einstein's first systematic exposition of general relativity [11] (PDF-file, 187 KB)
  Discussion of the development of Einstein's views on the foundations of general relativity, such as Einstein's embracing of Mach's principle during development of general relativity, (explicit introduction in 1918), and why Einstein abandoned Mach's principle in the early twenties.

### Reading lists

- Chris Hillman's Are There Any Good Books on Relativity Theory? [12]
- http://math.ucr.edu/home/baez/einstein/node11.html|"Bibliography". *The Meaning of Einstein's Equation*. http://math.ucr.edu/home/baez/einstein/node11.html. Retrieved on January 4 2006. By John Baez and Emory F. Bunn.

## References

[1] http://spacetimeandgeometry.net/
[2] http://relativity.livingreviews.org/Articles/lrr-2006-3/
[3] http://relativity.livingreviews.org
[4] http://www.einstein-online.info/en
[5] http://archive.ncsa.uiuc.edu/Cyberia/NumRel/NumRelHome.html
[6] http://relativity.livingreviews.org/
[7] http://www.pitt.edu/~jdnorton/jdnorton.html
[8] http://www.pitt.edu/~jdnorton/papers/ProfE_re-set.pdf
[9] http://www.pitt.edu/~jdnorton/papers/decades_re-set.pdf
[10] http://www.tc.umn.edu/~janss011/
[11] http://philsci-archive.pitt.edu/archive/00002123/01/annalen.pdf
[12] http://math.ucr.edu/home/baez/physics/Administrivia/rel_booklist.html

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