

# General Relativity: Exercises 2 -Solutions

May 25, 2011

## Homework 1: Foucault Pendulum

Equations of parallel transport of vector  $V$  are

$$\dot{V}^\mu + \Gamma_{\alpha\beta}^\mu V^\alpha \dot{x}^\beta = 0, \quad (1)$$

where dot means differentiation according to  $t$ . Taking Christoffel symbols for 2-spheres and choosing parametrization  $t = \phi$  we obtain system of coupled differential equations

$$\dot{V}^\theta - \sin \theta_0 \cos \theta_0 \dot{\phi} V^\phi = 0, \quad (2)$$

$$\dot{V}^\phi + \cot \theta_0 V^\theta = 0. \quad (3)$$

We can solve this system by differentiating first equation according to  $\phi$  and inserting second equation into it. We obtain differential equation of second order

$$\ddot{V}^\theta + \cos^2 \theta_0 V^\theta = 0, \quad (4)$$

Solution to this differential equation is given by

$$V^\theta = A \cos(\phi \cos \theta_0) + B \sin(\phi \cos \theta_0), \quad (5)$$

where  $A$  and  $B$  are integration constants which we can determine from condition  $V = (V^\theta, V^\phi) = (0, 1)$  at  $\phi = 0$ . We obtain  $A = 1$  and  $B = 0$ . With knowledge of  $V^\theta$  we can find (3) to be

$$\dot{V}^\phi = -\cot \theta_0 V^\theta = -\cot \theta_0 \cos[\phi \cos \theta_0], \quad (6)$$

which can be easily integrated and thus we obtain final solution

$$V^\theta = \cos[\phi \cos \theta_0], \quad (7)$$

$$V^\phi = -\frac{\sin[\phi \cos \theta_0]}{\sin \theta_0}. \quad (8)$$

To find angle by which is vector rotated we need

$$\cos \alpha = \frac{V \cdot V'}{|V| |V'|} \quad (9)$$

where  $V$  is  $V = V(\phi = 0)$  and  $V'$  is after parallel transport, i.e.  $V' = V(\phi = 2\pi)$  From there we can see that after parallel transport around full circle, i.e. from  $\phi = 0$  to  $\phi = 2\pi$ , vector  $V$  will be rotated by angle

$$\alpha = 2\pi \cos \theta_0, \quad (10)$$

what is exactly angle by which Foucault pendulum will be rotated by one day. This is because motion of Foucault pendulum is inertial, i.e. is parallelly transported. In one day it is parallelly transported around full circle (because of rotation of Earth surface).

# General Relativity Solutions To Exercises

**L. P. Hughston, K. P. Tod**



## General Relativity Solutions To Exercises:

**Solutions of Exercises of General Relativity Simplified & Assessed** Taha Sochi, This book contains detailed solutions of all the 606 exercises of my book General Relativity Simplified Assessed These exercises represent an integral part of the original book as they fill many gaps and provide essential extensions and elaborations **A Student's Manual for A First Course in General Relativity** Robert B. Scott, 2016-01-21 This comprehensive student manual has been designed to accompany the leading textbook by Bernard Schutz A First Course in General Relativity and uses detailed solutions cross referenced to several introductory and more advanced textbooks to enable self learners undergraduates and postgraduates to master general relativity through problem solving The perfect accompaniment to Schutz s textbook this manual guides the reader step by step through over 200 exercises with clear easy to follow derivations It provides detailed solutions to almost half of Schutz s exercises and includes 125 brand new supplementary problems that address the subtle points of each chapter It includes a comprehensive index and collects useful mathematical results such as transformation matrices and Christoffel symbols for commonly studied spacetimes in an appendix Supported by an online table categorising exercises a Maple worksheet and an instructors manual this text provides an invaluable resource for all students and instructors using Schutz s textbook *Solutions of Exercises of General Relativity Simplified & Assessed* Taha Sochi, 2020-07-29 This book contains detailed solutions of all the 606 exercises of my book General Relativity Simplified Assessed These exercises represent an integral part of the original book as they fill many gaps and provide essential extensions and elaborations [String Theory Methods for Condensed Matter Physics](#) Horatiu Nastase, 2017-09-21 The discovery of a duality between Anti de Sitter spaces AdS and Conformal Field Theories CFT has led to major advances in our understanding of quantum field theory and quantum gravity String theory methods and AdS CFT correspondence maps provide new ways to think about difficult condensed matter problems String theory methods based on the AdS CFT correspondence allow us to transform problems so they have weak interactions and can be solved more easily They can also help map problems to different descriptions for instance mapping the description of a fluid using the Navier Stokes equations to the description of an event horizon of a black hole using Einstein s equations This textbook covers the applications of string theory methods and the mathematics of AdS CFT to areas of condensed matter physics Bridging the gap between string theory and condensed matter this is a valuable textbook for students and researchers in both fields **Introduction to the AdS/CFT Correspondence** Horațiu Năstase, 2015-09-10 Providing a pedagogical introduction to the rapidly developing field of AdS CFT correspondence this is one of the first texts to provide an accessible introduction to all the necessary concepts needed to engage with the methods tools and applications of AdS CFT Without assuming anything beyond an introductory course in quantum field theory it begins by guiding the reader through the basic concepts of field theory and gauge theory general relativity supersymmetry supergravity string theory and conformal field theory before

moving on to give a clear and rigorous account of AdS CFT correspondence The final section discusses the more specialised applications including QCD quark gluon plasma and condensed matter This book is self contained and learner focused featuring numerous exercises and examples It is essential reading for both students and researchers across the fields of particle nuclear and condensed matter physics     *Elementary General Relativity* C. Clarke, Christopher James Seaton Clarke, 1980     *General Relativity Without Calculus* Jose Natario, 2011-07-30 General Relativity Without Calculus offers a compact but mathematically correct introduction to the general theory of relativity assuming only a basic knowledge of high school mathematics and physics Targeted at first year undergraduates and advanced high school students who wish to learn Einstein's theory beyond popular science accounts it covers the basics of special relativity Minkowski space time non Euclidean geometry Newtonian gravity the Schwarzschild solution black holes and cosmology The quick paced style is balanced by over 75 exercises including full solutions allowing readers to test and consolidate their understanding

Introduction to General Relativity Ronald Adler, Maurice Bazin, Menahem Schiffer, 1975     *Problem Book in Relativity and Gravitation* Alan P. Lightman, 1975-12-21 The authors have attempted to convey a mode of approach to these kinds of problems revealing procedures that can reduce the labor of calculations while avoiding the pitfall of too much or too powerful formalism     **A Short Course in General Relativity** James A. Foster, J. David Nightingale, 2010-04-30 Suitable for a one semester course in general relativity for senior undergraduates or beginning graduate students this text clarifies the mathematical aspects of Einstein's theory of relativity without sacrificing physical understanding The text begins with an exposition of those aspects of tensor calculus and differential geometry needed for a proper treatment of the subject The discussion then turns to the spacetime of general relativity and to geodesic motion A brief consideration of the field equations is followed by a discussion of physics in the vicinity of massive objects including an elementary treatment of black holes and rotating objects The main text concludes with introductory chapters on gravitational radiation and cosmology This new third edition has been updated to take account of fresh observational evidence and experiments It includes new sections on the Kerr solution in Chapter 4 and cosmological speeds of recession in Chapter 6 A more mathematical treatment of tensors and manifolds included in the 1st edition but omitted in the 2nd edition has been restored in an appendix Also included are two additional appendixes Special Relativity Review and The Chinese Connection and outline solutions to all exercises and problems making it especially suitable for private study     Quantum Gravity and Quantum Cosmology Gianluca Calcagni, Lefteris Papantonopoulos, George Siopsis, Nikos Tsamis, 2012-10-31 Quantum gravity has developed into a fast growing subject in physics and it is expected that probing the high energy and high curvature regimes of gravitating systems will shed some light on how to eventually achieve an ultraviolet complete quantum theory of gravity Such a theory would provide the much needed information about fundamental problems of classical gravity such as the initial big bang singularity the cosmological constant problem Planck scale physics and the early time inflationary evolution of our Universe

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*Introduction To General Relativity: Solutions To Problems* John Dirk Walecka, 2017-06-16 It is important for every physicist today to have a working knowledge of Einstein's theory of general relativity Introduction to General Relativity published in 2007 was aimed at first year graduate students or advanced undergraduates in physics Only a basic understanding of classical lagrangian mechanics is assumed beyond that the reader should find the material to be self contained The mechanics problem of a point mass constrained to move without friction on a two dimensional surface of arbitrary shape serves as a paradigm for the development of the mathematics and physics of general relativity Special relativity is reviewed The basic principles of general relativity are then presented and the most important applications are discussed The final special topics section takes the reader up to a few areas of current research An extensive set of accessible problems enhances and extends the coverage As a learning and teaching tool this current book provides solutions to those problems This text and solutions manual are meant to provide an introduction to the subject It is hoped that these books will allow the reader to approach the more advanced texts and monographs as well as the continual influx of fascinating new experimental results with a deeper understanding and sense of appreciation

Algebraic Computing in General Relativity M. A. H. MacCallum, 1994 This book provides a step by step approach to the facilities available in MAPLE REDUCE and SHEEP three innovative computer algebra systems for performing calculations relevant to general relativity theory research Beginning with MAPLE and REDUCE two widespread great purpose systems the authors describe how currently available packages perform tetrad coordinate system and Poincar gauge theory calculations A section on SHEEP and Stensor offers expert guidance on how they can be used to tackle a wide range of calculations in general relativity including the manipulation of indicial formulae With Algebraic Computing in General Relativity in hand students and researchers in mathematical physics and general relativity theory have an indispensable practical overview of the subject

American Journal of Physics ,1999      CERN Courier ,2010      **Mathematica(R) in Theoretical Physics** Gerd Baumann, 1996 The primary purpose of this book is to show readers how to solve physical problems and deal with their underlying theoretical concepts while using Mathematica to derive numerical and analytic solutions Used as an everyday tool Mathematica permits scientists and engineers to perform in depth analysis of scientific computations and results This book assumes only a basic understanding of theoretical concepts in physics It can be used as a textbook or as a reference work by

students and researchers alike A brief glossary of terms and functions as well as information explaining how to use the diskette are contained in the appendices      *Applied General Relativity* Michael H. Soffel, Wen-Biao Han, 2019-09-23 In the late 20th and beginning 21st century high precision astronomy positioning and metrology strongly rely on general relativity Supported by exercises and solutions this book offers graduate students and researchers entering those fields a self contained and exhaustive but accessible treatment of applied general relativity The book is written in a homogenous graduate level textbook style allowing the reader to understand the arguments step by step It first introduces the mathematical and theoretical foundations of gravity theory and then concentrates on its general relativistic applications clock rates clock sychronization establishment of time scales astronomical references frames relativistic astrometry celestial mechanics and metrology The authors present up to date relativistic models for applied techniques such as Satellite LASER Ranging SLR Lunar LASER Ranging LLR Globale Navigation Satellite Systems GNSS Very Large Baseline Interferometry VLBI radar measurements gyroscopes and pulsar timing A list of acronyms helps the reader keep an overview and a mathematical appendix provides required functions and terms      **Physics Briefs** ,1993      *An Introduction to General Relativity* L. P. Hughston, K. P. Tod, 1990 This textbook provides an introduction to general relativity for mathematics undergraduates or graduate physicists After a review of Cartesian tensor notation and special relativity the concepts of Riemannian differential geometry are introduced More emphasis is placed on an intuitive grasp of the subject and a calculational facility than on a rigorous mathematical exposition General relativity is then presented as a relativistic theory of gravity reducing in the appropriate limits to Newtonian gravity or special relativity The Schwarzschild solution is derived and the gravitational red shift time dilation and classic tests of general relativity are discussed There is a brief account of gravitational collapse and black holes based on the extended Schwarzschild solution Other vacuum solutions are described motivated by their counterparts in linearised general relativity The book ends with chapters on cosmological solutions to the field equations There are exercises attached to each chapter some of which extend the development given in the text

**Simon Stevin;** ,1991

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