

# General Relativity: Exercises 2 -Solutions

May 25, 2011

## Homework 1: Foucault Pendulum

Equations of parallel transport of vector  $V$  are

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

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

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

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

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  $V = (V^\phi, V^\theta) = (0, 1)$  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

**George Frederick James Temple**



## General Relativity Solutions To Exercises:

**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 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

*Iterative Solution of Large Linear Systems* David M. Young, 2003-01-01 This self contained treatment offers a systematic development of the theory of iterative methods Its focal point resides in an analysis of the convergence properties of the successive overrelaxation SOR method as applied to a linear system with a consistently ordered matrix The text explores the convergence properties of the SOR method and related techniques in terms of the spectral radii of the associated matrices as well as in terms of certain matrix norms Contents include a review of matrix theory and general properties of iterative methods SOR method and stationary modified SOR method for consistently ordered matrices nonstationary methods generalizations of SOR theory and variants of method second degree methods alternating direction implicit methods and a comparison of methods 1971 edition

*Foundations of Modern Analysis* Avner Friedman, 1982-01-01 Measure and integration metric spaces the elements of functional analysis in Banach spaces and spectral theory in Hilbert spaces all in a single study Only book of its kind Unusual topics detailed analyses Problems Excellent for first year graduate students almost any course on modern analysis Preface Bibliography Index

**Student Study Guide & Selected Solutions Manual** David D. Reid, 2007

*Cartesian Tensors* George Frederick James Temple, 2004-09-01 An introduction to the theory of Cartesian tensors this text notes the importance of the analysis of the structure of tensors in terms of spectral sets of projection operators as part of the very substance of quantum theory Covers isotropic tensors and spinor analysis within the confines of Euclidean space and tensors in orthogonal curvilinear coordinates Examples 1960 edition

**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

*The Philosophy of Set Theory* Mary Tiles, 2004-01-01 A century ago Georg Cantor demonstrated the possibility of a series of transfinite infinite numbers His methods unorthodox for the time enabled him to derive theorems that established a mathematical reality for a hierarchy of infinities Cantor s innovation was opposed and ignored by the establishment years later the value of his work was recognized

and appreciated as a landmark in mathematical thought forming the beginning of set theory and the foundation for most of contemporary mathematics As Cantor's sometime collaborator David Hilbert remarked No one will drive us from the paradise that Cantor has created This volume offers a guided tour of modern mathematics Garden of Eden beginning with perspectives on the finite universe and classes and Aristotelian logic Author Mary Tiles further examines permutations combinations and infinite cardinalities numbering the continuum Cantor's transfinite paradise axiomatic set theory logical objects and logical types and independence results and the universe of sets She concludes with views of the constructs and reality of mathematical structure Philosophers with only a basic grounding in mathematics as well as mathematicians who have taken only an introductory course in philosophy will find an abundance of intriguing topics in this text which is appropriate for undergraduate and graduate level courses

*Elementary General Relativity* C. Clarke, Christopher James Seaton Clarke, 1980

**The Mathematical Gazette**, 1926

**Problems And Solutions On Solid State Physics, Relativity And Miscellaneous Topics** Yung-kuo Lim, 1994-12-20 The material for this series was selected from the past 20 years examination questions for graduate students at the University of California Berkeley Columbia University the University of Chicago MIT the State University of New York at Buffalo Princeton University and the University of Wisconsin This volume comprises 165 problems The section on Solid State Physics includes crystal structures and properties electron theory energy bands and semiconductors The Relativity section covers both the special and general theories Topics that were not appropriate for the other 6 volumes in this series appear here under the heading of Miscellaneous Topics

The English Catalogue of Books [annual] Sampson Low, 1927 Vols for 1898 1968 include a directory of publishers

*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

**College Trigonometry** Richard N. Aufmann, Vernon C. Barker, Richard Nation, 2001-07-18 The Fourth Edition of College Trigonometry continues to promote student success by engaging students in mathematics thus helping

them see the dynamic link between concepts and applications The authors hallmark approach the Aufmann Interactive Method encourages students to interact with math by presenting an annotated example then guiding students with a Try Exercise and finally presenting a worked out solution for immediate reinforcement of the concept A wealth of new features designed to enhance learning include more in text guidance as well as special web based resources and an unparalleled Instructor s Annotated Edition facilitates teaching New An Instructor s Annotated Edition unlike any other offered for this course features reduced student text pages with special instructor resources in the margins teaching tips extra examples ideas for reinforcing concepts discussion suggestions highlighted vocabulary and symbols challenge problems quizzes suggested assignments and references to transparencies that may be found both in the Instructor s Resource Manual and on the web site New Side by Side Solutions to examples pair an algebraic solution and a graphical representation to accommodate different learning styles New Technology dependent modeling sections introduce the idea of mathematical modeling of data through linear quadratic exponential logarithmic and logistic regression New Integrated web resources include selected Take Note boxes identified by a special web icon which direct students to an interactive example or a downloadable file on the web site These special resources can be used by instructors for presentation purposes or can be assigned to students to help them visualize a concept New Concept Lists now prominently feature all the major topics at the beginning of each section preparing students for the concepts to follow A wide range of applications exercise sets and supplemental exercises many involving real data encourage problem solving skill building group work writing and manipulation of graphing calculators Exploring Concepts with Technology a special end of chapter feature expands on ideas introduced in the text by using technology to investigate extended mathematical applications or topics Projects at the end of each exercise set are designed to encourage students or groups of students to research and write about mathematics and its applications Additional Projects are included in the Instructor s Resource Manual and on the book s web site Topics for Discussion conceptual exercises included at the end of each section can be used for discussion or writing assignments Take Note and Math Matters formerly called Point of Interest margin notes alert students about interesting aspects of math history applications and points that require special attention

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