

# 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

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


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

**Gianluca Calcagni, Lefteris  
Papantonopoulos, George  
Siopsis, Nikos Tsamis**



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Elementary General Relativity C. Clarke, Christopher James Seaton Clarke, 1980      Introduction to General Relativity

Ronald Adler, Maurice Bazin, Menahem Schiffer, 1975

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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 **Problem Book in Relativity and Gravitation** Alan P Lightman, William H. Press, Richard H. Price, Saul A. Teukolsky, 2017-09-01 An essential

resource for learning about general relativity and much more from four leading experts Important and useful to every student of relativity this book is a unique collection of some 475 problems with solutions in the fields of special and general relativity gravitation relativistic astrophysics and cosmology The problems are expressed in broad physical terms to enhance their pertinence to readers with diverse backgrounds In their solutions 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 Although well suited for individual use the volume may also be used with one of the modern textbooks in general relativity     Progress of Theoretical Physics ,1960     *Fundamentals of Differential Equations and Boundary Value Problems* R. Kent Nagle,E. B. Saff,Arthur David Snider,2004 An introduction to powerful ideas on teaching and learning developed recently providing an integrative overview of how the various ideas come together to suggest a distinctive way of thinking about the influences affecting student learning Encourages teachers to use their knowledge and experiences to these ideas in their teaching

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