

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 ϕ 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^θ 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).

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1. Understanding the eBook General Relativity Solutions To Exercises
 - The Rise of Digital Reading General Relativity Solutions To Exercises
 - Advantages of eBooks Over Traditional Books
2. Identifying General Relativity Solutions To Exercises
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an General Relativity Solutions To Exercises
 - User-Friendly Interface
4. Exploring eBook Recommendations from General Relativity Solutions To Exercises
 - Personalized Recommendations
 - General Relativity Solutions To Exercises User Reviews and Ratings
 - General Relativity Solutions To Exercises and Bestseller Lists
5. Accessing General Relativity Solutions To Exercises Free and Paid eBooks
 - General Relativity Solutions To Exercises Public Domain eBooks
 - General Relativity Solutions To Exercises eBook Subscription Services
 - General Relativity Solutions To Exercises Budget-Friendly Options
6. Navigating General Relativity Solutions To Exercises eBook Formats

- ePub, PDF, MOBI, and More
- General Relativity Solutions To Exercises Compatibility with Devices
- General Relativity Solutions To Exercises Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of General Relativity Solutions To Exercises
 - Highlighting and Note-Taking General Relativity Solutions To Exercises
 - Interactive Elements General Relativity Solutions To Exercises
- 8. Staying Engaged with General Relativity Solutions To Exercises
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers General Relativity Solutions To Exercises
- 9. Balancing eBooks and Physical Books General Relativity Solutions To Exercises
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection General Relativity Solutions To Exercises
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine General Relativity Solutions To Exercises
 - Setting Reading Goals General Relativity Solutions To Exercises
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of General Relativity Solutions To Exercises
 - Fact-Checking eBook Content of General Relativity Solutions To Exercises
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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