

# 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

**Lingsheng Yao**



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