

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

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

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

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

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

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

G Orfield



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web your primary objective in this experiment is to test a saturated solution of calcium hydroxide and use your observations and measurements to calculate the ksp of the compound you will do this by titrating the prepared Ca(OH)_2 solution with a standard hydrochloric acid solution

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web in today's experiment you will determine the solubility product ksp of calcium hydroxide Ca(OH)_2 by measuring the concentration of Ca(OH)_2 in a saturated solution calcium hydroxide is a sparingly soluble salt that dissolves according to the following reaction the solubility product expression for this reaction is

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web expert verified chem 182 determining the ksp of calcium hydroxide calcium hydroxide is an ionic solid that is sparingly soluble in water a saturated aqueous solution of Ca(OH)_2 is represented in equation form as shown below $\text{Ca(OH)}_2 \rightleftharpoons \text{Ca}^{2+} + 2\text{OH}^-$ the solubility product expression describes in mathematical terms the equilibrium

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web ksp for calcium hydroxide calcium hydroxide is a soft white caustic powder used in making mortar cements calcium salts paints and petrochemicals it is also used in saltwater aquaria to make up kalkwasser limewater solutions for reef tanks and is used as a pH regulating agent notice that calcium hydroxide is divalent and thus has twice

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web use the concentration of calcium hydroxide to calculate the concentration of calcium ions and hydroxide ions in the solution $\text{Ca(OH)}_2 \rightleftharpoons \text{Ca}^{2+} + 2\text{OH}^-$ $5 \times 10^{-2} \text{ M}$ calcium ions $5 \times 10^{-2} \text{ M}$ $2 \times 10^{-2} \text{ M}$ hydroxide ions calculate calcium hydroxide ksp using the

concentrations of calcium ions and hydroxide ions

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web madison bowe elana keller april 15 2014 introduction the objective of this lab was to measure the K_{sp} of a slightly soluble basic salt and how solubility changes with temperature K_{sp} is another form of equilibrium expression that deals with solubility the reaction that will take place is $\text{Ca(OH)}_2 \rightleftharpoons \text{Ca}^{2+} + 2\text{OH}^-$

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web question experiment 8 determining K_{sp} for calcium hydroxide post lab report sheet data table 2 points trial 1 trial 2 HCl molarity 0.050 M volume of filtered Ca(OH)_2 solution mL 5.00 5.00 3.71 13.75 equivalence point volume mL OH^- in saturated Ca(OH)_2 M Ca^{2+} in saturated Ca(OH)_2 M K_{sp} of Ca(OH)_2 average K_{sp} of Ca(OH)_2

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web the chemical equation used was $\text{Ca(OH)}_2 \rightleftharpoons \text{Ca}^{2+} + 2\text{OH}^-$ the solubility product was determined to be $K_{sp} \text{Ca}^{2+} \text{OH}^-$ from the titration which was made by dripping a concentrated solution of calcium hydroxide into hydrochloric acid the calcium hydroxide was filtered before starting the titration

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web jul 12 2023 because the concentration of a pure solid such as Ca_3PO_4 is a constant it does not appear explicitly in the equilibrium constant expression the equilibrium constant expression for the dissolution of calcium phosphate is therefore $K_{sp} \text{Ca}_3\text{PO}_4 \rightleftharpoons 3\text{Ca}^{2+} + 4\text{PO}_4^{3-}$

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web lab report 8 determining K_{sp} of calcium hydroxide the purpose of this was to titrate a saturated Ca(OH)_2 solution with a standard HCl solution and find the K_{sp} or the OH^- concentration was found and then the concentration was found and pH for this experiment a titration of calcium hydroxide with hydrochloric acid

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