Science Textbook

A Latex Template for a Science Textbook

First Edition

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Self Publishers Worldwide
Seattle San Francisco New York
London Paris Rome Beijing Barcelona

This book was typeset using LaTeX software.

Preface

$$
\left.
\begin{aligned}
&\sqrt{{dX_1}^2 + {dX_2}^2 + {dX_3}^2} \\
&\qquad\qquad = \left(1 + \frac{\kappa}{8\pi} \int \frac{\sigma\, dV_0}{r}\right) \sqrt{{dx_1}^2 + {dx_2}^2 + {dx_3}^2}, \\
&\qquad dT = \left(1 - \frac{\kappa}{8\pi} \int \frac{\sigma\, dV_0}{r}\right) dl.
\end{aligned}
\right\}
$$

Table of Contents

Chapter 1

Prerequisites

The theory of relativity is intimately connected with the theory of space and time. I shall therefore begin with a brief investigation of the origin of our ideas of space and time, although in doing so I know that I introduce a controversial subject. The object of all science, whether natural science or psychology, is to co-ordinate our experiences and to bring them into a logical system. How are our customary ideas of space and time related to the character of our experiences?

1.1 First Principles

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1.1.2 Excessive Elaborations

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Chapter 2

Tensors

Chapter 3

Metric Tensor

Consider a vector that is represented in the Cartesian coordinate system and
***

You can use the Pythagoras' Theorem $a^2 + b^2 = c^2$ to find its length

$$
\begin{aligned}
||\vec{v}||^2 &= \left(v^1\right)^2 + \left(v^2\right)^2 \\
&= (3)^2 + (4)^2 \\
&= 25
\end{aligned}
$$

$$\therefore ||\vec{v}|| = \sqrt{25} = 5$$

But what if the vector is measured in this coordinate system? How would you measure its length? Let's try using Pythagoras' theorem and see if we get the same answer.

$$
\begin{aligned}
||\vec{v}||^2 &= \left(\tilde{v}^1\right)^2 + \left(\tilde{v}^2\right)^2 \\
&= \left(\frac{7}{5}\right)^2 + \left(\frac{13}{5}\right)^2 \\
&= \frac{218}{25}
\end{aligned}
$$

$$\therefore ||\vec{v}|| = \sqrt{\frac{218}{25}} \approx 2.95?$$

We got a different answer this time because Pythagoras' theorem only holds for the Cartesian coordinate system. In order to find the length of a vector in another coordinate system, recall that:

$$||\vec{v}||^2 = \vec{v} \cdot \vec{v}$$

If we represent the vector in terms of the Cartesian coordinate system, we get the Pythagoras' Theorem back.

$$\begin{aligned}
\vec{v} \cdot \vec{v} &= (v^1\vec{e}_1 + v^2\vec{e}_2) \cdot (v^1\vec{e}_1 + v^2\vec{e}_2) \\
&= v^1v^1(\vec{e}_1 \cdot \vec{e}_1) + v^1v^2(\vec{e}_1 \cdot \vec{e}_2) + v^2v^1(\vec{e}_2 \cdot \vec{e}_1) + v^2v^2(\vec{e}_2 \cdot \vec{e}_2) \\
&= (v^1)^2(\vec{e}_1 \cdot \vec{e}_1) + 2v^1v^2(\vec{e}_1 \cdot \vec{e}_2) + (v^2)^2(\vec{e}_2 \cdot \vec{e}_2) \\
&= (v^1)^2 + (v^2)^2 \qquad \text{(Because } \vec{e}_i \cdot \vec{e}_j = \delta_{ij}\text{)}
\end{aligned}$$

But if we represent the vector in terms of the basis vectors $\tilde{e_1}$ and $\tilde{e_2}$ we get:

$$\begin{aligned}
\vec{v} \cdot \vec{v} &= (\tilde{v}^1\tilde{e}_1 + \tilde{v}^2\tilde{e}_2) \cdot (\tilde{v}^1\tilde{e}_1 + \tilde{v}^2\tilde{e}_2) \\
&= \tilde{v}^1\tilde{v}^1(\tilde{e}_1 \cdot \tilde{e}_1) + \tilde{v}^1\tilde{v}^2(\tilde{e}_1 \cdot \tilde{e}_2) + \tilde{v}^2\tilde{v}^1(\tilde{e}_2 \cdot \tilde{e}_1) + \tilde{v}^2\tilde{v}^2(\tilde{e}_2 \cdot \tilde{e}_2) \\
&= (\tilde{v}^1)^2(\tilde{e}_1 \cdot \tilde{e}_1) + 2\tilde{v}^1\tilde{v}^2(\tilde{e}_1 \cdot \tilde{e}_2) + (\tilde{v}^2)^2(\tilde{e}_2 \cdot \tilde{e}_2) \qquad (3.1)
\end{aligned}$$

To find $(\tilde{e}_1 \cdot \tilde{e}_1)$, $(\tilde{e}_1 \cdot \tilde{e}_2)$,$(\tilde{e}_2 \cdot \tilde{e}_2)$ we represent them in Cartesian coordinates first

$$\begin{aligned}
\tilde{e}_1 \cdot \tilde{e}_1 &= (2\vec{e}_1 + 1\vec{e}_2) \cdot (2\vec{e}_1 + 1\vec{e}_2) \\
&= 2^2(\vec{e}_1 \cdot \vec{e}_1) + 2(2)(1)(\vec{e}_1 \cdot \vec{e}_2) + 1^2(\vec{e}_2 \cdot \vec{e}_2) \\
&= 2^2 + 1 = 5
\end{aligned}$$

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\tilde{e}_1 \cdot \tilde{e}_1 &= (2\vec{e}_1 + 1\vec{e}_2) \cdot (2\vec{e}_1 + 1\vec{e}_2) \\
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&= 2^2 + 1 = 5
\end{aligned}$$

The metric or fundamental tensor allows you to define fundamental properties like lengths and angles in a coordinate space

Chapter 4

Derivatives of Tensors

Chapter 5

Curvature

Chapter 6

Bibliography