

Preface

Since its beginning one hundred years ago, the special theory of relativity has become a cornerstone of modern physics. Over the course of time it has been scrutinized in a multitude of experiments and has always been verified with high accuracy. The correctness of this theory can no longer be called into question.

Right after its discovery by Albert Einstein in 1905, special relativity was only gradually accepted because it made numerous predictions contradicting common sense, fervently castigated by Einstein, and also defied experiment for too long a time. It was only with the advent of particle or high energy physics that matter could be accelerated to very high velocities, close to the speed of light, which not only verified special relativity but also made it a requirement for machine construction. The expansion of the physical research frontier toward astronomy and cosmology during the past ten to twenty years considerably increased the importance of special relativity and, above all, general relativity based thereupon. Since astrophysics has in the same time become very popular among readers with a scientific background, the two theories of relativity have attained unprecedented publicity. The fascination with astronomy of children and youths shall only be mentioned incidentally, it is, however, one of the most impressive features of schools today.

And still, the special theory of relativity is only of marginal importance in both high school and university curricula – not to mention general relativity. Both have an aura of incomprehensibility, thus being reserved for specialists only. The transfiguration of Einstein's person into the greatest genius in science history hardly contributes to lowering the mental

hurdles against his achievement. Therefore, a popularized, yet substantial and comprehensive treatise on special relativity, written for readers with a background in mathematics and physics, is needed.

This textbook for beginners attempts to secure easy access to special relativity. It addresses all students who have passed with ease their first undergraduate physics courses and enjoyed them. Even high school graduates, who excelled in mathematics and physics, may study this book unless they shy away from making up for unfamiliar mathematical formalism with the help of an additional textbook.

It must then be a discovery for readers that the notorious intricacies of special relativity are not rooted in mathematics. Unfamiliar, on the contrary, is the rigorous thinking at times required before a very simple formula can be committed to paper or interpreted. For the problems of relativity cannot be solved as mechanically as problems of pre-relativistic physics. Lest the red thread be lost, a textbook of relativity for beginners has to ponder hither and thither when our imagination leads us astray, when we grasp for orientation in the thicket of inertial frames, contractions, and dilations.

It is not below the standard of a textbook for beginners to expound problems detailed enough for readers to follow line by line. Desultory calculations are often considered an affront by those beginners who are apt to study everything down to the last detail, i.e. by the very best. They would prefer to see new and unfamiliar matter being presented by a few sample calculations. Studying physics is, in a sense, comparable to learning foreign languages. But no language textbook is limited to simply unfolding grammar and vocabulary, leaving the first construction of sentences to the learner's judgement. Therefore, the reader is urged to duplicate the calculations, if necessary, with paper and pencil, should this treatment not be exhaustive enough.

A first glance at this book should not deter anyone from grappling with the concepts disseminated herein, just because in some chapters the formulas seem to exceed the text lines. The more formulas appear in a scientific text the easier it is to grasp! Nothing is worse for beginners than derivations shortened by well-intentioned sentences. Such a procedure turns science into a secret science for the initiated. Formulas are, in the true sense of the word, democratic and international! Only for popular science texts, written

for quite a different readership, is the famous bon mot applicable that with every additional formula the number of prints sold is halved. With approximately 1000 formulas in this text the potential readership would have to be astronomically large for just one reader to be left after a reduction by a factor of 2^{1000} . But maybe there is also a reciprocal law saying that the number of prints sold doubles with each figure. Then those 100 figures in the text would not only be of didactical value but also promote the sales of this book!

To aid readers without any previous knowledge of relativity, all chapters containing only additional information that can be skipped are marked by an asterisk. This reduces the text by one half. For students preparing for exams as well as for scientists in need of a formulary on special relativity the gray shaded areas are of assistance in finding their way through this book.

The present textbook on special relativity comes to the point directly. The historical development of the late nineteenth century leading to the special theory of relativity is certainly intriguing but its knowledge is by no means a prerequisite for understanding the theory. Even Einstein reportedly ignored it. Readers appreciating this cultural-historical approach are given ample opportunity to become acquainted with it in many books. Instead, such concepts as time dilation, length contraction, Lorentz transformation, and Minkowski diagrams are introduced right at the beginning and in great detail on the level of modern high school texts. After the explanation of simultaneity and the addition theorem of velocity this book leaves, apart from minor exceptions, the scope of advanced secondary school books and turns to the more advanced topics, all the way to the four-vector formalism and the principles of invariance. The pace is thus increased and adjusted to the reader's growing ability to cope with the mathematics involved. The full tensor formalism, however, is dispensed with because it is not really needed before general relativity is introduced. Establishing tensor calculus prematurely is apt to deter readers altogether and is certainly one of the chief reasons why relativity suffers from an elitist smack.

The attentive reader cannot fail to notice that some crucial results of special relativity are derived more than once using varying approaches, e.g. the Lorentz transformation in one spatial direction is derived three times in Chapters 6 and 15, the Doppler formula four times (Chapters 14, 15,

and 31), the Lorentz transformation in two directions twice in Chapter 18, also twice the unification of electric and magnetic forces in Chapters 5 and 33, the velocity addition formula (Chapters 9 and 30), as well as the aberration formula (Chapters 10 and 31). This may be called a redundancy or a gain. Beginners will certainly be glad to find many routes to the goal, as is so often in physics. But for relativity, having had to fight so long for acceptance, this is of fundamental importance; it is self-contained and without contradictions.

It is to be hoped that many students will improve their ability in the mathematical methods of physics by working through this book. Beyond that they will not probably learn much physics of use for their theses and subsequent activities. But that is not the point here. On the contrary, the reader is to be carried away into a world that is, on superficial inspection, outlandish, paradoxical, even outright absurd. The intellectual penetration of these supposed absurdities makes up the appeal of the theory of relativity, it widens the horizon, it forms a new world view in the classical sense of the word. In this sense I wish you enjoy it!

Finally, I would like to express my gratitude to Emil Wiedemann from Fürth who took time to thoroughly and critically read my manuscript in all stages. His comments inspired me time and again.

Jürgen Freund

Aalen near Ulm, 14th March 2004

(Einstein's 125th Anniversary)

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P. S. (2nd January 2006) My special thanks go to Bill Beck from Seattle for his continued assistance in finding the most professional translations from German to English.

P. P. S. (4th January 2008) I want to express my sincere gratitude to Professor Kok Khoo Phua, Chairman of World Scientific, for his personal intervention on behalf of my manuscript, and to Alvin Chong, desk editor, for his admirable patience in view of my perfectionism.