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Relativity from Lorentz to Einstein

A Guide for Beginners, Perplexed and Experimental Scientists

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This book is a translation from Italian of:
La relatività da Lorentz a Einstein
Una guida per principianti, perplessi e scienziati sperimentali

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Foreword

There are thousands of books that expose and make popular Einstein's relativity theory with different levels of complexity. This literature has developed since 1919, when the theory of general relativity unexpectedly exploded in popularity worldwide, uninterrupted to this day. Within a couple of years, hundreds of popularizations[1] were published concerning both the theory of special relativity, which dates back to 1905, and that of general relativity, developed by Einstein in the following ten years. The production of literature continued uninterrupted always exhibiting the same theory with the same arguments and the same expressions. The standard way of describing special relativity was defined by different authors at a time roughly between 1911 and 1925, and has been maintained to date. If at a distance of so many years new books are written, that are very similar to the precedents, there must be a problem. In this discussion we adopt a different perspective in order to highlight the exact meaning of the theory of special relativity, to allow the reader to judge in full the kinematic part of theory, i.e. the one that speaks of space, time, and clocks, and to help the reader understand how the formula $E=mc^2$ can be derived.

In relativistic literature we find three kinds of books: introductory, popular, and specialist. In each kind there are many versions that are similar among them: all books converge towards the same results and all proceed with the same criterion. Those who have consulted many of them recognize familiar issues in each book and look for a single page or a single observation, hoping to shed light on a controversial point and to find help in grasping the whole of the theory. This is a common experience because many people have tried to study relativity and have grasped the pattern of reasoning and the elements of theory, but are still perplexed about the overall connection between them. However, especially with regard to special relativity, the whole literature can be divided into three sets of introductory, popular and specialized books. In the group of introductory treatises

[1] Isaacson 2007, Chapter 12.

there are the simplest ones, which are merely descriptive and serve to give a first idea of the theory, but they can neither explain nor make anything understood. They only serve to create expectations and provoke curiosity in the reader, making the conclusions of the theory known but leaving them unexplained. The books of this group are all superfluous, because what they can teach is already known through movies, television broadcasts, encyclopaedia entries and newspaper articles. In short, they repeat commonplaces and common knowledge.

The second group of treatises develops the reasoning process of the theory by using simple terms and a little algebra, but when such books are well written, they are able to give the readers an exact knowledge of the theory. This is because special relativity, also in its discussion by Einstein, makes almost no use of superior maths, except in the electrodynamic part where this is indispensable.

The third group of theory exposures is aimed at university education and at the specialist public and therefore it cannot be used by the reader who approaches it without specific training in physics, mathematics or engineering. However, this limit is far less significant than what one would think for readers who are not able to go beyond the level of the books of the second group, because the main issue of special relativity is not mathematics: it is logic. There is a logical process to follow, which is not easy, but the necessary math is the one of the school, not of the university.

This takes us to the heart of the problem: the whole relativistic literature has the defect of not fully explaining the premises and assumptions that must be made to understand the deduction of the consequences, and in this fault lies the great difficulty that almost everyone experiences in the theory. Indeed, it has often been found, and teachers confirm it, that the smartest students, those who want to go deep into things, are those who find more difficulty in understanding the deep connection between the elements of special relativity, while those who are content to learn how to repeat certain judgments and how to apply some not particularly complex mathematical formulas are usually satisfied both by the theory and

by themselves. Before beginning the study of relativity, those who know just the most general topics will probably start from the view that the difficulty of theory lies in the acceptance of the non-Euclidean description of space-time, going against habits consolidated for centuries. Given what is known before acquiring accurate knowledge of the theory this suspicion is reasonable and justified. But by carefully looking at the details we shall see that the concepts of the theory present no difficulty in themselves, and that the lack of understanding depends on a completely different and unexpected factor.

This book was written for two kinds of readers: those who know all the famous images and suggestions associated with special relativity and are curious about it, but who know nothing, except for having heard something or read some article or introductory book, and those who know the fundamentals, having studied them at the popular or specialist level, but are not convinced that they have understood and assimilated the concatenation of the elements of the theory. Many readers and scholars are in this condition even after going deep into the technical elements of the theory: they know the theory of Lorentz's transformations, Minkowski geometry, the derivation of the "World's most renowned formula", $E=mc^2$, from the space-time theory, but they recognize their tenuous grasp of the connection between the parts of the theory and the consistency of the demonstrations.

So this book describes the theory of special relativity with the simplicity necessary for it to be understood by non-specialist readers, who are only required to read it carefully. At the same time it analyzes the logic implied by the typical arguments of relativistic literature, and sheds light on the premises that for long tradition are not expressed with the necessary clarity, and therefore are at the root of the difficulty of understanding the theory. This book was written taking into account both the beginner's and the perplexed people's needs, the needs of those who know the elements of special relativity but feel they have not understood it. Therefore, readers already familiar with fundamentals of the theory will recognize many concepts they already understood and will read quickly or skip the

elementary expositions of the things they already know, to dwell on the discussions of the difficulties.

Obviously, this book was not written for those who know they have understood and assimilated the theory and do not feel the need for any clarification.

This book is, in a certain sense, a practical manual that gives the readers tips to guide them into a subject about which it cannot be the only source. As the readers assimilate this book, they will feel the need to compare it with relativistic literature, in which at that point they will feel comfortable. As for the reading method, note that in this book you will find few figures and few formulas. Better read it holding paper and pencil at hand to write down formulas and draw a few figures following the text instructions. Then, since relativistic literature is huge and full of repetitions of the same things, I have chosen to minimize the space dedicated to the most famous topics. This book should serve as an introductory guide to reading any other source about special relativity, of medium or specialist level. You can read other sources right away after finishing this, or even at the same time, by going to the specialist discussion of the single arguments after assimilating the introduction to the background ideas you find clearly stated here in a way that you will not find elsewhere. In particular, I advise to read, in parallel with this book, the popular account of the theory written by Einstein himself in 1916, widely available in many economic editions[2].

With regard to the logical structure of the deductive process of special relativity, there are many things yet to be said and therefore this book devotes the least possible space to dealing with what is known or is explained extensively elsewhere. This book explicitly states all that is necessary to know before entering into the deductive mechanism of special relativity, but for the simplest and most common notions, mostly historical and factual data on which there are no difficulties or discussions, you will often find the indication "see Encyclopaedia". It means that in order to deepen what may not

[2] Einstein, 1916.

be known or enough clear you are advised to stop the reading of this book and take a look at the subject matter in an encyclopaedia. Even Wikipedia will be fine, but with the warning to prioritize the entries in English rather than those in other languages.

Finally, for those who want to go back to school physics before getting into the study of special relativity, I recommend a basic English textbook, *Understand Physics: Teach Yourself* by Jim Breithaupt, a quick, pleasant, and effective read. I also recommend reading the book written and published by Einstein in 1938 in collaboration with Leopold Infeld: *The Evolution of Physics: The Growth of Ideas from Early Concepts to Relativity and Quanta*. This book by Einstein introduces the issue of relativity with total clarity as far as the antecedents are concerned. But as it moves to special relativity, it proposes reflections and considerations on it that are relevant to those who already know the theory, without being able to be a useful textbook for those who come to it for the first time. It is therefore advisable to read the first and second part, where the preconditions of special relativity are exposed, before going to study, and the third and fourth part after acquiring knowledge of the theory. The book of Einstein and Infeld is complete, it also deals with general relativity and refers to quantum physics from the point of view of Einstein, who, as is well known, was not favourable toward it.

In general, the biography of the author of a theory is not relevant for the judgment of her or his work; and as a rule, one should concentrate on studying a theory by remaining ignorant of the biography of the author, in order to avoid giving trivial psychological labels to what is not understood. But in Einstein's case, it is imperative to keep in mind the context of the theory, and therefore also the biography, for which I refer to a recent and somewhat voluminous book, *Einstein. His Life and Universe* by Walter Isaacson. We shall see that in the case of Einstein the history of the theory is particularly relevant for understanding the history of its fame and its acceptance by the mainstream of the scientific community. The theory of special relativity was born to answer a very specific question that in most of the books is completely

ignored, and in some other treatise is relegated to the background. We shall note that this fact undermines the understanding of the deductive chain of the theory, but we shall also understand why this change of perspective occurred, which at first sight should appear curious. The theory of special relativity quickly assumed a very different meaning than the original purpose, and we shall see why.

Some final practical information: the footnotes in the text contain only references to the bibliography, so you do not have to read them if you do not want to trace the sources of information. Any marginal remarks are not in footnotes, but are incorporated in the text. In the English translation of this book the concept of velocity has been referred to with the simple word “speed” instead of “velocity”, that means a vector speed having a given direction and sense. The popular character of this book allows this simplification. Only in literal quotations of English texts the term “velocity” will occur.

1. Basics

1.1 Special relativity and general relativity

I keep the promise made in the introduction and refer the reader to the Encyclopaedia (any Encyclopaedia, or any other source about the subject) for the preliminary historical notions. I just mention here what is indispensable to know.

Albert Einstein was born in 1879 in Ulm, in southern Germany, and because of family vagaries and vicissitudes, he lived in Italy and Switzerland the years of his youth. Legend has it that he was a bad student, but the study of his biography reveals that he was sometimes a brilliant student, but always rebellious and inclined to contradict teachers. It is interesting to note that, since his father and uncle were pioneer entrepreneurs in the field of electrical installations, Einstein was familiar with the properties of electrical equipment since he was young and could understand their peculiarities with great and innate ease. At sixteen he wrote an essay, conventional in content, about ether and electromagnetic theory, about what would be the central issue of special relativity, and at the same age he was able to help adults in calculations for the sizing up of electrical equipment[3]:

> Einstein spent the spring and summer of 1895 living with his parents in their Pavia apartment and helping at the family firm. In the process, he was able to get a good feel for the workings of magnets, coils, and generated electricity. Einstein's work impressed his family. On one occasion, Uncle Jakob was having problems with some calculations for a new machine, so Einstein went to work on it. "After my assistant engineer and I had been racking our brain for days, that young sprig had got the whole thing in just fifteen minutes," Jakob reported to a friend. "You will hear of him yet."

Einstein got a diploma with a mediocre score, because of controversies with his teachers at the Federal Polytechnic of Zurich, and it was not easy for him to find an occupation. His temper led him to experience intellectual unemployment, at that time more rare than

[3] Isaacson 2007, Chapter 2.

today. Finally, he found a modest job, which anyway was paid about twice the usual salary, at the Swiss Federal Bureau of Patents and in 1905 he published four papers in a major journal, *Annalen der Physik*, directed by Max Planck. Of the four papers the fourth is an appendix of the third and is only three pages long.

The year 1905, for this reason, is known as Einstein's "annus mirabilis", and the four papers have the titles: .....

(end of preview)

Back cover

Everyone knows that Einstein's special relativity contains a theory of time measurements, which are no longer conceived as absolute, but are related to the state of motion of the clock and to the point of view of the observer, and the same happens to space measurements. Everyone also knows that the theory contains the deduction that a small material mass can be converted into a huge amount of energy according to a precise quantitative relationship.

But many who have tried to study the theory have failed to understand it; yet, to fully understand the part of Einstein's theory about time and space measurements, readers just need to know what speed and square root are, and to obtain a simplified but clear idea of the part regarding the concepts of mass and energy they need just to remember elementary high-school physics. Apparently something is missing in all the many books that describe relativity in a simple or higher level.

This book is written in a different way from any other. A rigorous but clear exposition will show all readers, provided they know what speed and square root are, that they can understand fully and perfectly the space-time theory and can judge it with their own intelligence. In addition, readers will have a clear idea of the equivalence between mass and energy and its logical relationship with space-time theory.

This book was written for beginners and for perplexed people who have unsuccessfully attempted to study special relativity: both will understand the exact meaning of the famous and difficult essay in which Einstein expounded the theory in 1905, which is examined word by word in this book. And all readers will have a clearer idea of the relevance of relativity for the twentieth (and twenty-first) century culture.

Alberto Palazzi

A scholar of history and philosophy and designer of computer algorithms for problems of higher complexity, the author of this book brings together the skills necessary to analyze the scientific

significance of relativity and to reconstruct the historical and anthropological context in which it was born and became an institution of our time.