FOREWORD

Hundreds of books on Einstein and relativity have been written for lay readers, but the one you have in your hands is like no other. In all those other books, the authors strive to describe Einstein's work by analogy and metaphor, steering the reader as far as possible from the white water of mathematics and physics. Lillian and Hugh Lieber take an entirely different approach. Their little book was designed to teach—to almost anyone—the actual relativity of Albert Einstein, tensors and all. To follow all the mathematics in the second half of the book, you will need to know some differential calculus; but for most of the book, simple algebra and a little geometry will suffice. Even readers to whom mathematics is a foreign language can follow the arguments and see for themselves the breathtaking agreement between nature and Einstein's wonderful ideas.

Einstein's Theory of Relativity is actually two theories, or, more accurately, a theory that comes in two flavors, restricted and unrestricted. Einstein created the restricted theory in 1905 to resolve some troubling inconsistencies between the mechanical physics of Isaac Newton (1687) and the electric and magnetic physics of Michael Faraday (1844) and James Clerk Maxwell (1864). Einstein's theory ensured that measurements made by two observers in relative uniform (non-accelerated) motion would be consistent. At first, technology limited the experiments that could confirm or refute Einstein's theory, but over the past century, it has passed thousands of tests. More, Einstein's 1905 description of nature possesses a compelling simplicity and beauty absent from Newton's mechanics.

For ten years Einstein sought to generalize his principle to observers whose reference frames were moving with non-uniform velocity with respect to each other, or even to observers in any two frames related in any way whatsoever. Early on he felt that the extension to non-uniform motion might require, or otherwise include, the force of gravity. In 1915 he arrived at a generalized relativity, at its core a new theory of gravity. The original (restricted) Theory of Relativity then became known as *special relativity,* and the new (unrestricted) theory, Einstein's theory of gravity, was called *general relativity.*

Albert Einstein was not yet a household name when, in May of 1919, a solar eclipse visible in the southern hemisphere allowed for a sensitive test of general relativity. Astronomers traveled to the island of Principe off the coast of West Africa, and the town of Sobral in Brazil. Photographs taken during the eclipse were analyzed, and on November 6, 1919, during a special meeting of the Royal Society in London, the results were announced to the world. The data were fully consistent with Einstein's theory of gravity (but not with Newton's, which had predicted only half the observed value).

Until very recently, general relativity was taught only in postgraduate mathematics or physics courses, because the mathematical foundations of the theory were regarded as much too demanding for undergraduates. But the Liebers possessed an astounding, Promethean faith that a much larger audience could learn Einstein's theories—*the genuine article,* not watered-down explanations. They believed that Einstein's work, the deepest understanding of space and time yet conceived, belonged to all of us and should be made accessible to anyone who wanted to learn it. We share that belief. The first editions of this book were home-made by the Liebers (Hugh Lieber colored many of the illustrations by hand). After some years, a publisher took a chance, and kept the book in print for fifteen years. It has been out of print ever since, despite substantial efforts by the book's fans to get it republished. This new edition has made the dream of decades come true for us.

Many authors have described special relativity at about the same mathematical level as the first part of Professor Lieber's book, none with her economy or wit. The second part, describing general relativity, makes the book unique. The only other books providing such a close look at general relativity are textbooks; the authors of these books suppose their readers are already highly proficient with advanced mathematics. Professor Lieber assumes only geometry, hoping that you have a little calculus. If you do, and you're willing to grasp new tools, you will see *everything.* She shows you how to use these new tools (partial derivatives, determinants, tensor analysis), offers encouragement, and sympathetically warns you of approaching complications. She demonstrates the difficulties Einstein had to overcome, but she does not expect you to duplicate his labor.

The book's second part begins by justifying the use of non-Euclidean geometry. The tools and techniques for describing distances on a curved surface are introduced. The Riemann tensor is derived and Einstein's equations are stated. In the most mathematical part of the book (the reader is given fair warning), the Schwarzschild solution is derived, and from it is obtained a geodesic equation. This equation describes the motion of objects near a massive object (like our own sun). It provides the basis for three spectacular tests. Einstein's theory of gravity does not give the same answers as Newton's. Professor Lieber shows the reader how these theories differ in mathematical detail, philosophy, and predictions. She does not write down every step, hoping to spare readers a blizzard of symbols. Instead, she refers those seeking more details to a well-known textbook by the eminent English astrophysicist Sir Arthur Eddington. In two tests the math is elementary, and she shows exactly how numbers come out of Einstein's theory, to be compared with experimental data. One test involves gravity's unexpected influence on the rate of time, and the shift of atomic spectra towards the red end of the rainbow. (No such effect occurs in Newton's theory of gravity.) Professor Lieber shows that the ratio of a spectral line's frequency on earth to its frequency near an astronomical object of mass m and radius R is in the ratio $1 + (m/R)$: 1 (if the mass is measured in suitable units)—and the reader will have seen exactly how this comes about.

As a ninth grader in upstate New York, Robert Jantzen found this book in his small village public library, read it, and thought that when he got to college it would be fascinating to study the ideas on a deeper level. Even at Princeton, no undergraduate course was available. Robert joined a handful of classmates who convinced a visiting relativist, Remo Ruffini, to offer a seminar in general relativity. Robert made relativity his life's work, never forgetting it was this little book that started him on his career. David Derbes came to the book indirectly, from another work in the Lieber canon, and used it to teach a few of his high-school students an elective in relativity. Each was unaware of the other's fondness for the book, until David visited Robert's web page, read the tribute Robert paid to the Liebers' work, and learned that his old friend (and college classmate) was also interested in seeing the book republished.

Part of our job as editors has been to replace outdated references with more recent works. While deleting most, we have kept the references to classics but added newer (and more accessible) works in the footnotes and the bibliography. We have also provided notes to fill in nearly all the details Professor Lieber delegated to references in the works of Eddington and others. These are for readers who would like to work through everything but who lack easy access to technical libraries. It is perfectly possible to skim over much of the mathematical detail if you choose, but why not give the math a try? The poet Millay was perhaps overstating it to say that "Euclid alone has looked on Beauty bare," but we do agree with the great Russian theorist Lev Landau that "general relativity is probably the most beautiful of all physical theories."

Few people are as famous as Einstein, and few theories possess the almost magical powers of his relativity. We know of many scientists and mathematicians who as teenagers stumbled onto this little book, and were inspired by it. As a supplement to advanced high-school physics or math courses it could excite and inspire many more. Teachers of physics and calculus will enjoy working anew (or for the first time) to derive the famous predictions stunningly confirmed by the perihelion of Mercury, the spectral lines of Sirius, and the bending of starlight by the sun—thereby enriching their own understanding of these beautiful, deep ideas. It would be a wonderful thing if Einstein's relativity became part of the high-school curriculum.

We hope that many people will take up the challenge offered by the Liebers. Getting through their book is a little bit like running a marathon. Reading the book may likewise be demanding, but the rewards are also great.

David Derbes
University of Chicago Laboratory Schools

Robert Jantzen
Villanova University

March, 2008