This is a revised edition of a classic and highly regarded book, first published in 1981, giving a comprehensive survey of the intensive research and testing of general relativity that has been conducted over the last three decades. As a foundation for this survey, the book first introduces the important principles of gravitation theory, developing the mathematical formalism that is necessary to carry out specific computations so that theoretical predictions can be compared with experimental findings. A completely up-to-date survey of experimental results is included, not only discussing Einstein's "classical" tests, such as the deflection of light and the perihelion shift of Mercury, but also new solar system tests, never envisioned by Einstein, that make use of the high precision space and laboratory technologies of today. The book goes on to explore new arenas for testing gravitation theory in black holes, neutron stars, gravitational waves and cosmology. Included is a systematic account of the remarkable "binary pulsar" PSR 1913+16, which has yielded precise confirmation of the existence of gravitational waves.

The volume is designed to be both a working tool for the researcher in gravitation theory and experiment, as well as an introduction to the subject for the scientist interested in the empirical underpinnings of one of the greatest theories of the twentieth century.

Comments on the previous edition:

"consolidates much of the literature on experimental gravity and should be invaluable to researchers in gravitation" *Science*

"a concise and meaty book . . . and a most useful reference work . . . researchers and serious students of gravitation should be pleased with it" *Nature*

Theory and Experiment in Gravitational Physics

Revised Edition

THEORY AND EXPERIMENT IN GRAVITATIONAL PHYSICS

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Revised Edition

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Preface to the Revised Edition

Since the publication of the first edition of this book in 1981, experimental gravitation has continued to be an active and challenging field. However, in some sense, the field has entered what might be termed an Era of Opportunism. Many of the remaining interesting predictions of general relativity are extremely small effects and difficult to check, in some cases requiring further technological development to bring them into detectable range. The sense of a systematic assault on the predictions of general relativity that characterized the "decades for testing relativity" has been supplanted to some extent by an opportunistic approach in which novel and unexpected (and sometimes inexpensive) tests of gravity have arisen from new theoretical ideas or experimental techniques, often from unlikely sources. Examples include the use of laser-cooled atom and ion traps to perform ultra-precise tests of special relativity, and the startling proposal of a "fifth" force, which led to a host of new tests of gravity at short ranges. Several major ongoing efforts continued nonetheless, including the Stanford Gyroscope experiment, analysis of data from the Binary Pulsar, and the program to develop sensitive detectors for gravitational radiation observatories.

For this edition I have added chapter 14, which presents a brief update of the past decade of testing relativity. This work was supported in part by the National Science Foundation (PHY 89-22140).

Clifford M. Will
1992

Preface to First Edition

For over half a century, the general theory of relativity has stood as a monument to the genius of Albert Einstein. It has altered forever our view of the nature of space and time, and has forced us to grapple with the question of the birth and fate of the universe. Yet, despite its subsequently great influence on scientific thought, general relativity was supported initially by very meager observational evidence. It has only been in the last two decades that a technological revolution has brought about a confrontation between general relativity and experiment at unprecedented levels of accuracy. It is not unusual to attain precise measurements within a fraction of a percent (and better) of the minuscule effects predicted by general relativity for the solar system.

To keep pace with these technological advances, gravitation theorists have developed a variety of mathematical tools to analyze the new high-precision results, and to develop new suggestions for future experiments made possible by further technological advances. The same tools are used to compare and contrast general relativity with its many competing theories of gravitation, to classify gravitational theories, and to understand the physical and observable consequences of such theories.

The first such mathematical tool to be thoroughly developed was a "theory of metric theories of gravity" known as the Parametrized Post-Newtonian (PPN) formalism, which was suited ideally to analyzing solar system tests of gravitational theories. In a series of lectures delivered in 1972 at the International School of Physics "Enrico Fermi" (Will, 1974, referred to as TTEG), I gave a detailed exposition of the PPN formalism. However, since 1972, significant progress has been made, on both the experimental and theoretical sides. The PPN formalism has been refined, and new formalisms have been developed to deal with other aspects of gravity, such as nonmetric theories of gravity, gravitational radiation, and the motion of condensed objects. A recent review article (Will, 1979)[1] summarizes the principal results of these new developments, but gives none of the physical or mathematical details. Since 1972, there has been a need for a complete treatment of techniques for analyzing gravitation theory and experiment.

To fill this need I have designed this study. It analyzes in detail gravitational theories, the theoretical formalisms developed to study them, and the contact between these theories and experiments. I have made no attempt to analyze *every* theory of gravity or calculate *every* possible effect; instead I have tried to present systematically the *methods* for performing such calculations together with relevant examples. I hope such a presentation will make this book useful as a working tool for researchers both in general relativity and in experimental gravitation. It is written at a level suitable for use as either a reference text in a standard graduate-level course on general relativity or, possibly, as a main text in a more specialized course. Not the least of my motivations for writing such a book is the fact that it was my "centennial project" for 1979 – the 100th anniversary of Einstein's birth.

It is a pleasure to thank Bob Wagoner, Martin Walker, Mark Haugan, and Francis Everitt for helpful discussions and critical readings of portions of the manuscript. Ultimate responsibility for errors or omissions rests, of course, with the author. For his constant support and encouragement, I am grateful to Kip Thorne. Victoria LaBrie performed her usual feats of speedy and accurate typing of the manuscript. Thanks also go to Rose Aleman for help with the typing.

Preparation of this book took place while the author was in the Physics Department at Stanford University, and was supported in part by the National Aeronautics and Space Administration (NSG 7204), the National Science Foundation (PHY 76-21454, PHY 79-20123), the Alfred P. Sloan Foundation (BR 1700), and by a grant from the Mellon Foundation.

[1] See also Will (1984).