
A First Course In General Relativity

Bernard F Schutz

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General Relativity
Bernard F Schutz*

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A First Course in General Relativity *Cambridge University Press*

Second edition of a widely-used textbook providing the first step into general relativity for undergraduate students with minimal mathematical background.

A Student's Manual for A First Course in General Relativity

A First Course in Loop Quantum Gravity *OUP Oxford*

This book provides an accessible introduction to loop quantum gravity and some of its applications, at a level suitable for undergraduate students and others with only a minimal knowledge of college level physics. In particular it is not assumed that the reader is familiar with general relativity and only minimally familiar with quantum mechanics and Hamiltonian mechanics. Most chapters end with problems that elaborate on the text, and aid learning. Applications such as loop quantum cosmology, black hole entropy and spin foams are briefly covered. The text is ideally suited for an undergraduate course in the senior year of a physics major. It can also be used to introduce undergraduates to general relativity and quantum field theory as part of a 'special topics' type of course.

A First Course on Symmetry, Special Relativity and Quantum Mechanics

The Foundations of Physics *Springer Nature*

This book provides an in-depth and accessible description of special relativity and quantum mechanics which together form the foundation of 21st century physics. A novel aspect is that symmetry is given its rightful prominence as an integral part of this foundation. The book offers not only a conceptual understanding of symmetry, but also the mathematical tools necessary for quantitative analysis. As such, it provides a valuable precursor to more focused, advanced books on special relativity or quantum mechanics.

Students are introduced to several topics not typically covered until much later in their education. These include space-time diagrams, the action principle, a proof of Noether's theorem, Lorentz vectors and tensors, symmetry breaking and general relativity. The book also provides extensive descriptions on topics of current general interest such as gravitational waves, cosmology, Bell's theorem, entanglement and quantum computing. Throughout the text, every opportunity is taken to emphasize the intimate connection between physics, symmetry and mathematics. The style remains light despite the rigorous and intensive content. The book is intended as a stand-alone or supplementary physics text for a one or two semester course for students who have completed an introductory calculus course and a first-year physics course that includes Newtonian mechanics and some electrostatics. Basic knowledge of linear algebra is useful but not essential, as all requisite mathematical background is provided either in the body of the text or in the Appendices. Interspersed through the text are well over a hundred worked examples and unsolved exercises for the student.

A First Course in General Relativity
Cambridge University Press

This textbook develops general relativity and its associated mathematics from a minimum of prerequisites, leading to a physical understanding of the theory in some depth.

General Relativity

A First Course for Physicists

Gravity from the Ground Up

An Introductory Guide to Gravity and General Relativity
Cambridge University Press

This book invites the reader to understand our Universe, not just marvel at it. From the clock-like motions of the planets to the catastrophic collapse of a star into a black hole, gravity controls the Universe. Gravity is central to modern physics, helping to answer the deepest questions about the nature of time, the origin of the Universe and the unification of the forces of nature. Linking key experiments and observations through careful physical reasoning, the author builds the reader's insight step-by-step from simple but profound facts about gravity on Earth to the frontiers of research. Topics covered include the nature of stars and galaxies, the mysteries of dark matter and dark energy, black holes, gravitational waves, inflation and the Big Bang. Suitable for general readers and for undergraduate courses, the treatment uses only high-school level mathematics, supplemented by optional computer programs, to explain the laws of physics governing gravity.

Gravity

An Introduction to Einstein's General Relativity
Cambridge University Press

Einstein's theory of general relativity is a cornerstone of modern physics. It also touches upon a wealth of topics that students find fascinating – black holes, warped spacetime, gravitational waves, and cosmology. Now reissued by Cambridge University Press, this groundbreaking text helped to bring general relativity into the undergraduate curriculum, making it accessible to virtually all physics majors. One of the

pioneers of the 'physics-first' approach to the subject, renowned relativist James B. Hartle, recognized that there is typically not enough time in a short introductory course for the traditional, mathematics-first, approach. In this text, he provides a fluent and accessible physics-first introduction to general relativity that begins with the essential physical applications and uses a minimum of new mathematics. This market-leading text is ideal for a one-semester course for undergraduates, with only introductory mechanics as a prerequisite.

Introduction To Spacetime: A First Course On Relativity *World Scientific Publishing Company*

The theory of relativity is tackled directly in this book, dispensing with the need to establish the insufficiency of Newtonian mechanics. This book takes advantage from the start of the geometrical nature of the relativity theory. The reader is assumed to be familiar with vector calculus in ordinary three-dimensional Euclidean space.

General Relativity *University of Chicago Press*

"Wald's book is clearly the first textbook on general relativity with a totally modern point of view; and it succeeds very well where others are only partially successful. The book includes full discussions of many problems of current interest which are not treated in any extant book, and all these matters are considered with perception and understanding."—S. Chandrasekhar "A tour de force: lucid, straightforward, mathematically rigorous, exacting in the analysis of the theory in its physical aspect."—L. P. Hughston, *Times Higher Education Supplement* "Truly excellent. .

. . . A sophisticated text of manageable size that will probably be read by every student of relativity, astrophysics, and field theory for years to come."—James W. York, *Physics Today*

A Student's Manual for A First Course in General Relativity *Cambridge University Press*

This comprehensive student manual has been designed to accompany the leading textbook by Bernard Schutz, *A First Course in General Relativity*, and uses detailed solutions, cross-referenced to several introductory and more advanced textbooks, to enable self-learners, undergraduates and postgraduates to master general relativity through problem solving. The perfect accompaniment to Schutz's textbook, this manual guides the reader step-by-step through over 200 exercises, with clear easy-to-follow derivations. It provides detailed solutions to almost half of Schutz's exercises, and includes 125 brand new supplementary problems that address the subtle points of each chapter. It includes a comprehensive index and collects useful mathematical results, such as transformation matrices and Christoffel symbols for commonly studied spacetimes, in an appendix. Supported by an online table categorising exercises, a Maple worksheet and an instructors' manual, this text provides an invaluable resource for all students and instructors using Schutz's textbook.

A First Course in Differential Geometry

Surfaces in Euclidean Space *Cambridge University Press*

With detailed explanations and numerous examples, this textbook

covers the differential geometry of surfaces in Euclidean space.

Einstein's Theory

A Rigorous Introduction for the Mathematically Untrained *Springer Science & Business Media*

This book provides an introduction to the theory of relativity and the mathematics used in its processes. Three elements of the book make it stand apart from previously published books on the theory of relativity. First, the book starts at a lower mathematical level than standard books with tensor calculus of sufficient maturity to make it possible to give detailed calculations of relativistic predictions of practical experiments. Self-contained introductions are given, for example vector calculus, differential calculus and integrations. Second, in-between calculations have been included, making it possible for the non-technical reader to follow step-by-step calculations. Thirdly, the conceptual development is gradual and rigorous in order to provide the inexperienced reader with a philosophically satisfying understanding of the theory. The goal of this book is to provide the reader with a sound conceptual understanding of both the special and general theories of relativity, and gain an insight into how the mathematics of the theory can be utilized to calculate relativistic effects.

A First Course in Network Science *Cambridge University Press*

A practical introduction to network science for students across business, cognitive science, neuroscience, sociology, biology, engineering and other disciplines.

First Course in General Education

Elementary Arithmetic Teacher's Manual

A Short Course in General Relativity *Springer Science & Business Media*

Suitable for a one-semester course in general relativity for senior undergraduates or beginning graduate students, this text clarifies the mathematical aspects of Einstein's theory of relativity without sacrificing physical understanding.

A First Course in String Theory *Cambridge University Press*

String theory made understandable. Barton Zwiebach is once again faithful to his goal of making string theory accessible to undergraduates. He presents the main concepts of string theory in a concrete and physical way to develop intuition before formalism, often through simplified and illustrative examples. Complete and thorough in its coverage, this new edition now includes AdS/CFT correspondence and introduces superstrings. It is perfectly suited to introductory courses in string theory for students with a background in mathematics and physics. New sections cover strings on orbifolds, cosmic strings, moduli stabilization, and the string theory landscape. Now with almost 300 problems and exercises, with password-protected solutions for instructors at www.cambridge.org/zwiebach.

Foundations of Modern Physics *Cambridge University Press*

Nobel Laureate Steven Weinberg explains the foundations of modern physics in historical context for undergraduates and beyond.

All the Mathematics You Missed

But Need to Know for Graduate School

A First Course in Noncommutative Rings Springer Science & Business Media

One of my favorite graduate courses at Berkeley is Math 251, a one-semester course in ring theory offered to second-year level graduate students. I taught this course in the Fall of 1983, and more recently in the Spring of 1990, both times focusing on the theory of noncommutative rings. This book is an outgrowth of my lectures in these two courses, and is intended for use by instructors and graduate students in a similar one-semester course in basic ring theory. Ring theory is a subject of central importance in algebra. Historically, some of the major discoveries in ring theory have helped shape the course of development of modern abstract algebra. Today, ring theory is a fertile meeting ground for group theory (group rings), representation theory (modules), functional analysis (operator algebras), Lie theory (enveloping algebras), algebraic geometry (finitely generated algebras, differential operators, invariant theory), arithmetic (orders, Brauer groups), universal algebra (varieties of rings), and homological algebra (cohomology of rings, projective modules, Grothendieck and higher K-groups). In view of these basic connections between ring theory and other branches of mathematics, it is perhaps no exaggeration to say that a course in ring theory is an indispensable part of the education for any fledgling algebraist. The purpose of my lectures was to give a general introduction to the theory of rings, building on what the students have learned from a standard

first-year graduate course in abstract algebra.

A First Course in Algebraic Topology Cambridge University Press

This self-contained introduction to algebraic topology is suitable for a number of topology courses. It consists of about one quarter 'general topology' (without its usual pathologies) and three quarters 'algebraic topology' (centred around the fundamental group, a readily grasped topic which gives a good idea of what algebraic topology is). The book has emerged from courses given at the University of Newcastle-upon-Tyne to senior undergraduates and beginning postgraduates. It has been written at a level which will enable the reader to use it for self-study as well as a course book. The approach is leisurely and a geometric flavour is evident throughout. The many illustrations and over 350 exercises will prove invaluable as a teaching aid. This account will be welcomed by advanced students of pure mathematics at colleges and universities.

A First Course in General Relativity

Introduction to General Relativity Cambridge University Press

Student-friendly, well illustrated textbook for advanced undergraduate and beginning graduate students in physics and mathematics.

Geometrical Methods of Mathematical Physics Cambridge University Press

In recent years the methods of modern differential geometry have become of considerable importance in theoretical physics and have found application in relativity and cosmology, high-energy

physics and field theory, thermodynamics, fluid dynamics and mechanics. This textbook provides an introduction to these methods - in particular Lie derivatives, Lie groups and differential forms - and covers their extensive applications to theoretical physics. The reader is assumed to have some familiarity with advanced calculus, linear algebra and a little elementary operator theory. The advanced physics undergraduate should therefore find the presentation quite accessible. This account will prove valuable for those with backgrounds in physics and applied mathematics who desire an introduction to the subject. Having studied the book, the reader will be able to comprehend research papers that use this mathematics and follow more advanced pure-mathematical expositions.

A First Course in Optimization *CRC Press*

Give Your Students the Proper Groundwork for Future Studies in Optimization A First Course in Optimization is designed for a one-semester course in optimization taken by advanced undergraduate and beginning graduate students in the mathematical sciences and engineering. It teaches students the basics of continuous optimization and helps them better understand the mathematics from previous courses. The book focuses on general problems and the underlying theory. It introduces all the necessary mathematical tools and results. The text covers the fundamental problems of constrained and unconstrained optimization as well as linear and convex programming. It also presents basic iterative solution algorithms (such as gradient methods and the Newton-Raphson algorithm and its

variants) and more general iterative optimization methods. This text builds the foundation to understand continuous optimization. It prepares students to study advanced topics found in the author's companion book, *Iterative Optimization in Inverse Problems*, including sequential unconstrained iterative optimization methods.

Gravitation *Princeton University Press*

Spacetime physics -- Physics in flat spacetime -- The mathematics of curved spacetime -- Einstein's geometric theory of gravity -- Relativistic stars -- The universe -- Gravitational collapse and black holes -- Gravitational waves -- Experimental tests of general relativity -- Frontiers

Cosmology's Century

An Inside History of Our Modern Understanding of the Universe

Princeton University Press

From Nobel Prize-winning physicist P. J. E. Peebles, the story of cosmology from Einstein to today Modern cosmology began a century ago with Albert Einstein's general theory of relativity and his notion of a homogenous, philosophically satisfying cosmos. *Cosmology's Century* is the story of how generations of scientists built on these thoughts and many new measurements to arrive at a well-tested physical theory of the structure and evolution of our expanding universe. In this landmark book, one of the world's most esteemed theoretical cosmologists offers an unparalleled personal perspective on how the field developed. P. J. E. Peebles was at the forefront of many of the greatest discoveries of the past century, making fundamental contributions to our understanding of the presence of helium

and microwave radiation from the hot big bang, the measures of the distribution and motion of ordinary matter, and the new kind of dark matter that allows us to make sense of these results. Taking readers from the field's beginnings, Peebles describes how scientists working in independent directions found themselves converging on a theory of cosmic evolution interesting enough to warrant the rigorous testing it passes so well. He explores the major advances—some inspired by remarkable insights or perhaps just lucky guesses—as well as the wrong turns taken and the roads not explored. He shares recollections from major players in this story and provides a rare, inside look at how natural science is really done. A monumental work, *Cosmology's Century* also emphasizes where the present theory is incomplete, suggesting exciting directions for continuing research.

A General Relativity Workbook

General Relativity: The Essentials *Cambridge University Press*

In this short book, renowned theoretical physicist and author Carlo Rovelli gives a straightforward introduction to Einstein's General Relativity, our current theory of gravitation. Focusing on conceptual clarity, he derives all the basic results in the simplest way, taking care to explain the physical, philosophical and mathematical ideas at the heart of “the most beautiful of all scientific theories”. Some of the main applications of General Relativity are also explored, for example, black holes, gravitational waves and cosmology, and the book concludes with a brief introduction to quantum gravity. Written by an author well known for the clarity of his

presentation of scientific ideas, this concise book will appeal to university students looking to improve their understanding of the principal concepts, as well as science-literate readers who are curious about the real theory of General Relativity, at a level beyond a popular science treatment.

General Relativity

A Concise Introduction *Oxford University Press, USA*

Einstein's general theory of relativity -- currently our best theory of gravity -- is important not only to specialists, but to a much wider group of physicists. This short textbook on general relativity and gravitation offers students glimpses of the vast landscape of science connected to general relativity. It incorporates some of the latest research in the field. The book is aimed at readers with a broad range of interests in physics, from cosmology, to gravitational radiation, to high energy physics, to condensed matter theory. The pedagogical approach is “physics first”: readers move very quickly to the calculation of observational predictions, and only return to the mathematical foundations after the physics is established. In addition to the “standard” topics covered by most introductory textbooks, it contains short introductions to more advanced topics: for instance, why field equations are second order, how to treat gravitational energy, and what is required for a Hamiltonian formulation of general relativity. A concluding chapter discusses directions for further study, from mathematical relativity, to experimental tests, to quantum gravity. This is an introductory text, but it has also been written as a jumping-off point for readers who plan to study more

specialized topics.

A First Course in the Numerical Analysis of Differential Equations

Cambridge University Press

lead the reader to a theoretical understanding of the subject without neglecting its practical aspects. The outcome is a textbook that is mathematically honest and rigorous and provides its target audience with a wide range of skills in both ordinary and partial differential equations." --Book Jacket.

A First Course in Linear Model Theory

CRC Press

Thoroughly updated throughout, *A First Course in Linear Model Theory*, Second Edition is an intermediate-level statistics text that fills an important gap by presenting the theory of linear statistical models at a level appropriate for senior undergraduate or first-year graduate students. With an innovative approach, the authors introduce to students the mathematical and statistical concepts and tools that form a foundation for studying the theory and applications of both univariate and multivariate linear models. In addition to adding R functionality, this second edition features three new chapters and several sections on new topics that are extremely relevant to the current research in statistical methodology. Revised or expanded topics include linear fixed, random and mixed effects models, generalized linear models, Bayesian and hierarchical linear models, model selection, multiple comparisons, and regularized and robust regression. New to the Second Edition: Coverage of inference for linear models has been expanded into two chapters. Expanded coverage of multiple comparisons,

random and mixed effects models, model selection, and missing data. A new chapter on generalized linear models (Chapter 12). A new section on multivariate linear models in Chapter 13, and expanded coverage of the Bayesian linear models and longitudinal models. A new section on regularized regression in Chapter 14. Detailed data illustrations using R. The authors' fresh approach, methodical presentation, wealth of examples, use of R, and introduction to topics beyond the classical theory set this book apart from other texts on linear models. It forms a refreshing and invaluable first step in students' study of advanced linear models, generalized linear models, nonlinear models, and dynamic models.

Introducing Einstein's Relativity

Advanced Mechanics and General Relativity

Cambridge University Press
Aimed at advanced undergraduates with background knowledge of classical mechanics and electricity and magnetism, this textbook presents both the particle dynamics relevant to general relativity, and the field dynamics necessary to understand the theory. Focusing on action extremization, the book develops the structure and predictions of general relativity by analogy with familiar physical systems. Topics ranging from classical field theory to minimal surfaces and relativistic strings are covered in a homogeneous manner. Nearly 150 exercises and numerous examples throughout the textbook enable students to test their understanding of the material covered. A tensor manipulation package to help students overcome the computational challenge associated with general relativity is available on a site hosted by

the author. A link to this and to a solutions manual can be found at www.cambridge.org/9780521762458.

A First Course in Stochastic Calculus

American Mathematical Society

A First Course in Stochastic Calculus is a complete guide for advanced undergraduate students to take the next step in exploring probability theory and for master's students in mathematical finance who would like to build an intuitive and theoretical understanding of stochastic processes. This book is also an essential tool for finance professionals who wish to sharpen their knowledge and intuition about stochastic calculus. Louis-Pierre Arguin offers an exceptionally clear introduction to Brownian motion and to random processes governed by the principles of stochastic calculus. The beauty and power of the subject are made accessible to readers with a basic knowledge of probability, linear algebra, and multivariable calculus. This is achieved by emphasizing numerical experiments using elementary Python coding to build intuition and adhering to a rigorous geometric point of view on the space of random variables. This unique approach is used to elucidate the properties of Gaussian processes, martingales, and diffusions. One of the book's highlights is a detailed and self-contained account of stochastic calculus applications to option pricing in finance. Louis-Pierre Arguin's masterly introduction to stochastic calculus seduces the reader with its quietly conversational style; even rigorous proofs seem natural and easy. Full of insights and intuition, reinforced with many examples, numerical projects, and exercises, this book by a prize-winning mathematician and great teacher fully

lives up to the author's reputation. I give it my strongest possible recommendation. —Jim Gatheral, Baruch College I happen to be of a different persuasion, about how stochastic processes should be taught to undergraduate and MA students. But I have long been thinking to go against my own grain at some point and try to teach the subject at this level—together with its applications to finance—in one semester. Louis-Pierre Arguin's excellent and artfully designed text will give me the ideal vehicle to do so. —Ioannis Karatzas, Columbia University, New York

A First Course in Modular Forms

Springer Science & Business Media

This book introduces the theory of modular forms, from which all rational elliptic curves arise, with an eye toward the Modularity Theorem. Discussion covers elliptic curves as complex tori and as algebraic curves; modular curves as Riemann surfaces and as algebraic curves; Hecke operators and Atkin-Lehner theory; Hecke eigenforms and their arithmetic properties; the Jacobians of modular curves and the Abelian varieties associated to Hecke eigenforms. As it presents these ideas, the book states the Modularity Theorem in various forms, relating them to each other and touching on their applications to number theory. The authors assume no background in algebraic number theory and algebraic geometry. Exercises are included.

Spacetime and Geometry *Cambridge University Press*

Spacetime and Geometry is an introductory textbook on general relativity, specifically aimed at students. Using a lucid style, Carroll first covers the foundations of the theory and

mathematical formalism, providing an approachable introduction to what can often be an intimidating subject. Three major applications of general relativity are then discussed: black holes, perturbation theory and gravitational waves, and cosmology. Students will learn the origin of how spacetime curves (the Einstein equation) and how matter moves through it (the geodesic equation). They will learn what black holes really are, how gravitational waves are generated and detected, and the modern view of the expansion of the universe. A brief introduction to quantum field theory in curved spacetime is also included. A student familiar with this book will be ready to tackle research-level problems in gravitational physics.

A First Course in Logic *CRC Press*

A First Course in Logic is an introduction to first-order logic suitable for first and second year mathematicians and computer scientists. There are three components to this course: propositional logic; Boolean algebras; and predicate/first-order, logic. Logic is the basis of proofs in mathematics — how do we know what we say is true? — and also of computer science — how do I know this program will do what I think it will? Surprisingly little mathematics is needed to learn and understand logic (this course doesn't involve any calculus). The real mathematical prerequisite is an ability to manipulate symbols: in other words, basic algebra.

Anyone who can write programs should have this ability.

A First Course in Numerical Methods *SIAM*

Offers students a practical knowledge of modern techniques in scientific computing.

A First Course in Analysis *Cambridge University Press*

This rigorous textbook is intended for a year-long analysis or advanced calculus course for advanced undergraduate or beginning graduate students. Starting with detailed, slow-paced proofs that allow students to acquire facility in reading and writing proofs, it clearly and concisely explains the basics of differentiation and integration of functions of one and several variables, and covers the theorems of Green, Gauss, and Stokes. Minimal prerequisites are assumed, and relevant linear algebra topics are reviewed right before they are needed, making the material accessible to students from diverse backgrounds. Abstract topics are preceded by concrete examples to facilitate understanding, for example, before introducing differential forms, the text examines low-dimensional examples. The meaning and importance of results are thoroughly discussed, and numerous exercises of varying difficulty give students ample opportunity to test and improve their knowledge of this difficult yet vital subject.