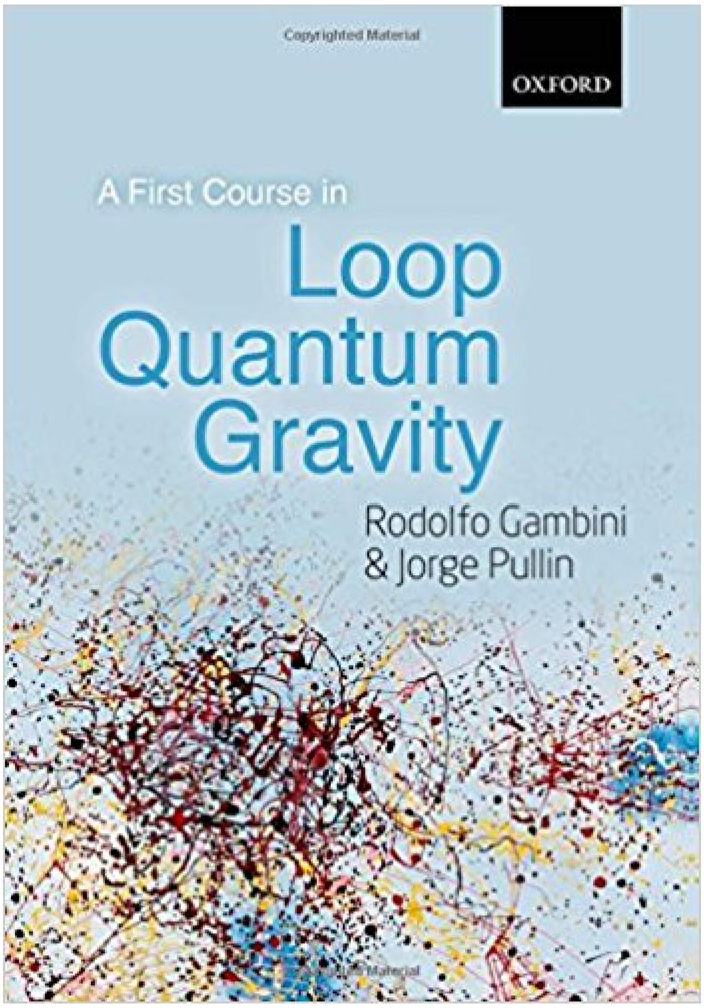
A First Course In Loop Quantum Gravity



Synopsis

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.To request a copy of the Solutions Manual, visit: http://global.oup.com/uk/academic/physics/admin/solutions

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Customer Reviews

"Gambini and Pullin have written an excellent and truly introductory book, aimed at the undergraduate level, which fills a gap in the existing literature, and responds to the growing interest in this subject. " -Ã Â Carlo Rovelli, Aix-Marseille University, FranceFrom Oxford University Press’ website.... the first book on this topic that is accessible already to undergraduates. No previous knowledge of general relativity and quantum field theory is required... The authors present the key features of loop quantum gravity, but also do not hide its weak points. Ã Â -Ã Â Claus Kiefer, University of Cologne, Germany From Oxford University Press’ websiteMarvellously succeeds in starting from the basics of special relativity and covering basic topics in Hamiltonian dynamics, Yang

Mills theory, general relativity and quantum field theory, ending with a tour on current (loop) quantum gravity research. This is done in a short 192 pages! * Bianca Dittrich, IOP Publishing * Loop quantum gravity is currently one of the main approaches in the search for a quantum theory of gravity. Written by well-known experts in this field, "A First Course in Loop Quantum gravity" is the first book on this topic that is accessible already to undergraduates. No previous knowledge of general relativity and quantum field theory is required; instead, the necessary material from these subjects is introduced in a clear and pedagogical way. The authors present the key features of loop quantum gravity, but also do not hide its weak points. The book can be recommended to anyone from student to established scientist who wants to get a short, reliable, and clear introduction to this fascinating field of research. * Claus Kiefer, University of Cologne, Germany * Gambini and Pullin have written an excellent and truly introductory book, aimed at the undergraduate level, which fills a gap in the existing literature, and responds to the growing interest in this subject. * Carlo Rovelli, Aix-Marseille University, France * I highly recommend this book ... Congratulations to the authors for the great, concise, effective presentation of this challenging field to students and interested researchers coming from other fields. * Christine Cordula Dantas, Toy Universes *

Rodolfo Gambini did his undergraduate work at the University of the Republic of Uruguay, went for a Ph.D. at the University of Paris and joined the faculty at the Universidad Simon Bolivar in Venezuela. He returned to Uruguay in 1997 where he has been director of several government funding agencies in addition to being a Professor at the University of the Republic. He has won the Trieste Prize in Physics, the presidential prize for scientific accomplishment in Uruguay and received an honorary doctorate from the University of the Republic.Jorge Pullin did his undergraduate work at the Instituto Balseiro in Bariloche, Argentina, did his Ph.D. thesis work at the University of Cordoba and moved as a post-doc to Syracuse University and the University of Utah. He became a faculty member at PennState and in 2001 joined the Louisiana State University as the HoraceHearne Chair in Theoretical Physics. He is the co-director of the Horace Hearne Institute of Theoretical Physics and the interim co-director of the Center for Computation and Technology at the Louisiana State University. He was the chair of the Topical Group in Gravitation of the American Physical Society and served on the editorial boards of Classical and Quantum Gravity and the New Journal of Physics and is currently on the board of Living Reviews, Papers in Physics and is managing editor of International Journal of Modern Physics D.

Many non-experts who are interested in physics know that the current theory of gravity, Einstein’s general theory of relativity, stands apart from the theories of the other three fundamental forces, the electromagnetic, weak nuclear, and strong nuclear forces, in that the former is a classical theory whereas the latter are quantum theories. Physicists like to unify things, so they would like to have the theory of gravity be a quantum theory as well, so they can then have a "theory of everything". In addition to being satisfying on a philosophical and esthetic level, this would also potentially be able to explain what’s going on at the center of black holes and at the "beginning" of the Big Bang, for which general relativity gives a singularity, an unphysical point of infinite energy density indicating that general relativity is no longer properly describing the physical reality in these situations.One approach to a quantum theory of gravity is the famous (perhaps infamous) "string theory". Another approach, the approach discussed in this book, is loop quantum gravity, in which a more traditional approach to quantizing the gravitational field is employed. In a nutshell, loop quantum gravity is a canonical quantization of a modification of the Hamiltonian formulation of general relativity originally developed by Arnowitt, Deser, and Misner in the early 1960s ("ADM formalism"), said modification being the replacement of the position and momentum variables used by ADM with a new set of variables introduced by Ashtekar in the 1980s. Canonical quantization refers to the quantization procedure based on the Hamiltonian originally developed by Dirac in the 1920s and further developed by him in the 1950s. Loop quantum gravity uses a "loop representation" which has as a key result that there is a minimum allowed length, area, and volume in the universe, i.e, these quantities are quantized. This in turn leads to the result that the universe has a minimum size, and if we play the movie of cosmic expansion backwards, we reach this minimum size before we reach the singularity, and the universe starts to expand again, the so-called "Big Bounce". Also, the relation between the surface area and entropy of a black hole reduces to a relationship between the number of area quanta which make up the surface area and the entropy.This book is directed at the advanced undergraduate level, and aims to fill a gap in the pedagogy of this subject, which requires much more math and physics background to really understand than any undergraduate would have. As a result, it takes a very simplistic approach and should be considered no more than a very preliminary introduction to the topic.The first part of the book covers all the basic background concepts needed to understand the program of loop quantum gravity, including general relativity, the generalized Hamiltonian with constraints, and canonical quantization. It then goes on to discuss the ADM formalism, Ashtekar variables, the loop representation, and applications of loop quantum gravity to cosmology and black hole thermodynamics. It ends with a very honest evaluation of the limitations and incompleteness of the theory at the present time. Loop quantum gravity is still a work in progress, and although there have been many important advances in terms of formulating a theory, there is as yet no validation experimentally, nor any obvious path to such a validation.You will not really understand loop quantum gravity when you finish this book, only understand a very superficial version of it "dumbed down" for the intended readership of this book, but still extremely formidable in terms of its demands on the reader mathematically speaking. If you haven’t already had at least an introductory exposure to general relativity, quantum mechanics, Lagrangian and Hamiltonian mechanics, and quantum field theory, you’re in for some very tough sledding indeed. If you have this background, after you finish this book you will be prepared to delve more deeply into the topic if you have the time and inclination. Included are references to more advanced texts as well as important review papers to guide this further exploration.I give this book 5 stars for identifying a pedagogical need, clearly defining the intended readership and the goals, and carefully describing the inevitable limitations and gaps in trying to present such a sophisticated, difficult topic to a relatively unprepared audience.

The book starts off assuming you don’t understand special relativity. About 10 pages later we’re on Yangs-Mills theory. I don’t exactly know how to present this material at a lower level, but the approach taken here doesn’t cut it. You can’t teach QFT in one page. Can’t teach constrained Hamiltonian theory in two pages.I give it three stars for the attempt, but I don’t actually think it’s possible to teach LQG at an undergraduate level.

Loop quantum gravity is an alternative to the string theory approach for quantizing the gravitational field. I purchased this volume as part of a program of self-study in quantum gravity, mainly because the string theories (which also encompass quantum physics, and are touted as being a unifying theory of all physical forces) have yet to provide testable predictions of new physics, despite their relative popularity within theoretical physics circles. (A reader seeking sophisticated background in the strings vs. loop quantum theory would make a good investment in Roger Penrose’s ’The Road to Reality’. For a decidedly anti-string treatment, Lee Smolin, a physicist at Princeton, has written several books outlining his skepticism regarding superstrings, in prose that is considerably less mathematical than Penrose.)Returning to the book at hand, Prof. Gambini is an engaging writer whose treatment of early chapters has motivated me to jump headlong into the more involved material in the second half of the book. As such, I am at the beginning of my work, and this review reflects a relatively fresh understanding of aspects of loop quantum gravity. Early chapters handle the basic results of Riemannian geometry and metrics in curved spaces that are relevant to General Relativity (GR). These are the tools of classical GR, which is well established as a valid descriptor of gravitation as we experience it billions of years after the Big Bang. I was fortunate enough have an undergraduate course in GR, without which I might have been snowed by the tensors and connections (mathematical constructs) necessary for the basic study of GR as we know it. A technically sophisticated novice would benefit from a study of basic GR as handled by Weinberg (which I own, and like, though some consider it 'old fashioned') or Wald (which I do not have, but is a popular GR text). As I move into later chapters involving Lagrangian densities and Hamiltonians (which lie in the realm of classical and quantum mechanics), I have found it valuable to have Sakurai's 'Advanced Quantum Mechanics' and Ryder's 'Quantum Field Theory' on hand. In summary, then, this is not a book for the layman, and fellow readers who embark on this will want to have advanced physics texts at their disposal.The loop vs. string controversy will undoubtedly continue. In the meantime, I plan to move to more advanced texts on the subject of loop quantum gravity, when my basic understanding of the subject is sufficient. I would like to turn the clock ahead a decade, to see what transpires in in this field. Since practical time travel is not yet perfected, I'll just have to wait.

The best book of its kind,

Excellent introductory text for loop quantum gravity. Gives necessary background and defines notation. Has excellent up-to-date references.

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