Superstring Theory

Volume 1: Introduction

25th Anniversary Edition

Twenty-five years ago, Michel Green, John Schwarz, and Edward Witten wrote two volumes on string theory. Published during a period of rapid progress in this subject, these volumes were highly influential for a generation of students and researchers. Despite the immense progress that has been made in the field since then, the systematic exposition of the foundations of superstring theory presented in these volumes is just as relevant today as when first published.

A self-contained introduction to superstrings, Volume 1 begins with an elementary treatment of the bosonic string, before describing the incorporation of additional degrees of freedom: fermionic degrees of freedom leading to supersymmetry, and internal quantum numbers leading to gauge interactions. A detailed discussion of the evaluation of tree-approximation scattering amplitudes is also given.

Featuring a new Preface setting the work in context in light of recent advances, this book is invaluable for graduate students and researchers in general relativity and elementary particle theory.

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Preface to the 25th Anniversary Edition

In the twenty-five years since the original publication of these two Volumes, there have been numerous developments in string theory. The curious twists and turns that marked its pre-1987 evolution have continued apace, and current research makes contact with a wide range of areas of mathematics and physics. In the following we will mention briefly some of these developments and then explain why we believe that these volumes are still useful.

Major insights into the non-perturbative structure of string theory followed from the discovery of non-perturbative duality symmetries of super-string theory. This led to the realization that the myriad of apparently distinct superstring theories that arise in ten or fewer dimensions actually are different perturbative approximations to the same underlying theory, which has come to be known as M-theory. Furthermore, M-theory has eleven-dimensional supergravity as another semiclassical limit. The understanding of these interconnections was aided by the simultaneous discovery of the properties of a family of dynamical objects called p-branes, which are extended objects that fill p spatial dimensions, as opposed to the 1 dimension of the string. p-branes can be viewed as solitons that are generalizations of the magnetic monopoles of conventional quantum field theory and the black holes of general relativity. Indeed, these discoveries have stimulated impressive advances in understanding the quantum and thermodynamic properties of large classes of black holes.

An important outcome of these considerations has been striking progress in understanding the nonperturbative structure of the quantum field theories that arise from string theory in various limits. Most notably, it has led to the gauge/gravity correspondence, also known as holographic duality, according to which a quantum theory of gravity in a D-dimensional asymptotically anti-de Sitter spacetime is equivalent to a $(D - 1)$-dimensional local quantum field theory. The most studied example is an equivalence between four-dimensional maximally supersymmetric $U(N)$ Yang–Mills field theory and type IIB superstring theory in five-dimensional anti-de Sitter space times a five-dimensional sphere with N units of Ramond–Ramond flux.

In 1987, the main focus of this field was the application of string perturbation theory to describe the fundamental forces and particles. This remains a focus, but nowadays nonperturbative methods are used as well. The possibilities for using string theory to construct models of particle physics that are at least semi-realistic have proliferated since 1987, and some physicists, in part because of clues coming from cosmological observations, have come to suspect that the “landscape” of string theory possibilities is actually the way the Universe works. In addition, nowadays, string theory is applied to other types of problems in theoretical physics, including the modeling of heavy ion collisions and the theory of quantum critical points relevant to condensed matter physics. From a contemporary point of view, the gauge/gravity correspondence means that string theory and quantum gravity are inevitable parts of the description of strongly coupled quantum systems.

Many of the developments of the last quarter century, which of course are not covered in these two volumes, have been described in more recent books and review articles. These more recent developments are rooted to a large extent in the basic material covered here. Given the immense breadth and volume of recent research, it is extremely difficult for newer books and articles to present all the details of the more basic underlying material. For this reason, we feel that the material contained in these volumes remains of value and we hope it will continue to provide stimulus for further research in this rich field – wherever it eventually may lead.

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