PREFACE

In the last decade classical fields have become of great importance in theoretical physics. The reason for that is the realization by both physicists and mathematicians that gauge fields are just the right mathematical tool for describing particle physics as well as other branches of physics. As a consequence, general relativity theory has become a center of attention from the point of view of gauge fields.

The classical theory of fields is no longer a theory of electrodynamics and gravitation as two separate topics which can be formally and technically put together in one text. Rather, classical fields should include electrodynamics, gauge fields, and gravitation, and the three fields should be presented with a common physical and mathematical foundation. This book is the first text that undertakes such a task in presenting classical fields.

The book is based on lectures given by the author in two graduate courses at the Institute for Theoretical Physics at Stony Brook, New York, where he was a Visiting Professor in 1977–1978, and at the Ben Gurion University thereafter. Approximately half of the material is on gravitation, and the other half deals with classical gauge fields. More than half of the content is based on material that has not yet appeared in other books.

The emphasis here is on the classical field theory aspect of the topic. Also, only those topics of gauge field theory that blend naturally with gravitation are included. These topics of gauge fields include the spinor formulation and the classification of SU(2) gauge fields, as well as the null tetrad formulation of the Yang–Mills field in the presence of gravitation (and, of course, in its absence). Material found in the many available books on *quantum* field theory is not included.

The book consists of ten chapters, which are divided into sections, usually ending with problems, many of which are completely or partially solved. Chapters 1 and 2 are devoted to the physical foundations of the theory of gravitation and to the mathematical theory of the geometry of curved spacetimes needed to describe the general theory of relativity and the other topics in the remainder of the book.

The gravitational field equations, their properties and generalizations, are presented in Chapter 3. Here, the concepts of the Lie derivative, Killing equation, null tetrad formulation of the Einstein field equations along with the Newman–Penrose equations, and perturbation on gravitational background are introduced. In Chapter 4 the Einstein field equations are solved for mass systems. These include, in addition to the standard metrics, the Vaidya radiating metric, the Tolman metric, and the Einstein–Rosen metric describing cylindrical gravitational waves, which is of importance in constructing cosmological models. Chapter 5 is devoted to the general properties of the gravitational field, including such topics as the weak gravitational field, experimental verification of gravitational theory, gravitational radiation, the energy-momentum pseudotensor, and gravitational bremsstrahlung.

Chapter 6 is devoted to the derivation of the equations of motion of material bodies—including spinning particles—within the framework of general relativity. This includes geodesic motion, the Einstein–Infeld–Hoffmann post-Newtonian equation of motion and its Lagrangian formulation, and the Papapetrou equations for a spinning particle and their applications to motion in the Schwarzschild and Vaidya fields. In Chapter 7 the theory of axisymmetric exact solutions of the Einstein equations is given and, using the Ernst potential method, the metrics of Kerr, Tomimatsu–Sato, NUT–Taub, Demianski–Newman, and variable-mass Kerr are presented.

In Chapter 8 the spinor formulation of both the gravitational and the gauge fields is given. Here we introduce two-component spinors, the electromagnetic and the gravitational spinors. The SU(2) gauge field theory is subsequently given. This is then followed by the gauge field spinors and their transformation rules, the geometry of gauge fields, and the Euclidean gauge field spinors.

Chapter 9 is devoted to the classification of gauge fields. This problem is of great importance in connection with the finding of exact solutions to the Yang–Mills field equations, as experience has shown in general relativity theory with respect to the Petrov classification,

In Chapter 10 the Einstein field equations are written in relation to other gauge fields. Also, the Yang–Mills theory is formulated in null coordinates in both the cases of the presence and the absence of gravitation. As is well known, these methods have brought great insight into the theory of gravitation. The chapter also includes the theory of differential geometrical analysis, fiber bundles and their application to gauge fields and general relativity, magnetic monopoles, null tetrad formulation of the Yang–Mills theory, and monopole solution of the Yang–Mills equations.

The book can be used as a text for a one-year graduate course in theoretical physics, as has been done by the author in the last four years. It can also be used as a supplementary book to other texts in graduate courses in classical field theory or mathematical physics. We hope that it can fill the gap of a needed text on the subject, where classical fields are treated in a modern approach different from available books. The reader will find other aspects of gauge field theory in flat spacetime (Minkowskian and Euclidean) in the author's other book *Classical Fields: Electrodynamics and Gauge Theory*, now in preparation.

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