Part I: Gravitation and Cosmology

The first part of this volume, dealing essentially with classical general relativity and cosmology, consists of discussions at several different levels. It begins with an elementary, but adequate, presentation of the basic tenets and mathmatical tools of general relativity. Glimpses of some interesting developments in black-hole physics and cosmology are presented with suitable introductory articles preceding these discussions. Finally, some of the advanced mathematical techniques that have become indispensable to current research are also introduced.

The chapter by P. C. Vaidya (Chapter 1) takes the special theory of relativity as its starting point and demonstrates how the phenomenon of gravitation naturally leads to the Riemannian geometry of curved spacetime. The basic mathematical techniques of tensor analysis and differential geometry are developed ending with Einstein's field equation. This article forms the foundation for all others involving classical general relativity.

Black-hole physics has been one of the most important developments in general relativity during the past two decades or so. An elementary introduction to the geometrical structure of black holes is provided by the first of the two chapters by C. V. Vishveshwara (Chapter 2). The characteristic properties of the nonrotating and rotating black holes are pointed out, compared and contrasted using simple mathematics. Some of the important results that have emerged in black-hole physics are also briefly described.

The above chapter serves as a preamble for the next one by B. R. Iyer (Chapter 3). One of the most fascinating features of black holes is the Hawking radiation and the consequent quantum evaporation of black holes. This phenomenon is discussed, first considering black hole thermodynamics. Ideas such as the reversible and irreversible processes, the thermodynamic quantities associated with the blackhole – especially the notion of its temperature – and, finally, the Hawking radiation exhibiting a Planckian distribution corresponding to this temperature, are the main points focussed on in this chapter.

The second chapter by C. V. Vishveshwara (Chapter 4) is again a short introduction to the relativistic cosmological models. The fundamental observational facts of isotropy and homogeneity leading to the simple Robertson–Walker geometries are explained. The different Friedmann models and their evolution are considered. Finally, the observational contacts of these different models are discussed. This article is the prelude to the two chapters on cosmology to follow.

The possible creation of the universe as a whole with the Big Bang has excited, intrigued and tantalized all cosmologists. In Chapter 5, J. V. Narlikar considers in sufficient detail the formation and evolution of the relics of the Big Bang. After considering the thermodynamics of the early universe, Narlikar goes into various

B. R. Iyer et al. (eds.), Gravitation, Gauge Theories and the Early Universe, 1–2.

questions related to these relics such as the synthesis of helium and the characteristic features of the microwave background. The interplay between particle physics and cosmology, which has become increasingly intense in recent years, is anlayzed. Some problems related to the very early universe, including galaxy formation, are also touched upon.

Although the universe, as we see it today, appears to be isotropic to an extraordinary degree, it is not inconceivable – or rather it should be expected – that the universe was once anisotropic. A. K. Raychaudhuri's Chapter 6 starts by setting out the motivation for the study of anisotropic cosmological models. It then offers the mathematical basis for the study of such models as well as the description of some of the exact solutions of this genre. Killing vectors that spell out spacetime symmetries, are defined and the Bianchi classification of spacetimes based on the structure of the Killing vectors described. After considering the kinematics of matter flow, some of the known solutions are presented and their properties described.

Global techniques have found an important place in the study of spacetime structure. In Chapter 7, P. S. Joshi elucidates some of the mathematical concepts underlying these techniques. After introducing the idea of a differentiable manifold, diffeomorphisms of spacetime, Lie derivatives and Killing symmetries are introduced. The chapter ends with the treatment of the conformal compactification which facilitates the study of null boundaries of spacetime.

Differential forms have proved to be of great efficacy in computations and analyses within the framework of general relativity. In Chapter 8, A. R. Prasanna develops the algebra and the calculus of differential forms. The results are then applied to the Einstein–Cartan theory, which includes spin as a source term in addition to the usual energy-momentum of the distribution. The relation of this theory to a possible gauge theory of gravity is also examined.

To sum up, this part of the book centres around classical general relativity and cosmology. It includes foundations for more advanced topics as well as glimpses of some problems of current interest. It should profitably serve as a take-off point for the different directions in general relativity.