

Contents

	<i>page</i>
List of contributors	xi
Preface	xv
1. An introductory survey	1
<i>S. W. Hawking and W. Israel</i>	
1.1 Historical background	1
1.2 The field equations	9
1.3 Cosmology	11
1.4 Gravitational collapse	15
1.5 Quantum gravity	21
1.6 Future prospects	23
2. The confrontation between gravitation theory and experiment	24
<i>C. M. Will</i>	
2.1 Introduction	24
2.2 Principles of equivalence and the foundations of gravitation theory	26
2.3 Post-Newtonian gravity in the solar system	40
2.4 Gravitational radiation as a tool for testing gravitation theory	62
2.5 Stellar-system tests: the binary pulsar	70
2.6 Gravitation in the universe: the influence of global structure on local physics	84
2.7 Summary	88
3. Gravitational-radiation experiments	90
<i>D. H. Douglass and V. B. Braginsky</i>	
3.1 Introduction	90
3.2 Characteristics of gravitational radiation	94

Contents

	<i>page</i>
3.3 Sources of gravitational radiation	97
3.4 Detection of gravitational radiation	119
3.5 Prospects for the future	135
4. The initial value problem and the dynamical formulation of general relativity	138
<i>A. E. Fischer and J. E. Marsden</i>	
4.1 Canonical formalism	140
4.2 The constraint manifold	158
4.3 The abstract Cauchy problem and hyperbolic equations	168
4.4 The Cauchy problem for relativity	183
4.5 Linearization stability of the vacuum Einstein equations	194
4.6 The space of gravitational degrees of freedom	202
5. Global structure of spacetimes	212
<i>R. Geroch and G. T. Horowitz</i>	
5.1 Introduction	212
5.2 What is the topology of our universe?	217
5.3 Is our universe singular?	255
5.4 How noticeably singular is our universe?	269
5.5 Conclusion	288
5.6 Appendix	289
6. The general theory of the mechanical, electromagnetic and thermodynamic properties of black holes	294
<i>B. Carter</i>	
6.1 Introduction	294
6.2 The evolution of the horizon	302
6.3 Local properties of a stationary horizon	314
6.4 Energy and angular momentum transport in a black hole background	328
6.5 Electromagnetic effects in a black hole background space	336
6.6 The total mass and angular momentum	352
6.7 Uniqueness and no-hair theorems	359

Contents

	<i>page</i>
7. An introduction to the theory of the Kerr metric and its perturbations <i>S. Chandrasekhar</i>	370
7.1 The tetrad formalism	371
7.2 The Newman–Penrose formalism	375
7.3 Tetrad transformations and related matters	383
7.4 The Kerr metric and the perturbation problem	391
7.5 The solution of Maxwell's equations	404
7.6 Gravitational perturbations	411
7.7 The solution of Dirac's equation	425
7.8 The potential barriers round the Kerr black hole and the problem of reflection and transmission	429
8. Black hole astrophysics <i>R. D. Blandford and K. S. Thorne</i>	454
8.1 Introduction	454
8.2 On the character of research in black hole astrophysics	457
8.3 Isolated holes produced by collapse of normal stars	461
8.4 Black holes in binary systems	469
8.5 Black holes in globular clusters	481
8.6 Black holes in quasars and galactic nuclei	485
8.7 Primordial black holes	494
8.8 Concluding remarks	502
9. The big bang cosmology – enigmas and nostrums <i>R. H. Dicke and P. J. E. Peebles</i>	504
9.1 Introduction	504
9.2 Enigmas	504
9.3 Nostrums and elixirs	510
10. Cosmology and the early universe <i>Ya B. Zel'dovich</i>	518
10.1 Introduction	518
10.2 The average matter density in the universe	520
10.3 The lepton era	522
10.4 The hadron era	523
10.5 The quantum era and its effect	526

Contents

	<i>page</i>
11. Anisotropic and inhomogeneous relativistic cosmologies <i>M. A. H. MacCallum</i>	533
11.1 Introduction	533
11.2 Spacetime symmetries	536
11.3 Spatially-homogeneous anisotropic metrics	542
11.4 Inhomogeneous metrics	563
11.5 Physics of the models	570
11.6 Constraints and inferences	576
12. Singularities and time-asymmetry <i>R. Penrose</i>	581
12.1 Introduction	581
12.2 Statement of the problem	582
12.3 Singularities: the key?	611
12.4 Asymmetric physics?	635
13. Quantum field theory in curved spacetime <i>G. W. Gibbons</i>	639
13.1 Introduction	639
13.2 Basic notions	640
13.3 Applications	663
13.4 Conclusion	679
14. Quantum gravity: the new synthesis <i>B. S. DeWitt</i>	680
14.1 Introduction	680
14.2 The quantum ether	683
14.3 The back reaction	698
14.4 The one-loop approximation	702
14.5 The full quantum theory	720
14.6 Conclusion	743
15. The path-integral approach to quantum gravity <i>S. W. Hawking</i>	746
15.1 Introduction	746
15.2 The action	749

Contents

	<i>page</i>
15.3 Complex spacetime	752
15.4 The indefiniteness of the gravitational action	757
15.5 The stationary-phase approximation	762
15.6 Zeta function regularization	766
15.7 The background fields	771
15.8 Gravitational thermodynamics	778
15.9 Beyond one loop	782
15.10 Spacetime foam	785
 16. Ultraviolet divergences in quantum theories of gravitation	 790
<i>S. Weinberg</i>	
16.1 Introduction	790
16.2 Renormalizable theories of gravitation	792
16.3 Asymptotic safety	798
16.4 Physics at ordinary energies	809
16.5 Dimensional continuation	814
16.6 Gravity in $2 + \varepsilon$ dimensions	822
16.7 Appendix. Calculation of b	828
 References	 833
Index	903