Contents

1. The Equivalence Principle

1.1 The Eötvos Experiment 1
1.2 Negative Mass 5
1.3 Equivalence of Different Frames of Reference 6
1.4 Gravitational Red Shift of Spectral Lines 8
1.5 Further Remarks on the Equivalence Principle 9

2. Generalization of the Special Theory of Relativity

2.1 The Idea of Covariance 11
2.2 The Metric Tensor 12
2.3 The Metric Tensor in Curved Spaces and Accelerated Frames 12
2.4 General Covariance 15

3. Riemannian Geometry and Tensor Calculus

3.1 Some Ideas about Curvature 17
3.2 Transformation Laws for Different Kinds of Tensors . . 18
3.3 Parallel Displacement and Covariant Differentiation . . 22
3.4 The Curvature Tensor 28
3.5 The Bianchi Identities 32
3.6 Geodesics 34
3.7 Some Useful Calculational Aids 37
3.8 Length Measurements 39
3.9 Determination of the Metric Tensor 41

4. Field Equations of General Relativity and Electromagnetism

4.1 The Gravitational Field Equations 43
4.2 Variational Principle Deduction of the Field Equations 50
4.3 Maxwell's Equations 53
4.4 Motion of a Charged Particle 54

5. Experimental Tests of General Relativity

5.1 The Schwarzschild Solution 56
5.2 The Gravitational Red Shift 60
5.3 Effects on Planetary Orbits 64
5.4 Deflection of Light 67
5.5 Concluding Remarks 69

6. The Conservation Laws

6.1 The Canonical Stress Energy Pseudotensor 70
6.2 Other Conservation Laws 79
6.3 Further Remarks on the Conservation Laws 85

7. Gravitational Waves

7.1 Weak-Field Solutions 87
7.2 Riemann Tensor for a Wave of Arbitrary Strength Which is Locally Plane 90
7.3 Approximate Evaluation of Source Volume Integrals . 92
7.4 Weak-Field Approximations for Energy Flux and Energy Density 94
7.5 Linear Mass Quadrupole Oscillator 95
7.6 Radiation from a Spinning Rod 97
7.7 Further Remarks on the Weak-Field Solutions 98
7.8 Exact Cylindrical Wave Solutions 99
7.9 Interaction of a Particle with Cylindrical Gravitational Waves. 102
7.10 Exact Plane-Wave Solutions. 105
7.11 Initial-Value Formulation of the Radiation Problem . . 107
7.12 Time-Symmetric Solution With Positive Energy 110
7.13 Conditions on the Differentiability and Continuity of Manifolds 113
7.14 Six-Dimensional Treatment of Gravitational Radiation . 113
7.15 Other Petrov Class II Wave Solutions 119

8. Detection and Generation of Gravitational Waves

8.1 Detection 124
8.2 Mass Quadrupole Detector 126
8.3 Interaction of a Crystal with a Gravitational Wave . . 131
8.4 Rotations Induced by Gravitational Radiation 138
8.5 Generation of Gravitational Waves. 140
8.6 Other Radiation Experiments 144

9. Selected Topics in General Relativity

9.1 Unified Field Theories 146
9.2 Equations of Motion 153
9.3 Mach's Principle 157
9.4 Remarks on Cosmology 162
9.5 Hamiltonian Formulation 167
9.6 Remarks on Quantization of General Relativity 184
9.7 Spinors in General Relativity 186

Excercises. 191

Index 194