

Contents

Preface — V

Prologue — 1

1 The concept of Spacetime — 2

- 1.1 Hypotheses — 2
- 1.2 Space and time, spacetime — 3
 - 1.2.1 The principle of relativity — 4
 - 1.2.2 The speed of light — 4
 - 1.2.3 Lorentz transformations — 5
- 1.3 Radical relativity — 7
 - 1.3.1 Local and non-local observers — 8
 - 1.3.2 Observables in space and time — 9
- 1.4 More Hypotheses — 10
 - 1.4.1 Mass — 11
 - 1.4.2 Charge — 13
 - 1.4.3 Spin — 14
 - 1.4.4 Wave-Particle duality — 14

2 Theory — 17

- 2.1 Coordinate systems and Coordinates — 17
- 2.2 Local observers: aberration and Doppler shift — 19
 - 2.2.1 The everyday phenomena — 19
 - 2.2.2 An uncommon way to relativity: conformal maps of celestial spheres — 20
 - 2.2.3 Aberration — 25
 - 2.2.4 Doppler shift — 26
 - 2.2.5 Velocity composition law — 29
- 2.3 Non-local observers: Minkowski spacetime and Lorentz transformations — 30
 - 2.3.1 Lorentz transformations from the metrics in Minkowski space — 31
 - 2.3.2 Lorentz transformations from aberration and Doppler shift — 36
 - 2.3.3 Geometric representations of Lorentz transformations — 38
 - 2.3.4 Algebraic representations of Lorentz transformations — 40

3 Consequences of the special theory of relativity — 43

- 3.1 Kinematics — 43
 - 3.1.1 Coordinate velocity and proper velocity — 43
 - 3.1.2 Rapidity, the integrated proper acceleration — 45
- 3.2 Dynamics — 47

3.2.1	Newton’s second law —	47
3.2.2	Momentum and energy —	51
3.3	Electrodynamics —	52
3.3.1	Maxwell equations —	52
3.3.2	Lorentz transformation of electromagnetic fields —	56
3.3.3	Coulomb and Lorentz force —	59
4	Special Relativity Revisited —	61
4.1	Ether drift experiments —	61
4.2	Superluminal motion —	64
4.3	Relativistic mass —	65
4.4	Isotropy and the one-way velocity of light —	66
4.5	Length and time —	72
4.6	The spacetravelling twins —	73
5	Limits of the special theory of relativity —	77
5.1	Equivalence principle —	77
5.2	Curvature of spacetime —	78
5.2.1	Free fall in gravitational fields —	78
5.2.2	Planetary orbits —	79
5.3	General relativity —	81
5.3.1	Einsteins tests of general relativity —	82
5.3.2	Black holes: horizons and singularities —	83
5.3.3	Classical approaches to general relativity —	85
6	Experimental evidences —	88
6.1	Time dilation —	88
6.1.1	Cosmic radiation: muons —	88
6.1.2	Global navigation satellite system (GPS) —	90
6.1.3	The Hafele-Keating experiment —	92
6.2	Electromagnetism —	93
6.2.1	Voltage and current —	93
6.2.2	Generators and Motors —	95
6.3	Electromagnetic radiation fields —	97
6.3.1	Definitions —	97
6.3.2	Black-body radiation —	99
6.3.3	Accelerated charges —	103
6.4	Relativistic effects in atoms —	115
6.4.1	The ionization energy of hydrogen —	116
6.4.2	Spin-orbit interaction —	118

- 7 Space travel — 120**
 - 7.1 Can we cross the universe — **120**
 - 7.1.1 Requirements — **120**
 - 7.1.2 Uniformly accelerated flight — **121**
 - 7.2 Spacecrafts — **124**
 - 7.2.1 Rocket equations — **124**
 - 7.2.2 Electrostatic ion propulsion systems — **126**
 - 7.2.3 Electromagnetic thrusters — **127**
 - 7.2.4 Ramjets — **128**
 - 7.3 Challenges — **132**
 - 7.3.1 Orientation — **132**
 - 7.3.2 Navigation — **137**
 - 7.3.3 Communication — **141**
 - 7.4 Horizons and obstacles — **144**
 - 7.4.1 Cosmology and limits of special relativity — **144**
 - 7.4.2 Interstellar matter — **147**
 - 7.4.3 Electromagnetic radiation — **148**
 - 7.5 Conclusions — **150**

Epilogue — 151

Bibliography — 153

Index — 158