Contents

Preface ix

Preface to the First Edition xi

(A) The Historical and Physical Context of Relativity Theory 1

1. Introduction and Overview 3
1a. Special relativity is NOT incorrect! 3
1b. Idea #1: Einstein's first postulate of relativity (the principle of relativity) is the only necessary ingredient of a viable theory 4
1c. Idea #2: The principle of relativity is useful as a limiting principle in the discussion of the physics of accelerated frames 7
2. Space, Time and Inertial Frames 12
2a. Space 12
2b. Time 13
2c. Inertial frames of reference 14
2d. Coordinate transformations 15
2e. Units of space and time 16
3. The Nontrivial Pursuit of Earth's Absolute Motion 19
3a. Newton's frame of absolute rest 19
3b. Measuring Earth's velocity 22
4. On the Right Track: Voigt, Lorentz, and Larmor 27
4a. Lorentz's heuristic local time 27
4b. Development of the Lorentz transformations 29
5. The Contributions of Poincaré 36
5a. Poincaré's insight into physical time 36
5b. Poincaré and the principle of relativity 38
5c. Poincaré's theory of relativity 41
5d. Conformal transformations and a frame of 'absolute rest' 47
5e. Poincaré's impact on relativity and symmetry principles 51
5f. Retro physics: Past and present views of the ether 54
6. The Novel Creation of the Young Einstein 64
6a. Fresh thoughts from a young mind 64
6b. The theory of special relativity 65
6c. Derivation of the Lorentz transformation 66
6d. Relativity of space and time 68
6e. The completion of special relativity by Minkowski's idea of 4-dimensional spacetime 73
6f. Einstein and Poincaré 75

(B) A Broader View of Relativity: The Central Role of the Principle of Relativity 85

7. Relativity Based Solely on the Principle of Relativity 87
7a. Motivation 87
7b. A brief digression: natural units and their physical basis 88
7c. Taiji relativity: A relativity theory based solely on the principle of relativity 89
7d. Realization of taiji time 92
7e. The conceptual difference between taiji relativity and special relativity 93
7f. The role of a second postulate 95
8. Common Relativity 100
8a. A new unit for time 100
8b. Operationalizing the common-second and the equivalence of inertial frames 102
8c. Coordinate transformations in common relativity 104
8d. Physical interpretation of the ligh function b 106
8e. Implications of common time 109
9. Experimental Tests I 114
9a. Time intervals versus optical path length 114
9b. The Michelson-Morley experiment 114
9c. The Kennedy-Thorndike experiment 118
9d. The Fizeau experiment 121
10. Experimental Tests II 128
10a. The Ives-Stilwell experiment 128
10b. Atomic energy levels and Doppler shifts in taiji relativity 128
10c. Atomic energy levels and Doppler shifts in common relativity 130
10d. Lifetime dilation of cosmic-ray muons 133
10e. The cosmic-ray muon experiment and taiji relativity 134
10f. Decay-length dilation in quantum field theory and taiji relativity 135
10g. Cosmic-ray muons and common relativity 138
10h. Quantum field theory and the decay length in common relativity 140
11. Group Properties of Taiji Relativity and Common Relativity 143
11a. General group properties 143
11b. Lorentz group properties 146
11c. Poincaré group properties 152
12. Invariant Actions in Relativity Theories and Truly Fundamental Constants 158
12a. Invariant actions for classical electrodynamics in relativity theories 158
12b. Universal constants and invariant actions 163
12c. Dirac's conjecture regarding the fundamental constants 165
12d. Truly fundamental constants 166
13. Common Relativity and Many-Body Systems 170
13a. Advantages of common time 170
13b. Hamiltonian dynamics in common relativity 173

13c. Invariant kinetic theory of gases 178
13d. Invariant Liouville equation 182
13e. Invariant entropy, temperature and the Maxwell-Boltzmann distribution 184
13f. Invariant Boltzmann-Vlasov equation 186
13g. Boltzmann's transport equation with 4-dimensional symmetry 192
13h. Boltzmann's H theorem with 4-dimensional symmetry 195
14. Common Relativity and the 3K Cosmic Microwave Background 200
14a. Implications of an invariant and non-invariant Planck's law for blackbody radiation 200
14b. Invariant partition function 200
14c. Covariant thermodynamics 202
14d. The canonical distribution and blackbody radiation 205
14e. The question of Earth's "absolute" motion relative to the 3K cosmic microwave background 208
15. Common Relativity and Quantum Mechanics 213
15a. Fuzziness at short distances and the invariant genergy 213
15b. Fuzzy quantum mechanics with an inherent fuzziness in the position of a point particle 215
15c. Fuzzy point and modified Coulomb potential at short distances 220
15d. Suppression of the contribution of large momentum states to physical processes 222
16. Common Relativity and Fuzzy Quantum Field Theory 225
16a. Fuzzy quantum field theories 225
16b. Fuzzy quantum electrodynamics based on common relativity 231
16c. Experimental tests of the 4-dimensional symmetry of special relativity at very high energies 235
17. Extended Relativity: A Weaker Postulate for the Speed of Light 240
17a. Four-dimensional symmetry as a guiding principle 240
17b. Edwards' transformation with Reichenbach's time 242
17c. Difficulties of Edwards' transformation 245
17d. Extended relativity: A 4-dimensional theory with Reichenbach's time (a universal 2-way speed of light) 247
17e. The two basic postulates of extended relativity 251
17f. Invariant action for a free particle in extended relativity 254
17g. Comparison of extended relativity and special relativity 256
17h. An unpassable limit and a non-constant speed of light 258
17i. Lorentz group and the space-lightime transformations 259
17j. Decay rate and "lifetime dilation" of unstable particles 261

(C) The Role of the Principle of Relativity in the Physics of Accelerated Frames 265

18. The Principle of Limiting Lorentz and Poincaré Invariance 267
18a. An answer to the young Einstein's question and its implications 267
18b. Generalizing Lorentz transformations from inertial frames to accelerated frames 271

18c. Physical time and 'spacetime clocks' in linearly accelerated frames 274
18d. Møller's gravitational approach to accelerated transformations 275
18e. Accelerated transformations with the limiting Lorentz and Poincaré invariance 279
19. Extended Lorentz Transformations for Frames with Constant-Linear-Accelerations 284
19a. Generalized Møller-Wu-Lee transformation 284
19b. Minimal generalization of the Lorentz transformation: The Wu transformations 288
19c. A comparison of the generalized MWL and Wu transformations 290
19d. Four-momentum and constant-linear-acceleration of an accelerated particle 292
19e. Experiments on Wu-Doppler effects of waves emitted from accelerated atoms 294
20. Physical Properties of Spacetime in Accelerated Frames 297
20a. A general transformation for a CLA frame with an arbitrary $\beta(w)$ 297
20b. The singular wall and horizons in the Wu transformation 300
20c. Generalized Møller-Wu-Lee transformation for an accelerated frame 305
20d. Decay-length dilations due to particle acceleration 310
20e. Discussions 314
21. Extended Lorentz Transformations for Accelerated Frames and a Resolution to the "Two-Spaceship Paradox" 319
21a. The two-spaceship paradox 319
21b. Generalized Møller and Wu transformations 321
21c. Motion and length contraction involving accelerations 324
21d. Discussion 326
22. Dynamics of Classical and Quantum Particles in Constant-Linear-Acceleration Frames 330
22a. Classical electrodynamics in constant-linear-acceleration frames 330
22b. Quantum particles and Dirac's equation in a CLA frame 334
22c. Stability of atomic levels against constant accelerations 336
22d. Electromagnetic fields produced by a charge with a constant-linear-acceleration 340
22e. Covariant radiative reaction force in special relativity and common relativity 349
23. Quantizations of Scalar, Spinor, and Electromagnetic Fields In Constant-Linear-Acceleration Frames 356
23a. Scalar field in constant-linear-acceleration frames 356
23b. Quantization of scalar fields in CLA frames 359
23c. Quantization of spinor fields in CLA frames 366
23d. Quantization of the electromagnetic field in CLA frames 373
24. Group and Lie Algebra Properties of Accelerated Spacetime Transformations 378
24a. The Wu transformation with acceleration in an arbitrary direction 378

24b. Generators of the Wu transformation in cotangent spacetime 380
24c. The Wu algebra in a modified momentum space and the classification of particles 384
25. Coordinate Transformations for Frames with a General-Linear Acceleration 389
25a. Spacetime transformations based on limiting Lorentz and Poincaré invariance 389
25b. Physical implications and discussion 396
26. A Taiji Rotational Transformation with Limiting 4-Dimensional Symmetry 402
26a. A smooth connection between rotational and inertial frames 402
26b. A taiji rotational transformation with limiting 4-dimensional symmetry 403
26c. Physical properties of the taiji rotational transformation 406
26d. The metric tensors for the spacetime of rotating frames 408
26e. The invariant action for electromagnetic fields and charged particles in rotating frames and truly fundamental constants 410
26f. The 4-momentum and the 'lifetime dilation' of a particle at rest in a rotating frame 412
27. Epilogue 416

(D) Appendices 423

A. Systems of Units and the Development of Relativity Theories 425
Aa. Units, convenience and physical necessity 425
Ab. Time, length and mass 426
Ac. Other SI base units 430
Ad. Other units 434
Ae. Status of the fundamental constants 434
Af. Discussion and conclusion 436
B. Can one Derive the Lorentz Transformation from Precision Experiments? 441
Ba. Introduction 442
Bb. Three classical tests of special relativity 443
Bc. Deriving the Lorentz transformation? 446
Bd. A more general form 455
Be. Discussions and conclusions 462
C. Quantum Electrodynamics in Both Linearly Accelerated and Inertial Frames 465
Ca. Quantum electrodynamics based on taiji relativity 465
Cb. Experimental measurements of dilations of decay-lengths and decay-lifetimes in inertial frames 470
Cc. Quantum electrodynamics of bosons in accelerated and inertial frames 470

Cd. Feynman rules for QED with fermions in both CLA and inertial frames 476
Ce. Some QED results in both CLA and inertial frames 478
D. Yang-Mills Gravity with Translation Gauge Symmetry in Inertial and Non-inertial Frames 483
Da. Translation gauge transformations and an 'effective metric tensor' in flat spacetime 483
Db. Yang-Mills theory with translation gauge symmetry 489
Dc. Gravitational action with quadratic gauge-curvature 490
Dd. Linearized equations of the tensor field and the Hamilton-Jacobi equation for particles 492
De. The gauge field equation in inertial and non-inertial frames 494
Df. Perihelion shifts and bending of light 498
Dg. The Yang-Mills gravitational force 504

Author Index 509
Subject Index 513