CONTENTS

| Preface | vii |
|--|-------|
| Table of Particles | xviii |
| Notation | xix |
| Chapter 1. Basic Notions. Coordinate Transformations. Special Relativity. Accelerated Reference Frames | 1 |
| 1-1. Basic Notions Particle Rigid Body Reference Frame Coordinate System Clock Momentum Mass Force Energy | 3 |
| 1-2. Inertial Reference Frames | 13 |
| 1-3. Coordinate Transformations Within a Reference Frame Covariance Homogeneity and Isotropy of Space | 16 |

| 1-4. Transformations Between Inertial Frames: Special Relativity The Principle of Special Relativity The Galileo Transformation | 26 |
|---|----|
| Galileo Transformation Between Inertial Frames | |
| Galilean Invariance of Instantaneous Action at a Distance Force | |
| Breakdown of Galilean Invariance in the Electromagnetic Interaction The Lorentz Transformation | |
| 1-5. Earthbound Reference Frame and Inertial Frames Inertial Forces Weightlessness in a Freely Falling Laboratory Relation Between Earth Frame and Inertial Frames | 38 |
| Problems | 46 |

| Chapter 2. The Lorentz Transformation and the Kinematics of a Particle | 48 |
|---|-----|
| 2-1. The Postulates of Special Relativity | 48 |
| 2-2. The Location of Events in Space and Time | 54 |
| 2-3. The Lorentz Transformation | 58 |
| 2-4. Intervals | 75 |
| 2-5. Proper Time and Proper Length; Time Dilation and Length Contraction | 80 |
| 2-6. Minkowski's Hyperbolic Graph | 86 |
| 2-7. Tests of the Einstein Dilation; the Twin "Paradox" | 94 |
| 2-8. Transformation of Velocity | 104 |
| 2-9. Spacetime | 111 |
| 2-10. Spacetime Description of Particle Motion: Four-Velocity, Four-Acceleration | 118 |
| 2-11. Uniform Longitudinal Acceleration | 124 |
| 2-12. Constant Transverse Acceleration | 127 |
| Problems | 130 |

CONTENTS

| Chap | ter 3. Dynamics of a Particle | 136 |
|-------|--|-----|
| 3-1. | The Law of Motion for a Charged Particle | 136 |
| 3-2. | Interaction Between Charged Particles Moving with the Same Velocity | 143 |
| 3-3. | Dynamics Based on Momentum Conservation | 146 |
| 3-4. | Covariant Equation of Motion of a Charged Particle | 152 |
| 3-5. | Energy, Momentum, and Velocity | 155 |
| 3-6. | Four-Momentum | 159 |
| 3-7. | General Covariant Equation of Motion | 166 |
| 3-8. | Momentum Space and Momentum Distributions. Cross Sections | 168 |
| 3-9. | Motion of a Charged Particle in a Constant Electromagnetic Field Charged Particle in Magnetic Field Charged Particle in a Coulomb Field (Hydrogenic Atom) | 182 |
| Probl | lems | 197 |
| Chap | ter 4. Transitions of a System. Conservation of Four-Momen- tum. The Mass-Energy Relation. Relativistic Kinematics | 202 |
| 4-1. | Scattering Processes | 202 |
| 4-2. | Relativistic Units | 204 |
| 4-3. | Four-Momentum of a Complex System. Inertia of Energy | 207 |
| 4-4. | Conservation of Four-Momentum | 214 |
| 4-5. | Rest Energy. Nonconservation of Proper Mass | 217 |
| 4-6. | Radiative Transitions | 218 |
| 4-7. | Two-Body Final State, both of Zero Proper Mass | 225 |
| 4-8. | Two-Body Final State: General Case | 227 |
| 4-9. | Two-Body Initial State (Binary Collisions) One-Body Final State Elastic Scattering Inelastic Scattering, Two-Body Final State | 231 |

| CONTENTS |
|----------|
|----------|

| | Inelastic Scattering, the General Case. Thresholds | 250 |
|-------|---|-----|
| 4-10. | Relativistic Kinematics | 250 |
| Probl | ems | |
| | | |
| Chapt | ter 5. Successive Lorentz Transformations. Motion of Spin | 258 |
| 5-1. | Transformation Matrices in Spacetime | 258 |
| 5-2. | Composition of Reference-Frame Transformations Composition of Parallel Lorentz Transformations The Velocity Parameter ("Rapidity") α and its Hyperbolic Functions Composition of Lorentz Transformations in Different Directions | 264 |
| 5-3. | Spin: Kinematics Turning of Spin and Velocity in a Pure Lorentz Transformation Thomas Precession | 281 |
| 5-4. | Dynamics of Spin Motion in a Transverse Magnetic Field. "g-2" Experiments Motion in a Transverse Electric Field (Spin-Orbit Interaction) Equation of Motion of Four-Spin | 291 |
| Probl | ems | 304 |
| | | |
| Chap | ter 6. Principle of Equivalence. Motion in a Weak Gravitational Field | 309 |
| 6-1. | The Principle of Equivalence | 309 |
| 6-2. | The Effect of a Gravitational Field on Clocks and Measuring Rods | 311 |
| 6-3. | The Gravitational Red Shift | 316 |
| 6-4. | Free Fall of a Material Particle Motion Parallel to Field Motion Perpendicular to Field The General Case | 320 |

Problems

CONTENTS

| Appendix A Transformation Properties of Vectors. Tensors. Polar and Axial Vectors Rotation of Cartesian Axes Inversion of Cartesian Axes Polar and Axial Vectors | 327 327 333 336 |
|--|---------------------------------|
| Appendix B Galilean Kinematics of Accelerated Reference Frames Analysis of Motion into Translation and Rotation Motion of the Basis Vectors Transformation Equations for the Velocity and Acceleration of a Particle | 341 341 345 346 |
| Appendix C Detectable Effects of the Earth's Rotation with Respect to Inertial Frames | 351 |
| Appendix D Transformation Law of Charge and Electromagnetic Field | 355 |
| Appendix E The Constant of Integration in the Expression for the Energy of a Particle | 360 |
| Appendix F Doppler Effect | 362 |
| References | 366 |
| Index | 370 |