

Contents

<i>Preface</i>	page xi
----------------	---------

Part I Fundamentals

1	From Pythagoras to spacetime geometry	3
1.1	Pythagoras and the measurement of space	4
1.2	The differential version, in D dimensions	9
1.3	Rotations preserve the Euclidean metric	10
1.4	Infinitesimal rotations	12
1.5	Could a line element include time?	14
1.6	The Lorentz transformation	17
2	Light surprises everyone	21
2.1	Conflicting ideas about space and light	22
2.2	Maxwell's transverse undulations	25
2.3	Galilean relativity and the ether	28
2.4	The Michelson–Morley experiment	31
2.5	Einstein ponders electromagnetism and relativity	36
2.6	Einstein's two postulates	37
2.7	From light waves to spacetime geometry	46
3	Elements of spacetime geometry	55
3.1	Space and spacetime	55
3.2	Vectors on a manifold	67
3.3	Vectors in spacetime	75
3.4	Tensors and forms	83
3.5	The Principle of Relativity as a geometric principle	89
4	Mechanics in spacetime	95
4.1	Equations of motion in spacetime	95

4.2	Momentum and energy in spacetime	101
4.3	Energy and momentum conservation in spacetime	105
4.4	Relativistic kinematics	109
4.5	Fission, fusion, and $E = Mc^2$	119
4.6	Rigid body mechanics	123
5	Spacetime physics of fields	127
5.1	What is a field?	128
5.2	Differential calculus in spacetime	132
5.3	Integral calculus in spacetime	146
5.4	Continuous systems in spacetime	156
5.5	Electromagnetism	169
5.6	What about the gravitational field?	189
6	Causality and relativity	197
6.1	What is time?	197
6.2	Causality and spacetime	205
Part II Advanced Topics		219
7	When quantum mechanics and relativity collide	221
7.1	Yet another surprise about light	222
7.2	The Schrödinger equation is not covariant	225
7.3	Some new ideas from the Klein–Gordon equation	231
7.4	The Dirac equation and the origin of spin	233
7.5	Relativity demands a new approach	242
7.6	Feynman diagrams and virtual particles	251
8	Group theory and relativity	260
8.1	What is a group?	260
8.2	Finite and infinite groups	267
8.3	Rotations form a group	270
8.4	Lorentz transformations form a group	277
8.5	The Poincaré group	282
9	Supersymmetry and superspace	287
9.1	Bosons and fermions	289
9.2	Superspace	293
9.3	Supersymmetry transformations	297
9.4	$\mathcal{N} = 1$ supersymmetry in four dimensions	302
9.5	Massless representations	306

Looking onward	312
10.1 Relativity and gravity	312
10.2 The standard model of elementary particle physics	320
10.3 Supersymmetry	323
10.4 The relativistic string	331
10.5 Superstrings	338
10.6 Recent developments in superstring theory	340
10.7 Problems and prospects	344
Appendix 1 Where do equations of motion come from?	349
Appendix 2 Basic group theory	359
Appendix 3 Lie groups and Lie algebras	362
Appendix 4 The structure of super Lie algebras	365
<i>References</i>	367
<i>Index</i>	369