

Contents

<i>Preface</i>	<i>page</i>	xi
<i>Acknowledgements</i>		xv
<i>Aims</i>		xvi
1 Introduction		1
1.1 The Basic Ideas		1
1.2 Events		3
1.3 Inertial Reference Frames		3
1.4 Simultaneity: Measuring Times		7
1.5 Simultaneity: Measuring Lengths		9
1.6 The Clock Hypothesis		10
1.7 Standard Configuration		12
1.8 Further Reading		13
Exercises		16
2 The Axioms		18
2.1 The First Postulate: the Principle of Relativity		18
2.2 The Second Postulate: the Constancy of the Speed of Light		27
Exercises		29
3 Length Contraction and Time Dilation		32
3.1 Simultaneity		32
3.2 Length Contraction and Time Dilation, Qualitatively		34
3.3 The Light Clock		37
3.4 The Horizontal Light Clock: Length Contraction		40
3.5 Is There Anything I Can Hold on To?		42
Exercises		43
4 Spacetime and Geometry		45
4.1 Natural Units		46
4.2 The Minkowski Diagram		50

viii

4.3	Plane Rotations	55
4.4	The Invariant Interval	56
4.5	Changes of Frame, and Perspective	61
4.6	Length and Time in the Minkowski Diagram	63
4.7	Worldlines and Causality	66
	Exercises	68
5	The Lorentz Transformation	72
5.1	The Derivation of the Lorentz Transformation	72
5.2	Addition of Velocities	75
5.3	The Invariant Interval and the Geometry of Spacetime	77
5.4	Proper Time and the Invariant Interval	78
5.5	Applications of the Lorentz Transformation	79
5.6	The Equations of Special Relativity in Physical Units	83
5.7	Paradoxes	84
5.8	Some Comments on the Lorentz Transformation	93
	Exercises	98
6	Vectors and Kinematics	103
6.1	Three-Vectors	103
6.2	Four-Vectors	105
6.3	Velocity and Acceleration	110
6.4	Velocities and Tangent Vectors	114
6.5	The Frequency Vector, and the Doppler Shift	115
	Exercises	118
7	Dynamics	125
7.1	Energy and Momentum	125
7.2	Photons	131
7.3	Relativistic Collisions and the Centre-of-Momentum Frame	132
7.4	But Where's This Mass Coming From?	136
7.5	More Unit Fun: an Aside on Electron-volts	137
7.6	Relativistic Force	138
7.7	An Example: Compton Scattering	139
7.8	Not The End	140
	Exercises	141
	<i>Appendix A</i> An Overview of General Relativity	145
A.1	Some Thought Experiments on Gravitation	146
A.2	Geometry	153
A.3	Gravity	160
A.4	Solutions of Einstein's Equation	163

<i>Appendix B</i> Relativity's Contact with Experimental Fact	177
B.1 Special Relativity	178
B.2 General Relativity: Classical and Post-classical Tests	183
B.3 A Closer Look at the 1919 Eclipse Observations	186
<i>Appendix C</i> Maths Revision	194
C.1 Complex Numbers	194
C.2 The Hyperbolic Functions	196
C.3 Linear Algebra	198
<i>Appendix D</i> How to Do Calculations: a Recipe	200
D.1 Key Things to Remember	200
D.2 A Checklist for Relativity Problems	200
D.3 Which Equation When?	202
D.4 Rest, Moving and Stationary Frames: Be Careful!	203
D.5 Length Contraction, Time Dilation, and 'Rest Frames'	204
<i>References</i>	205
<i>Index</i>	211