relativity

DeMYSTiFieD

A SELF-TEACHING GUIDE



Take the WARP out of the SPACE/TIME CONTINUUM!



LEARN a complex subject via HUNDREDS of SIMPLE examples



Get both the MATH and the PHYSICS of relativity



Find PRACTICAL TOOLS for problem-solving



David McMahon



	Preface	xi
CHAPTER 1	A Quick Review of Special Relativity	1
	Frame of Reference	5
	Clock Synchronization	5
	Inertial Frames	6
	Galilean Transformations	7
	Events	7
	The Interval	8
	Postulates of Special Relativity	9
	Three Basic Physical Implications	13
	Light Cones and Spacetime Diagrams	17
	Four Vectors	19
	Relativistic Mass and Energy	20
	Quiz	21
CHAPTER 2	Vectors, One Forms, and the Metric	23
	Vectors	23
	New Notation	25
	Four Vectors	27
	The Einstein Summation Convention Tangent Vectors, One Forms, and the	28
	Coordinate Basis	29
	Coordinate Transformations	31

	The Metric	32
	The Signature of a Metric	36
	The Flat Space Metric	37
	The Metric as a Tensor	37
	Index Raising and Lowering	38
	Index Gymnastics	41
	The Dot Product	42
	Passing Arguments to the Metric	43
	Null Vectors	45
	The Metric Determinant	45
	Quiz	45
CHAPTER 3	More on Tensors	47
	Manifolds	47
	Parameterized Curves	49
	Tangent Vectors and One Forms, Again	50
	Tensors as Functions	53
	Tensor Operations	54
	The Levi-Cevita Tensor	59
	Quiz	59
CHAPTER 4	Tensor Calculus	60
	Testing Tensor Character	60
	The Importance of Tensor Equations	61
	The Covariant Derivative	62
	The Torsion Tensor	72
	The Metric and Christoffel Symbols	72
	The Exterior Derivative	79
	The Lie Derivative	81
	The Absolute Derivative and Geodesics	82
	The Riemann Tensor	85
	The Ricci Tensor and Ricci Scalar	88
	The Weyl Tensor and Conformal Metrics	90
	Quiz	91

CHAPTER 5	Cartan's Structure Equations Introduction	93 93
B.	Holonomic (Coordinate) Bases	93 94
	Nonholonomic Bases	95
	Commutation Coefficients	96
	Commutation Coefficients and Basis One Forms	
	Transforming between Bases	98 100
	A Note on Notation	100
	Cartan's First Structure Equation and the Ricci Rotation Coefficients	
		104
	Computing Curvature Quiz	112
	Quiz	120
CHAPTER 6	The Einstein Field Equations	122
	Equivalence of Mass in Newtonian Theory	123
	Test Particles	126
	The Einstein Lift Experiments	126
	The Weak Equivalence Principle	130
	The Strong Equivalence Principle	130
	The Principle of General Covariance	131
	Geodesic Deviation	131
	The Einstein Equations	136
	The Einstein Equations with Cosmological	
	Constant	138
	An Example Solving Einstein's Equations	
	in $2+1$ Dimensions	139
	Energy Conditions	152
	Quiz	152
CHAPTER 7	The Energy-Momentum Tensor	155
	Energy Density	156
	Momentum Density and Energy Flux	156
	Stress	156
	Conservation Equations	157

	Dust	158
	Perfect Fluids	160
	Relativistic Effects on Number Density	163
	More Complicated Fluids	164
	Quiz	165
CHAPTER 8	Killing Vectors	167
	Introduction	167
	Derivatives of Killing Vectors	177
	Constructing a Conserved Current	
	with Killing Vectors	178
	Quiz	178
CHAPTER 9	Null Tetrads and the Petrov	
Clini int	Classification	180
	Null Vectors	182
	A Null Tetrad	184
	Extending the Formalism	190
	Physical Interpretation and the Petrov	
	Classification	193
	Quiz	201
CHAPTER 10	The Schwarzschild Solution	203
	The Vacuum Equations	204
	A Static, Spherically Symmetric Spacetime	204
	The Curvature One Forms	206
	Solving for the Curvature Tensor	209
	The Vacuum Equations	211
	The Meaning of the Integration Constant	214
	The Schwarzschild Metric	215
	The Time Coordinate	215
	The Schwarzschild Radius	215
	Geodesics in the Schwarzschild Spacetime Particle Orbits in the Schwarzschild	216
	Spacetime	218

	The Deflection of Light Rays	224
	Time Delay	229
	Quiz	230
CHAPTER 11	Black Holes	233
	Redshift in a Gravitational Field	234
	Coordinate Singularities	235
	Eddington-Finkelstein Coordinates	236
	The Path of a Radially Infalling Particle	238
	Eddington-Finkelstein Coordinates	239
	Kruskal Coordinates	242
	The Kerr Black Hole	244
	Frame Dragging	249
	The Singularity	252
	A Summary of the Orbital Equations	
	for the Kerr Metric	252
	Further Reading	253
	Quiz	254
CHAPTER 12	Cosmology	256
	The Cosmological Principle	257
	A Metric Incorporating Spatial	
	Homogeneity and Isotropy	257
	Spaces of Positive, Negative, and	
	Zero Curvature	262
	Useful Definitions	264
	The Robertson-Walker Metric and the	
	Friedmann Equations	267
	Different Models of the Universe	271
	Quiz	276
CHAPTER 13	Gravitational Waves	279
	The Linearized Metric	280
	Traveling Wave Solutions	284
	The Canonical Form and Plane Waves	287

The Benavior of Particles as a	
Gravitational Wave Passes	291
The Weyl Scalars	294
Review: Petrov Types and the	
Optical Scalars	295
pp Gravity Waves	297
Plane Waves	301
The Aichelburg-Sexl Solution	303
Colliding Gravity Waves	304
The Effects of Collision	311
More General Collisions	312
Nonzero Cosmological Constant	318
Further Reading	321
Quiz	322
Final Exam	323
Quiz and Exam Solutions	329
References and Bibliography	333
Index	

The Robavier of Particles as a