Preface .		VII
Chapter	I. ESSENTIAL TENSOR FORMULAE FOR RIE- MANNIAN SPACE-TIME	
1.	The metric tensor and admissible coordinates	1
2.	Derivatives and geodesics	3
3.	Orthonormal tetrads and Frenet-Serret formulae	8
4.	Parallel transport and Fermi-Walker transport	12
5.	The tensors of Riemann, Ricci and Einstein	15
6.	The deviation of geodesics	19
7.	Hamiltonian theory of rays and waves	25
8.	Gaussian coordinates	35
9.	Junction conditions across a 3-space of discontinuity.	39
10.	Theorems of Stokes and Green	41

# Chapter II. THE WORLD-FUNCTION $\mathcal{Q}$

1.	The world-function $\Omega$ and its covariant derivatives as	
	a two-point invariant and two-point tensors	47
2.	Coincidence limits	51
3.	Evaluation of the second derivatives of the world-	
	function by use of the parallel propagator	57
4.	Evaluation of the covariant derivatives of the parallel	
	propagator	64
5.	Evaluation of the higher derivatives of the world-	
	function $\ldots$	67
6.	Solution of finite geodesic triangles in space-time of	
	small curvature	70
7.	Solution of small geodesic triangles	73
8.	Quasi-Cartesian coordinates	76
9.	Changing the origin of quasi-Cartesian coordinates .	81
10.	Fermi coordinates and optical coordinates	83
11.	Metrics for Fermi coordinates and optical coordinates	87

12.	Geodesics in terms of Fermi coordinates and optical	~ ~
13.	The world-function and its derivatives for two points	91
	on a timelike curve	95
14.	The world-function in terms of Fermi coordinates for	
	two points on adjacent timelike curves	100
Chapter	III. CHRONOMETRY IN RIEMANNIAN SPACE-	
	TIME	
1.	Natural observations (NO) and mathematical ob-	
_	servations (MO)	103
2.	Chronometry and the Riemannian hypothesis	105
3.	The geodesic hypothesis	109
4. F	Spatial measure, orthogonality, and scalar products.	112
5. 4	The measurement of direction	114
0. 7	Relative velocity and the Doppler effect	110
8	Fermi transport and the bouncing photon	123
9	The falling apple	132
10.	The ballistic suicide problem	141
11.	Statical measurement of gravitational fields	144
12.	Fermi-Walker transport along a spacelike curve and its	
	physical meaning	150
13.	The physical meaning of absolute differentiation and	
	the systematic measurement of gravitational fields $% \left( {{{\left[ {{{\left[ {{{\left[ {{{c}} \right]}} \right]_{{{\rm{c}}}}}}} \right]}_{{{\rm{c}}}}}} \right)$	156
Chapter	IV. THE MATERIAL CONTINUUM	
1.	A statistical model	159
2.	Conservation laws in the statistical model	165
3.	Kinematics of a continuum	169
4.	The energy tensor of a continuum	173
5.	The field equations and the Newtonian comparison $\ .$	179
6.	Survey of field equations and coordinate conditions .	184
7.	Note on the motion of an isolated body	194
Chapter	V. SOME PROPERTIES OF EINSTEIN FIELDS	
1.	The basic formula for retarded or advanced potential	200
2.	The linear approximation $\ldots$ $\ldots$ $\ldots$ $\ldots$	202

XIII

3. A statical Einstein field with embedded bodies	205
4. Two lemmas	211
5. The Cauchy problem in normal Gaussian coordinates .	213
6. The Cauchy problem in normal Gaussian coordinates	
for a perfect fluid	218
7. Characteristics and shock waves	223
N N N N N N N N N N N N N N N N N N N	
CHAPTER VI. INTEGRAL CONSERVATION LAWS AND	
EQUATIONS OF MOTION	
1. The concept of integral conservation laws	229
2. Integral conservation laws based on the Einstein	
tensor	232
3. Space-time admitting a group of motions.	234
4. Integral conservation laws based on the Riemann	
tensor	237
5. Space-time viewed from the Euclidean standpoint	243
6. Equations of motion for an isolated body	246
7. The pseudo-tensor. $\ldots$ $\ldots$ $\ldots$	252
CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY	
CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY 1. Space-time of constant curvature (de Sitter universe)	256
CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY <ol> <li>Space-time of constant curvature (de Sitter universe)</li> <li>Metric forms for spherical symmetry</li></ol>	256 265
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY</li> <li>1. Space-time of constant curvature (de Sitter universe)</li> <li>2. Metric forms for spherical symmetry</li></ul>	256 265 270
CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY <ol> <li>Space-time of constant curvature (de Sitter universe)</li> <li>Metric forms for spherical symmetry</li></ol>	256 265 270 274
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY</li> <li>1. Space-time of constant curvature (de Sitter universe)</li> <li>2. Metric forms for spherical symmetry</li> <li>3. Various formulae for spherical symmetry</li> <li>4. The exterior Schwarzschild field</li> <li>5. The complete field of a spherically symmetric distri-</li> </ul>	256 265 270 274
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY</li> <li>1. Space-time of constant curvature (de Sitter universe)</li> <li>2. Metric forms for spherical symmetry</li></ul>	256 265 270 274 278
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY</li> <li>1. Space-time of constant curvature (de Sitter universe)</li> <li>2. Metric forms for spherical symmetry</li></ul>	256 265 270 274 278 281-
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY</li> <li>1. Space-time of constant curvature (de Sitter universe)</li> <li>2. Metric forms for spherical symmetry</li> <li>3. Various formulae for spherical symmetry</li> <li>4. The exterior Schwarzschild field</li> <li>5. The complete field of a spherically symmetric distribution of matter</li></ul>	256 265 270 274 278 281-
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY</li> <li>1. Space-time of constant curvature (de Sitter universe)</li> <li>2. Metric forms for spherical symmetry</li> <li>3. Various formulae for spherical symmetry</li> <li>4. The exterior Schwarzschild field</li> <li>5. The complete field of a spherically symmetric distribution of matter</li></ul>	256 265 270 274 278 281- 285
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY <ol> <li>Space-time of constant curvature (de Sitter universe)</li> <li>Metric forms for spherical symmetry</li></ol></li></ul>	256 265 270 274 278 281- 285 289
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY <ol> <li>Space-time of constant curvature (de Sitter universe)</li> <li>Metric forms for spherical symmetry</li> <li>Various formulae for spherical symmetry</li> <li>The exterior Schwarzschild field</li></ol></li></ul>	256 265 270 274 278 281- 285 289 298
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY <ol> <li>Space-time of constant curvature (de Sitter universe)</li> <li>Metric forms for spherical symmetry</li> <li>Various formulae for spherical symmetry</li> <li>The exterior Schwarzschild field</li></ol></li></ul>	256 265 270 274 278 281- 285 289 298
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY <ol> <li>Space-time of constant curvature (de Sitter universe)</li> <li>Metric forms for spherical symmetry</li> <li>Various formulae for spherical symmetry</li> <li>The exterior Schwarzschild field</li> <li>The complete field of a spherically symmetric distribution of matter</li></ol></li></ul>	256 265 270 274 278 281- 285 289 298
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY <ol> <li>Space-time of constant curvature (de Sitter universe)</li> <li>Metric forms for spherical symmetry</li></ol></li></ul>	256 265 270 274 278 281- 285 289 298 309
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY <ol> <li>Space-time of constant curvature (de Sitter universe)</li> <li>Metric forms for spherical symmetry</li></ol></li></ul>	256 265 270 274 278 281- 285 289 298 309 317
<ul> <li>CHAPTER VII. FIELDS WITH SPHERICAL SYMMETRY <ol> <li>Space-time of constant curvature (de Sitter universe)</li> <li>Metric forms for spherical symmetry</li></ol></li></ul>	256 265 270 274 278 281- 285 289 298 309 317 322

XIV

# CHAPTER IX. GRAVITATIONAL WAVES

1.	Plane gravitational waves	343
2.	The world-function for a plane gravitational wave and	
	quasi-Cartesian coordinates	347
3.	A particular plane gravitational wave and remarks on	
	cylindrical and spherical waves	350

## CHAPTER X. ELECTROMAGNETISM

electromagnetic energy
coherent charged fluid . 360
ems
and the  for an inc etic theor 

# CHAPTER XI. GEOMETRICAL OPTICS

1.	Wave-kinematics in space-time	•	•	•	372
2.	Waves, rays and photons in a dispersive medium	•	•	•	375
З.	Variational principles in geometrical optics	•	•		380
4.	Geometrical optics in a static universe	•	•	•	386
5.	Astronomical observations	•	•		390
6.	Stellar aberration	•	•		393
7.	Differential chronometry	•	•	•	401
8.	A five-point curvature detector	•	•	•	408
9.	Spectral shift in a continuum	•		•	411

## APPENDIX

А.	A. Notation		415
В.	3. Numerical values of some phy	vsical quantities expressed	
	in seconds		421
Bil	Bibliography		427
Ind	ndex		491