Table of Contents

Chap	oter 1. Introduction	1
§ 1.	On the Beginning of Relativity	1
§ 2.	The Space-Time Structure of Special Relativity and First Basic	
0	Consequences	2
§ 3.	On the Operational Aspect of Physical Concepts	4
§ 4.	New Ideas on Mass and Energy, in Contrast with Classical Physics,	
	Accepted on the Basis of Special Relativity Kinematics	5
§ 5.	On Forces, Cauchy Equations of Continuous Media, and the First	
	Principle of Thermodynamics in Special Relativity	7
§ 6.	On Electromagnetism, Heat Conduction, and Constitutive Equations	
	in Special Relativity	9
	Gravitation and Relativity	10
§ 8.	On the Local Equivalence Principle and the Basic Local Laws of the	
	Electromagnetic Field and Continuous Media, Other than the Poisson	
	Equation, in General Relativity. A Criterion Connecting those Laws	
	with Their Analogues in Classical Physics or Special Relativity	13
§ 9.	On the Invariance of Physical Equations and on the Possible Physical	
	Equivalence of the Frames in which these Equations have the Same	
	Form. On a Privileged Absolute Concept of Event Point	16
§ 10.	On Harmonic Coordinates and the Existence of General Frames not	
	Physically Equivalent in General Relativity	19
§ 11.	Some Distinctive Properties of General Relativity. On the Equivalence	
	of General Frames in General Relativity	20
	What We Mean by General Theory of Relativity	23
§ 13.	On the Development of General Relativity. Inclusion of Elasticity,	
A 4 -	Electromagnitostriction, Couple Stresses, and Hereditary Phenomena	25
	Scope and Plan of the Present Tract	27
Foot	tnotes to Chapter 1	28

Part I. Basic Equations of Gravitation, Thermodynamics and Electromagnetism, and Constitutive Equations from the Eulerian Point of View

Chap	oter 2. Space-Time Kinematics Including Masses	35
§ 15.	On the Riemannian Relativistic Space-Time Metric Introduced as a Chronometry. Admissible Frames. Some Possible Axioms for Non-	
	Cosmological Relativity	35
	On Tensors in Relativistic Space-Time On Tensors in S_4 in Connection with a Moving Continuous Body \mathscr{C} or an Ideal Fluid \mathfrak{F} . Spatial Projections and Natural Decompositions of	39
§ 18.	Tensors, Spatial Derivatives and Spatial Divergences	40
§ 19.	metry ds^2 . Ordinary Units	44 46
§ 20.	Material Derivatives, the Spatial Ricci Tensor, and the Relative Rate of Change of Proper Volume Dealt with from the Eulerian Point of View	50
§ 21.	On Gravitational Mass and Reference or Conventional Mass. The Con- tinuity Equation	53
§ 22.	Angular and Deformation Velocities. Convected and Co-Rotational Fluxes. On $T_{\alpha\beta}^{\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $	56
Foot	$\begin{array}{c} \text{finites of } \alpha_{\alpha\beta} & \text{for } \alpha_{[\alpha\beta]} & \text{or } \alpha_{[\alpha\beta]} $	58
Char	oter 3. Gravitation and Conservation Equations. Fluids and Elastic	
Wav		60
§ 23.	The Einstein Gravitation Equations and Basic Consequences	
		60
§ 24.	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem	60 61
§ 24.	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry	61
§ 24. § 25.	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient	61 63
 § 24. § 25. § 26. § 27. 	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient	61
 § 24. § 25. § 26. § 27. 	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient On the Paradox of an Infinite Velocity of Heat Propagation from the Classical Point of View and the Relativistic One On the Local Spatial Physical Isotropy of S_4	61 63 69
 § 24. § 25. § 26. § 27. § 27. § 28. 	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient	61 63 69 75 77
 § 24. § 25. § 26. § 27. § 28. § 29. 	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient	61 63 69 75
 § 24. § 25. § 26. § 27. § 28. § 29. 	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient On the Paradox of an Infinite Velocity of Heat Propagation from the Classical Point of View and the Relativistic One On the Local Spatial Physical Isotropy of S_4	 61 63 69 75 77 80
 § 24. § 25. § 26. § 27. § 28. § 29. § 30. 	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient On the Paradox of an Infinite Velocity of Heat Propagation from the Classical Point of View and the Relativistic One On the Local Spatial Physical Isotropy of S_4	 61 63 69 75 77 80 81
 § 24. § 25. § 26. § 27. § 28. § 29. § 30. § 31. 	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient On the Paradox of an Infinite Velocity of Heat Propagation from the Classical Point of View and the Relativistic One On the Local Spatial Physical Isotropy of S_4	 61 63 69 75 77 80 81 84
 § 24. § 25. § 26. § 27. § 28. § 29. § 30. § 31. § 32. 	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient On the Paradox of an Infinite Velocity of Heat Propagation from the Classical Point of View and the Relativistic One On the Local Spatial Physical Isotropy of S_4	 61 63 69 75 77 80 81
 § 24. § 25. § 26. § 27. § 28. § 29. § 30. § 31. § 32. § 33. 	The Case of Interacting Matter Capable of Heat Conduction On the Second Principle of Thermodynamics, the Clausius-Duhem Inequality and Fourier's Law. A Relativistic Proof of the Symmetry of the Heat Conduction Coefficient On the Paradox of an Infinite Velocity of Heat Propagation from the Classical Point of View and the Relativistic One On the Local Spatial Physical Isotropy of S_4	 61 63 69 75 77 80 81 84

·	ter 4. Electromagnetism from the Eulerian Point of View. Polarizable	90
0	Introductory Considerations. The Ohm Law and the Relations Between the Electric and Magnetic Fields and the Respective Inductions On the Maxwell Equations in Space Time	90 93
§ 36.	On the Electromagnetic Energy Tensor $E_{\alpha\beta}$. Some Requirements for it in the Absence of Polarization. Its Indeterminancy in the Presence of	
§ 37.	Polarization	97
	Tensor $E_{\alpha\beta}$ and Some Instances of $E^{\alpha\beta}_{\beta}$	99 102
0	Some Uniqueness Properties of the Electromagnetic Energy Tensor $E_{\alpha\beta}$. On Its Arbitrariness in Connection with Heat Conduction	105
§ 40.	Some Historical Hints. Basic General Energetic Properties of Min- kowski's Tensor and the Instances ${}^{5}E_{\alpha\beta}$ to ${}^{7}E_{\alpha\beta}$ of $E_{\alpha\beta}$	108
	Some Versions of Poynting's Theorem for Moving Media	112
	W as the Proper Density of Non-Material Electromagnetic Energy On the Equations of Gravitation and Energy Balance in the Presence of	113
Foot	Electromagnetic Phenomena	115 116
Char	oter 5. On Media Capable of Electromagnetic Phenomena from the	
Chap	Eulerian Point of View. Magneto-Elastic Waves in Ideal Conductors	118
	Introduction	118
	Black Body and Absolute Temperature in Thermodynamic Equilibrium	119
U	Polarizable Non-Viscous Fluids	121
	Polarizable Viscous Fluid	125
§ 48.	The Cauchy Equations in the Presence of Heat Conduction and an	400
§ 49.	Electromagnetic Field; Preliminaries for Ideal Conductors Dynamic Discontinuity Equations for Magneto-Elastic Acceleration	128
	Waves in Magnetizable Fluids	129
§ 50.	Magneto-Elastic Acceleration Waves in Magnetizable Non-Viscous	
	Fluids	131
Foot	notes to Chapter 5	134

Part II. Materials from the Lagrangian Point of View

Chap	ter 6. Kinematics and Stresses from the Lagrangian Point of View	137
§ 51.	Historical Hints at Relativistic Theories of Elastic and More General	
	Materials	137
§ 52.	On the Representation of the Motion \mathcal{M} of \mathscr{C}	138
§ 53.	Lagrangian Spatial Derivative and Absolute Derivative of a Double	
	Tensor Field with Respect to the Motion \mathcal{M} of \mathscr{C}	141

§ 54.	Polar Decomposition of the Position Gradient α_L^{ρ} and Principal	
	Axes of Strain	144
	Fermi Transport	147
§ 56.	On the Dilation Coefficients for Line, Volume, and Surface Elements,	
	and the Ratio dC/dC^*	148
§ 57.	The Vectors V_L^* and V_*^L for V_ρ Spatial. Expressions of $\dot{\alpha}_L^\rho$ and \dot{C}_{LM} in	
	Terms of $u_{\rho/\sigma}$	152
§ 58.	New Determination of the General Solution for the Continuity	
	Equation. Connection of $D^c V_{\rho}$ and $D_c V_{\rho}$ with DV_*^L and DV_L^* for V_{ρ}	
	Spatial, and Lagrangian Expression for the Electromagnetic Work $d_3\lambda$	153
§ 59.	The First and Second Piola-Kirchhoff Stress Tensors $K^{\rho M}$ and Y^{LM} ,	
0.00	and Lagrangian Expressions for $dl^{(i)}$	155
§ 60.	Connection Between $X^{\rho\sigma_{\downarrow}}_{\sigma}$ and $K^{\rho M}_{M}$	156
	On α_{LM}^{ρ} and the Lagrangian Expression of $\overline{g}_{\lambda}^{\rho} X_{J\sigma}^{2\sigma_{\perp}}$	158
§ 62.	Explicit Form in Co-Moving Co-Ordinates for Some of the Preceding	
F (Lagrangian Formulas	159
Foot	notes to Chapter 6	162
Char	pter 7. Elasticity, Acceleration Waves, and Variational Principles for	
	ble Materials	164
§ 63.	Foundations of Elasticity	164
-	Some Theorems on Elastic Materials	166
	On Discontinuity Surfaces in Space-Time	
	Dynamic Equations of Elastic Acceleration Waves	
	Polarization and Inertial-Mass Quadrics. Acoustic Axes	
	Pure Pressure States. Isotropic Elastic Materials. Comparison with the	
	Classical Theory	176
§ 69.	A Principle Concerning the Variation of the Metric Tensor of	
	Riemannian Space-Time in the Adiabatic Elastic Case	179
	Variation of World Lines in the Adiabatic Elastic Case	182
Foo	tnotes to Chapter 7	187
Char	pter 8. Piezo-Elasticity and Magnetoelastic Waves from the Lagrangian	
	t of View	188
0	Introduction	188
872.	Extension of the Operations $T \dots \rightarrow T^* \dots T^* \longrightarrow T^*_*, D^c$ and D_c to	188
g 75.	Tensors of Arbitrary Order $\dots \dots \dots$	190
8 74	On Rigid Motions in the Born Sense	190
	Born Rigidity and Stationary Tensors	192
	Some Invariance Properties of Ideal Conductors	
	Dynamic Equations for Piezo-Elastic Ideal Conductors	197
	Magneto-Elastic Acceleration Waves in Piezo-Elastic Ideal Conductors	200
-	tnotes to Chapter 8	202
	-	
-	pter 9. Materials with Memory and Axiomatic Foundations	203
§ 79.	Introduction to a Relativistic Theory of Materials with Memory	203

Table of Contents

0	Intrinsic Kinematic Histories. Total Geodesic Derivatives A Relativistic Version of the Principle of Material (Frame) Indifference	204 207
	Some Consequences of the Principle of Material Indifference	212
0	On the Axiomatic Foundations of the Preceding Theory. Primitive	
3	Notions and First Axioms	216
8 84	On Kinematic Axioms and the Notion of Physical Possibility	218
0	Conservation Equations and Maxwell Equations in Our Axiomatic	
3 001	Theory	220
Foot	notes to Chapter 9	223
Chap	oter 10. Couple Stresses and More General Stresses	226
8 86	Introduction	226
	Contributions of Couple Stresses to the Expression of $\mathcal{U}_{\alpha\beta}$ and to the	220
ş 07.	Equation of Energy Balance \ldots \ldots \ldots \ldots \ldots	227
8 8 8	The Relativistic Cauchy Equations of Continuous Media in the Case of	221
y 00.	Couple Stresses	230
8 80	The Non-Working Part of $m^{\alpha\beta\gamma}$	230
	Some Commutation Formulas for Lagrangian Spatial Derivatives	233
	A Useful Expression for C_{LAB} .	235
	A Lagrangian Expression for the Work of Stress and Couple Stress	250
§ 92.		238
\$ 02	in Special or General Relativity	
•	Elasticity with Couple Stress	239
g 94.	Hints at Non-Viscous Fluids Capable of Couple Stress and at Electro-	244
0.05	magnetoelasticity with Couple Stress	241
§ 95.	Some Preliminary Variational Formulas Related to Second Order	~
0.07	Lagrangian Kinematics and the Variation of Space-Time Metric	245
§ 96.	A Variational Principle Involving Couple Stress and the Variation	
	of Space-Time Metric	247
§ 97.	A Variational Principle Involving the Variation of World Lines in the	
	Presence of Couple Stresses. On Constitutive Equations	249
§ 98.	On General Materials of Order $n=2$ in the Adiabatic Case. Variations	
	of $g_{\alpha\beta}$ and World Lines	250
§ 99.	Variational Principles for Elastic Materials of any Order $n \ge 1$, not	
	Capable of Heat Conduction	253
Foot	notes to Chapter 10	257
App	endix A. Double Tensors	258
8 A 1	Definition of Double Tensors Related to Two Topological Spaces	258
	Partial Covariant Derivative and Total Covariant Derivative Based on	250
yn 2.		259
812	a Mapping	4.57
SH3	Case of Arguments Fulfilling Typical Regular Conditions	261
0.		
§A 4	. Partial Derivative of any Double Tensor \hat{T} (<i>H</i>) Defined Only for	
	Values of H" that are Symmetric, Skewsymmetric, Spatial, or Subject	
	to Other Particular Conditions	266

Appendix B. Two Uniqueness Properties of $E_{\alpha\beta}$	269		
Appendix C. On the Divergence of Spatial Vectors in Space-Time	273		
Appendix D. On the Lie Derivatives \mathscr{L}_u, D^c, D_c and the Lagrangian Represen-			
tation $\stackrel{\perp}{T}$ $\stackrel{*}{\longrightarrow}$ $\stackrel{*}{T}$ Application to Linear Elasticity	277		
References	280		
Index	287		