

ELECTRODYNAMICS AND CLASSICAL THEORY OF FIELDS & PARTICLES

A.O. BARUT

*Professor of Physics
University of Colorado*

DOVER PUBLICATIONS, INC.
NEW YORK

C O N T E N T S

<i>Preface</i>	Page vii
<i>Introduction</i>	xiii

PART I. RELATIVISTIC DESCRIPTION OF FIELDS AND PARTICLES

CHAPTER 1 Lorentz Transformations	3
1. The Physical Basis of the Lorentz Transformations	3
2. Mathematical Properties of the Lorentz Space	6
Notations	6
Vectors and Scalar Products	8
Basis	11
Complex Lorentz Space	11
3. Properties of the Lorentz Transformations	12
4. Special Lorentz Transformations: Applications	16
5. The Lorentz Group and its Representations	22
A. The Four Parts of the Lorentz Group	22
B. Correspondance with the 2×2 Unimodular Group	23
C. Spinors	25
D. Higher-Order Spinor and Tensor Representations	29

	Page
E. Infinitesimal Generators of the Lorentz and Unimodular Groups	32
F. Complex Lorentz Group	34
6. The Principle of Relativity: Invariance and Covariance	35
7. Tensor and Spinor Fields and Momentum Space Functions	36
8. Analysis	38
9. Further Developments and Exercises	41
Bibliography for Chapter I	45
 CHAPTER II Relativistic Dynamics	 47
1. Proper Time Form of the Equations of Motion	48
Particles with Zero Rest Mass	52
Explicit Forms of the Minkowski Force K^μ	54
Angular Momentum	57
Systems of Colliding Particles	58
2. Lagrangian Form of the Equations of Motion	60
3. Canonical Form of the Equations of Motion	68
4. Electric and Magnetic Moments: Classical Spin	73
5. Further Developments and Exercises	80
Notes and Bibliography for Chapter II	83
 CHAPTER III Relativistic Field Theory	 85
1. Intuitive Introduction of Fields	85
2. The Electromagnetic Field	88
Basic Equations	88
Lorentz Electrodynamics	92
Covariant Form of Maxwell—Lorentz Equations	93
Gauge Transformations	94
Invariants	95
Covariant Form of Maxwell's Equations in Material Media	96
Spinor Form of the Maxwell Equations	97
3. Lagrangian Form of Field Equations	99
(A) Variations with a Fixed Boundary B	
(B) Variations Involving a Change of Boundary B	103
4. Conservation Laws	105
(A) Conservation Laws in Integral Form	105
(B) Conservation Laws in Differential Form	112

	Page
(C) Lagrangians Not Invariant Under Translations	115
(D) Explicit Forms of Conserved Quantities	116
5. Canonical Form of the Field Equations	119
6. Lagrangians Involving Higher-Order Derivatives	122
7. Further Developments and Exercises	127
Bibliography for Chapter III	130

PART II INTERACTIONS OF FIELDS AND PARTICLES

CHAPTER IV Equations of Motion and Their Solutions	135
1. Interactions of Fields with External "Currents"	135
2. Interactions of Fields with a Particle	138
3. Interactions Between Fields	142
4. Solutions of Field Equations: Green's Functions	148
5. Further Developments and Exercises	163
Bibliography for Chapter IV	164
CHAPTER V Radiation and Radiation Reaction	165
1. Radiation Field of a Moving Particle	165
Lienard-Wiechert Potentials	165
The Field Tensor $F^{\mu\nu}$	168
2. Properties of the Radiation Field	170
Null Fields	170
Plane Wave Decomposition of the Radiation Field	172
Energy and Momentum of the Radiation Field	175
3. Canonical Formalism for the Radiation Field in Terms of the Transverse Vector Potential	177
4. Energy and Momentum Radiated	179
5. Radiation Reaction	184
(A) Energy Balance	184
(B) Interacting Fields and Particles	186
(C) Finite Part of Self-Force	187
(D) Mass Renormalization	190
6. Equations of Motion with Radiation Reaction	195
7. Theory of the Electromagnetic Mass	199
8. Further Developments and Exercises	203

	Page
Bibliography for Chapter V	211
CHAPTER VI Action-at-a-Distance Electrodynamics	213
1. The Action Principle of Fokker-Schwarzschild-Tetrode	214
2. Action Principle with Self-Energy	217
3. Mass Renormalization	219
Related Mathematical Books	221
Author Index	225
Subject Index	231