

F. Electromagnetic Fields & Interactions

Richard Becker



Copyright © 1964 by Blaisdell Publishing Company and Blackie and Son Limited.
All rights reserved.

This Dover edition, first published in 1982 and reissued in 2012, is an unabridged republication in one volume of the work originally published in two volumes in 1964 by Blaisdell Publishing Company, N.Y., simultaneously with Blackie and Son Limited, Glasgow. This is the only authorized translation of the original German *Theorie der Elektrizität*, published by the B. G. Teubner Verlagsgesellschaft, Stuttgart. The present edition is published by special arrangement with Blackie and Son Limited.

Library of Congress Cataloging in Publication Data

Becker, Richard, 1887-1955.

Electromagnetic fields and interactions.

Translation of: *Theorie der Elektrizität*.

Reprint. Originally published: New York : Blaisdell Pub. Co., c1964. (A Blaisdell book in the pure and applied sciences).

Includes indexes.

Contents: v. 1. Electromagnetic theory and relativity — v. 2. Quantum theory of atoms and radiation / translated by Ivor de Teisser ; rev. by Günther Leibfried and Wilhelm Brenig.

1. Electromagnetic fields. 2. Relativity (Physics) 3. Electrons. 4. Quantum theory. I. Sauter, Fritz, 1906- . II. Title. III. Series: Blaisdell book in the pure and applied sciences.

QC665.E4B413 1982

530.1'41

81-19451

ISBN-13: 978-0-486-64290-1

AACR2

ISBN-10: 0-486-64290-9

Manufactured in the United States by Courier Corporation
64290908

www.doverpublications.com

CONTENTS

PART A. Introduction to vector and tensor calculus

Chapter AI. Vectors

§1	Definition of a vector	3
§2	Addition and subtraction of vectors	4
§3	Unit vectors, base vectors, components	6
§4	The inner or scalar product	9
§5	The outer or vector product	10
§6	Products of three and four vectors	12
§7	Differentiation of vectors with respect to a parameter	14

Chapter AII. Vector fields

§8	Definition of a vector field	16
§9	The space derivative of a field quantity. The gradient	17
§10	The strength of a source field and its divergence. Gauss's theorem and Green's theorem	20
§11	The line integral and the curl. Stokes's theorem	26
§12	Calculation of a vector field from its sources and vortices	32
§13	Orthogonal curvilinear coordinates	37

Chapter AIII. Tensors

§14	Definition of a tensor. The anti-symmetric tensor	41
§15	The symmetric tensor and its invariants. The deviator	46

PART B. The electrostatic field

Chapter BI. Electric charge and the electrostatic field in vacuum

§16	Electric charge	55
§17	The elementary electrical quantum	55
§18	Electric field strength and the electric potential	59
§19	Coulomb's law. The flux of electric force	63
§20	The distribution of electricity on conductors	67
§21	The capacitance of spherical and parallel-plate capacitors	69
§22	The prolate ellipsoid of revolution	71
§23	Induced charges	75
§24	The electric field at a great distance from field-producing charges. The dipole and quadrupole field	80

Chapter BII. Electrostatics of dielectrics

§25	The parallel-plate capacitor with dielectric insulation	89
§26	Dielectric polarization	91

§27	The fundamental equations of electrostatics for insulators. The Maxwell displacement vector	96
§28	Point charge opposite a semi-infinite dielectric	99
§29	Dielectric sphere in a uniform field	101
§30	The homogeneously polarized ellipsoid	102
Chapter BIII. Force effects and energy relations in the electrostatic field		
§31	Systems of point charges in free space	108
§32	Field energy when conductors and insulators are present. Thomson's theorem	114
§33	Thermodynamical considerations of the field energy	118
§34	Force effects in the electrostatic field calculated by means of the field energy; several simple examples	121
§35	General calculation of the force on an insulator in an electric field	125
§36	The Maxwell stresses	129
§37	Electric force effects in homogeneous liquids and gases	134
PART C. Electric current and the magnetic field		
Chapter CI. The laws of the electric current		
§38	Current strength and current density	141
§39	Ohm's law	144
§40	Joule heating	148
§41	Impressed forces. The galvanic chain	149
§42	Inertia effects of electrons in metals	155
Chapter CII. Force effects in the magnetic field		
§43	The magnetic field vectors	159
§44	The force on a current-carrying conductor. The Lorentz force	162
§45	The Faraday law of induction	166
Chapter CIII. Magnetic fields of currents and permanent magnets		
§46	The magnetic field of steady currents. Oersted's law	172
§47	The ring current as a magnetic dipole	179
§48	Magnetization and magnetic susceptibility	186
Chapter CIV. Electrodynamics of quasi-stationary currents		
§49	Self-induction and mutual induction	192
§50	Circuit with resistance and self-inductance. The vector diagram	198
§51	Circuit with resistance, self-inductance and capacitance	203
§52	The energy theorem for a system of linear currents	207

Contents

PART D. The general fundamental equations of the electromagnetic field

Chapter DI. Maxwell's theory for stationary media

§53	Completing the Maxwell equations	215
§54	The energy theorem in Maxwell's theory. The Poynting vector	218
§55	Magnetic field energy. Forces in the magnetic field	221
§56	The momentum theorem in Maxwell's theory. The momentum density of the radiation field	224

Chapter DII. Electromagnetic waves

§57	Electromagnetic waves in a vacuum	228
§58	Plane waves in stationary homogeneous media	233
§59	The reflection of electromagnetic waves at boundary surfaces	244
§60	Current displacement or the skin effect	248
§61	Electromagnetic waves along ideal conductors	252
§62	Waves along wires of finite resistance	259
§63	Waves in hollow conductors	262

Chapter DIII. The electromagnetic field of a given distribution of charge and current

§64	The field of a uniformly moving charged particle	267
§65	Energy and momentum for a uniformly moving charged particle	274
§66	The electromagnetic potential of an arbitrary distribution of charge and current	279
§67	The Hertz solution for the oscillating dipole	283
§68	The radiation of electromagnetic waves by an emitter	286
§69	The field of an arbitrarily moving point charge	292

Chapter DIV. The field equations in slowly moving non-magnetic media

§70	Derivation of the field equations	296
§71	Experimental confirmation of the basic equations	299
§72	Fizeau's investigation	304
§73	The Michelson experiment	308
§74	Search for an explanation of the negative result of the Michelson experiment	312

PART E. The theory of relativity

Chapter EI. The physical basis of relativity theory and its mathematical aids

§75	Revision of the space-time concept	317
§76	The Lorentz transformation	320
§77	Consequences of the Lorentz transformation	325
§78	Programme of the special theory of relativity	331
§79	The general Lorentz group	333
§80	Four-vectors and four-tensors	338

Chapter EII. The relativistic electrodynamics of empty space

§81	The field equations	343
§82	The force density	349
§83	The energy-momentum tensor of the electromagnetic field	352
§84	The plane light-wave	357
§85	The radiation field of a moving electron	364

Chapter EIII. The relativistic electrodynamics of material bodies

§86	The field equations	367
§87	The moments tensor	374
§88	Unipolar induction	378

Chapter EIV. Relativistic mechanics

§89	The mechanics of mass points	384
§90	The inertia of energy	388
§91	Mechanical stresses	394

PART F. Exercise problems and solutions

Chapter FI. Exercises

A.	Vector and tensor calculus	405
B.	The electrostatic field	406
C.	The electric current and the magnetic field	408
D.	The fundamental equations of the electromagnetic field	411
E.	Relativity theory	412

Chapter FII. Solutions

A.	Vector and tensor calculus	413
B.	The electrostatic field	414
C.	The electric current and the magnetic field	415
D.	The fundamental equations of the electromagnetic field	417
E.	Relativity theory	418

PART G. List of formulae

Chapter GI. Vector and tensor calculus

- | | | |
|---|-----------------|-----|
| 1 | Vector algebra | 423 |
| 2 | Vector analysis | 424 |
| 3 | Tensor algebra | 425 |

Chapter GII. Electrodynamics

- | | | |
|---|---|-----|
| 1 | The field equations and the constitutive equations | 427 |
| 2 | The material constants | 428 |
| 3 | Energy and force expressions | 428 |
| 4 | Wave propagation | 429 |
| 5 | Electrotechnical concepts | 430 |
| 6 | Conversion table from MKSA units to the Gaussian system | 431 |

Chapter GIII. Relativity theory 433

Index 435