



INTERNATIONAL SERIES IN PURE AND APPLIED PHYSICS
G. P. HARNWELL, CONSULTING EDITOR

ADVISORY EDITORIAL COMMITTEE; E. U. Condon, George R. Harrison,
Elmer Hutchisson, K. K. Darrow

STATIC AND DYNAMIC
ELECTRICITY

STATIC AND DYNAMIC ELECTRICITY

BY
W. R. Smythe
WILLIAM R. SMYTHE
Professor of Physics
California Institute of Technology

SECOND EDITION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK TORONTO LONDON
1950

INTERNATIONAL SERIES IN
PURE AND APPLIED PHYSICS
G. P. HARNWELL, *Consulting Editor*

WAVE PROPAGATION IN PERIODIC STRUCTURES
ELECTRICITY
APPLIED X-RAYS
ELECTRICAL MEASUREMENTS
ANALYTIC AND VECTOR MECHANICS
BURG—ATOMIC PHYSICS
INTRODUCTION TO STATISTICAL MECHANICS
ND PERRIN—THE PRINCIPLES OF OPTICS
L—ELECTRICITY AND ELECTROMAGNETISM
LL AND LIVINGOOD—EXPERIMENTAL ATOMIC PHYSICS
—PRINCIPLES OF MATHEMATICAL PHYSICS
AND DuBRIDGE—PHOTOELECTRIC PHENOMENA
HIGH-FREQUENCY MEASUREMENTS
LL, ZOBEL, AND INGERSOLL—HEAT CONDUCTION
—THE FUNDAMENTAL PRINCIPLES OF QUANTUM
MECHANICS
D—KINETIC THEORY OF GASES
—THE PHYSICS OF ELECTRON TUBES
—VIBRATION AND SOUND
—PHYSICAL PRINCIPLES OF OIL PRODUCTION
AND GOUDSMIT—THE STRUCTURE OF LINE SPECTRA
TER AND KENNARD—INTRODUCTION TO MODERN PHYSICS
AND UREY—ATOMS, MOLECULES, AND QUANTA
—QUANTUM MECHANICS
THE MODERN THEORY OF SOLIDS
—INTRODUCTION TO CHEMICAL PHYSICS
MICROWAVE TRANSMISSION
AND FRANK—ELECTROMAGNETISM
INTRODUCTION TO THEORETICAL PHYSICS
MECHANICS
—STATIC AND DYNAMIC ELECTRICITY
ON—ELECTROMAGNETIC THEORY
—INTRODUCTION TO ATOMIC SPECTRA

A. DuBridge was consulting editor of the series from 1939 to 1946.

QC 518
S55
1950
COPY 2

STATIC AND DYNAMIC ELECTRICITY

ht, 1939, 1950, by the McGraw-Hill Book Company, Inc. Printed in
ed States of America. All rights reserved. This book, or parts thereof,
be reproduced in any form without permission of the publishers.

PREFACE TO THE SECOND EDITION

The wide use of rationalized mks units and the increased importance of microwaves made this radical revision of the first edition imperative. The units are changed throughout. The resultant extensive resetting of the text permits a modernization of nomenclature through such changes as "capacitor" for "condenser" and "electromotance" for "electromotive force." The original wording has been preserved only in the Cambridge problems. In static-field chapters, forty problems of above-average difficulty have been added, usually covering boundary conditions omitted in the first edition. The expanded treatment of electromagnetic waves made necessary the rewriting of the parts of Chapter V dealing with Bessel functions and led to the introduction of vector surface harmonics, which greatly simplify some calculations. Much of Chapter XI on eddy currents has been rewritten, and two of the three electromagnetic-wave chapters are entirely new. Both the text and the 150 problems include methods and results not found in the literature. Two groups of advanced Ph.D. students worked over this material to get practice in attacking every type of wave-field problem. Many are too difficult for first-year graduate students, but every problem was solved by at least one of the advanced students. They can be worked either directly from the text or by fairly obvious extensions of it. Some useful results appear in the problems and are listed in the Index, which should be consulted by engineers with boundary value problems to solve. Chapter XV of the first edition is omitted because none of the remaining theory is based on it and because to bring it up to date would require an excessive amount of space.

None of the new topics appears to lie outside the scope of the mathematical preparation assumed for readers of the first edition. That the successful solution of electrical problems depends on physical rather than mathematical insight is borne out by the author's experience with the first edition, which shows that graduate students in electrical engineering and physics greatly excel those in mathematics.

It is believed that very few of the errors and obscure or ambiguous statements in the first edition escaped the scrutiny of the 375 students at the California Institute of Technology who worked it through. No infallible system for locating errors caused by the transposition of units has been found, and the author will appreciate letters from readers pointing them out.

WILLIAM R. SMYTHE

PASADENA, CALIF.
July, 1950

v

RECEIVED
SEP 26 1950
WRIGHT OFFICE

10 THE MAPLE PRESS COMPANY, YORK, PA.

CONTENTS

PREFACE TO THE SECOND EDITION	v
PREFACE TO THE FIRST EDITION	vii
TABLE OF SYMBOLS	xvii
CHAPTER I	
BASIC IDEAS OF ELECTROSTATICS	1
Electrification, conductors, and insulators—Positive and negative electricity—Coulomb's law, unit charge, dielectrics—Limitations of the inverse-square law—Electrical induction—The elementary electric charges—Electric field intensity—Electrostatic potential—Electric dipoles and multipoles—Interaction of dipoles—Lines of force—Equipotential surfaces—Gauss's electric flux theorem—Lines of force from collinear charges—Lines of force at infinity—Potential maxima and minima. Earnshaw's theorem—Potential of electric double layer—Electric displacement and tubes of force—Stresses in an electric field—Gauss's electric flux theorem for nonhomogeneous mediums—Boundary conditions and stresses on the surface of conductors—Boundary conditions and stresses on the surface of a dielectric—Displacement and intensity in solid dielectric—Crystalline dielectrics—Problems—References.	
CHAPTER II	
CAPACITORS, DIELECTRICS, SYSTEMS OF CONDUCTORS.	25
Uniqueness theorem—Capacitance—Capacitors in series and parallel—Spherical capacitors—Cylindrical capacitors—Parallel-plate capacitors—Guard rings—Energy of a charged capacitor—Energy in an electric field—Parallel-plate capacitor with crystalline dielectric—Stresses when the capacity is a function of density—Electrostriction in liquid dielectrics—Force on conductor in dielectric—Green's reciprocity theorem—Superposition of fields—Induced charges on earthed conductors—Self- and mutual elastance—Self- and mutual capacitance—Electric screening—Elastances and capacitances for two distant conductors—Energy of a charged system—Forces and torques on charged conductors—Problems—References.	
CHAPTER III	
GENERAL THEOREMS.	48
Gauss's theorem—Stokes's theorem—Equations of Poisson and Laplace—Orthogonal curvilinear coordinates—Curl in orthogonal curvilinear coordinates— $\nabla \cdot (\epsilon \mathbf{V})$ in other coordinate systems—Green's theorems—Green's reciprocity theorem for dielectrics—Green's function—Solution of Poisson's equation—Uniqueness theorem with dielectrics present—Introduction of new conductor—Green's equivalent stratum—Energy of a dielectric body in an electric field—Effect of an increase of capacity—Potential of axially symmetrical field—Problems—References.	

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.