

Solution Electromagnetic Field Theory Fundamentals

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Explore foundational concepts and problem-solving techniques in Electromagnetic Field Theory. This resource covers essential principles, Maxwell's equations, and various analytical solutions, providing a clear understanding of how electromagnetic fields behave and interact.

Students benefit from organized study guides aligned with academic syllabi.

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Electromagnetic Field Theory Fundamentals

Guru and Hizioglu have produced an accessible and user-friendly text on electromagnetics that will appeal to both students and professors teaching this course. This lively book includes many worked examples and problems in every chapter, as well as chapter summaries and background revision material where appropriate. The book introduces undergraduate students to the basic concepts of electrostatic and magnetostatic fields, before moving on to cover Maxwell's equations, propagation, transmission and radiation. Chapters on the Finite Element and Finite Difference method, and a detailed appendix on the Smith chart are additional enhancements. MathCad code for many examples in the book and a comprehensive solutions set are available at www.cambridge.org/9780521830164.

Solutions Manual to Accompany Electromagnetic Field Theory Fundamentals

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Electromagnetic Field Theory Fundamentals

This Book Is Designed To Present The Fundamental Concepts Of Electromagnetic Field Theory As They Relate To Modern Engineering Applications. As An Up-To-Date Reference It Can Be Used By Practicing Engineers, Or As A Text/Supplement In Standard University Courses In Electromagnetics Or Electromagnetic Fields Theory. The Book Has Been Designed For Self-Study With A Problem-Solving Approach. Numerous Examples With Complete, Worked-Out Solutions Guide The Reader Through The

Concepts Under Discussion. Beginning With A Review On Vectors And Coordinate Systems, The Book Covers Basic Coulomb's Law In Vector Form Up Through The Propagation Of The Electromagnetic Wave In Wave Guides. Maxwell's Equations Which Form The Central Theme Are Developed From The Historical Approach Wherein Relevant Experimental Laws Are Gradually Introduced And Manipulated With The Help Of Steadily Increasing Knowledge Of Vector Calculus. These Equations Are Identified As And When They Occur For Static And Time Varying Fields. In The Last Two Chapters These Equations Are Then Explored In A Collective Way.

Electro Magnetic Field Theory

Numerical methods for solving boundary value problems have developed rapidly. Knowledge of these methods is important both for engineers and scientists. There are many books published that deal with various approximate methods such as the finite element method, the boundary element method and so on. However, there is no textbook that includes all of these methods. This book is intended to fill this gap. The book is designed to be suitable for graduate students in engineering science, for senior undergraduate students as well as for scientists and engineers who are interested in electromagnetic fields. Objective Numerical calculation is the combination of mathematical methods and field theory. A great number of mathematical concepts, principles and techniques are discussed and many computational techniques are considered in dealing with practical problems. The purpose of this book is to provide students with a solid background in numerical analysis of the field problems. The book emphasizes the basic theories and universal principles of different numerical methods and describes why and how different methods work. Readers will then understand any methods which have not been introduced and will be able to develop their own new methods. Organization Many of the most important numerical methods are covered in this book. All of these are discussed and compared with each other so that the reader has a clear picture of their particular advantage, disadvantage and the relation between each of them. The book is divided into four parts and twelve chapters.

Electromagnetic Field Theory Fundamentals

The Second Edition of this book, while retaining the contents and style of the first edition, continues to fulfil the requirements of the course curriculum in Electromagnetic Theory for the undergraduate students of electrical engineering, electronics and telecommunication engineering, and electronics and communication engineering. The text covers the modules of the syllabus corresponding to vectors and fields, Maxwell's equations in integral form and differential form, wave propagation in free space and material media, transmission line analysis and waveguide principles. It explains physical and mathematical aspects of the highly complicated electromagnetic theory in a very simple and lucid manner. This new edition includes : • Two separate chapters on Transmission Line and Waveguide • A thoroughly revised chapter on Plane Wave Propagation • Several new solved and unsolved numerical problems asked in various universities' examinations

Fundamentals of Electromagnetic Fields

Electromagnetic Field Theory and Transmission Lines is an ideal textbook for a single semester, first course on Electromagnetic Field Theory (EMFT) at the undergraduate level. This book uses plain and simple English, diagrammatic representations and real life examples to explain the fundamental concepts, notations, representation and principles that govern the field of EMFT. The chapters cover every aspect of EMFT from electrostatics to advanced topics dealing with Electromagnetic Interference (EMI)/Electromagnetic Compatibility (EMC), EMC standards and design methods for EMC. Careful and detailed.

Electromagnetic Field Theory

Electrostatics - Magnetostatic field and quasi-stationary electromagnetic fields - Circuit analysis - Electromagnetic waves - Relativity, particle-field interactions.

Numerical Analysis of Electromagnetic Fields

After a brief introduction into the theory of electromagnetic fields and the definition of the field quantities the book teaches the analytical solution methods of Maxwell's equations by means of several characteristic examples. The focus is on static and stationary electric and magnetic fields, quasi stationary fields, and electromagnetic waves. For a deeper understanding, the many depicted

field patterns are very helpful. The book offers a collection of problems and solutions which enable the reader to understand and to apply Maxwell's theory for a broad class of problems including classical static problems right up to waveguide eigenvalue problems.

FUNDAMENTALS OF ELECTROMAGNETIC THEORY, Second Edition

Reviews the fundamental concepts behind the theory and computation of electromagnetic fields The book is divided in two parts. The first part covers both fundamental theories (such as vector analysis, Maxwell's equations, boundary condition, and transmission line theory) and advanced topics (such as wave transformation, addition theorems, and fields in layered media) in order to benefit students at all levels. The second part of the book covers the major computational methods for numerical analysis of electromagnetic fields for engineering applications. These methods include the three fundamental approaches for numerical analysis of electromagnetic fields: the finite difference method (the finite difference time-domain method in particular), the finite element method, and the integral equation-based moment method. The second part also examines fast algorithms for solving integral equations and hybrid techniques that combine different numerical methods to seek more efficient solutions of complicated electromagnetic problems. Theory and Computation of Electromagnetic Fields, Second Edition: Provides the foundation necessary for graduate students to learn and understand more advanced topics Discusses electromagnetic analysis in rectangular, cylindrical and spherical coordinates Covers computational electromagnetics in both frequency and time domains Includes new and updated homework problems and examples Theory and Computation of Electromagnetic Fields, Second Edition is written for advanced undergraduate and graduate level electrical engineering students. This book can also be used as a reference for professional engineers interested in learning about analysis and computation skills.

Electromagnetic Field Theory and Transmission Lines

Discussed is the electromagnetic field theory and its mathematical methods. Maxwell's equations are presented and explained. It follows a detailed discussion of electrostatics, flux, magnetostatics, quasi stationary fields and electromagnetic fields. The author presents how to apply numerical methods like finite differences, finite elements, boundary elements, image charge methods, and Monte-Carlo methods to field theory problems. He offers an outlook on fundamental issues in physics including quantum mechanics. Some of these issues are still unanswered questions. A chapter dedicated to the theory of special relativity, which allows to simplify a number of field theory problems, complements this book. A book whose usefulness is not limited to engineering students, but can be very helpful for physicists and other branches of science.

Problems and Solutions on Electromagnetism

Reviews the fundamental concepts behind the theory and computation of electromagnetic fields The book is divided in two parts. The first part covers both fundamental theories (such as vector analysis, Maxwell's equations, boundary condition, and transmission line theory) and advanced topics (such as wave transformation, addition theorems, and fields in layered media) in order to benefit students at all levels. The second part of the book covers the major computational methods for numerical analysis of electromagnetic fields for engineering applications. These methods include the three fundamental approaches for numerical analysis of electromagnetic fields: the finite difference method (the finite difference time-domain method in particular), the finite element method, and the integral equation-based moment method. The second part also examines fast algorithms for solving integral equations and hybrid techniques that combine different numerical methods to seek more efficient solutions of complicated electromagnetic problems. Theory and Computation of Electromagnetic Fields, Second Edition: Provides the foundation necessary for graduate students to learn and understand more advanced topics Discusses electromagnetic analysis in rectangular, cylindrical and spherical coordinates Covers computational electromagnetics in both frequency and time domains Includes new and updated homework problems and examples Theory and Computation of Electromagnetic Fields, Second Edition is written for advanced undergraduate and graduate level electrical engineering students. This book can also be used as a reference for professional engineers interested in learning about analysis and computation skills.

Electromagnetic Field Theory

This textbook is a revised and enlarged version of notes for a one-semester course on electromagnetism. It covers the theory of electromagnetic phenomena in vacuum and in material media. The book includes a CD-ROM with didactic software, to solve boundary value problems in electrostatics and magnetostatics.

Theory and Computation of Electromagnetic Fields

This book includes thirteen chapters cover the principles of electromagnetic field theory, where: chapter one gives an introduction of vector analyses, while chapter two introduces the basics of electrostatic. Chapter three covers the solution to electrostatic problems. Chapter four explains the electrostatic field in dielectric media, while chapter five studies the microscopic theory of dielectrics. In chapter seven the continuity equation of the electric current is derived and explained, and in chapter eight, the magnetic field of steady current is explored and discussed. In addition, chapter nine has covered and interpreted electromagnetic induction, and in chapter ten, the magnetic properties of matter have been discussed and formulated. In chapter eleven, the concept of magnetic energy has discussed and elicited. Finally, in chapter twelve, Maxwell's equations have presented and discussed, and chapter 13 includes general solved problems. This book is intended primarily as a textbook for physics and electrical engineering students at the undergraduate or beginning graduate level, in addition, we hope the book may be useful as a base for research workers too.

Electromagnetic Field Theory for Engineers and Physicists

The study of electromagnetic field theory is required for proper understanding of every device wherein electricity is used for operation. The proposed textbook on electromagnetic fields covers all the generic and unconventional topics including electrostatic boundary value problems involving two- and three-dimensional Laplacian fields and one- and two- dimensional Poissonion fields, magnetostatic boundary value problems, eddy currents, and electromagnetic compatibility. The subject matter is supported by practical applications, illustrations to supplement the theory, solved numerical problems, solutions manual and Powerpoint slides including appendices and mathematical relations. Aimed at undergraduate, senior undergraduate students of electrical and electronics engineering, it: Presents fundamental concepts of electromagnetic fields in a simplified manner Covers one two- and three-dimensional electrostatic boundary value problems involving Laplacian fields and Poissonion fields Includes exclusive chapters on eddy currents and electromagnetic compatibility Discusses important aspects of magneto static boundary value problems Explores all the basic vector algebra and vector calculus along with couple of two- and three-dimensional problems

Theory and Computation of Electromagnetic Fields

This first volume of this two-volume set deals with the important recent discovery of the photomagneton of electromagnetic radiation, a discovery which is fundamental in quantum field theory and in quantum mechanics in matter. The photomagneton is the elementary quantum of magnetic flux density carried by the individual photon in free space, and is generated directly by the intrinsic angular momentum of the free photon. The volume develops the theory of the photomagneton in a series of papers, which cover all the major aspects of the theory, from classical electrodynamics to the relativistic quantum field. Several suggestions are given for experimental tests, and the available experimental evidence is discussed in detail. The overall conclusion of the series of papers is that the photomagneton, which is observable experimentally in magneto-optical phenomena, indicates the presence in free space of a novel, longitudinal, magnetic flux density, linked ineluctably to the usual transverse components. If the photomagneton is not observed, then a paradox would have emerged at the most fundamental electrodynamical level, necessitating a modification of the Maxwell equations themselves.

Fundamentals of Electromagnetism

The book deals with formal aspects of electromagnetic theory from the classical, the semiclassical and the quantum viewpoints in essays written by internationally distinguished scholars from several countries. The fundamental basis of electromagnetic theory is examined in order to elucidate Maxwell's equations, identify problematic aspects as well as outstanding problems, suggest ways and means of overcoming the obstacles, and review existing literature. This book will be especially valuable for those who wish to go in depth, rather than simply use Maxwell's equations for the solution of engineering problems. Graduate students will find it rich in dissertation topics, and advanced researchers will relish the controversial and detailed arguments and models.

Fundamentals of Electromagnetic Field Theory

The author uses a unique approach which emphasizes the field theoretic aspects of gravitation and the strong analogies between gravitation and the other areas that are studied in physics. The theory-centered text begins with the simplest experimental facts then proceeds to the corresponding differential equations, theoretical constructs such as energy, momentum and stress and several applications. End-of-chapter problems provide students with an opportunity to test their understanding, serve as an introduction to and a review of material not included in the book and can be used to develop examples, extensions and generalizations of the material presented.

Concepts of Electromagnetic Theory

"An IEEE reprinting of this classic 1968 edition, FIELD COMPUTATION BY MOMENT METHODS is the first book to explore the computation of electromagnetic fields by the most popular method for the numerical solution to electromagnetic field problems. It presents a unified approach to moment methods by employing the concepts of linear spaces and functional analysis. Written especially for those who have a minimal amount of experience in electromagnetic theory, this book illustrates theoretical and mathematical concepts to prepare all readers with the skills they need to apply the method of moments to new, engineering-related problems. Written especially for those who have a minimal amount of experience in electromagnetic theory, theoretical and mathematical concepts are illustrated by examples that prepare all readers with the skills they need to apply the method of moments to new, engineering-related problems."

Electromagnetic Fields

Review of Electrostatic and Magnetostatics. Time Varying Fields Maxwell's equations in differential and integral forms concept of displacement current. Boundary conditions. Electromagnetic Waves Wave equation and its solution in different media, Plane wave, Sinusoidal time variation, Polarization. Reflection of waves by perfect dielectrics and by perfect insulators. Surface impedance, Poynting theorem and Poynting vector. Guided Waves Waves between parallel planes. TE and TM waves and their characteristics. TEM waves, Velocities of propagation, Attenuation in parallel plane guides, Wave impedance. Transmission Lines Circuit representation of parallel plane transmission lines. Parallel plane transmission line with losses. Low loss RF and UHF transmission lines. Distortionless condition. Transmission line charts-impedance matching. Waveguides Rectangular and circular waveguides. TE and TM waves in rectangular waveguides. Impossibility of TEM wave in waveguides. Wave impedance and characteristics impedances. Transmission line analogy for waveguides. Attenuation and factor of waveguides. Dielectric slab waveguides.

The Photomagneton and Quantum Field Theory

The comprehensive study of electric, magnetic and combined fields is nothing but electromagnetic engineering. Along with electronics, electromagnetics plays an important role in other branches. The book is structured to cover the key aspects of the course Electromagnetic Field Theory for undergraduate students. The knowledge of vector analysis is the base of electromagnetic engineering. Hence book starts with the discussion of vector analysis. Then it introduces the basic concepts of electrostatics such as Coulomb's law, electric field intensity due to various charge distributions, electric flux, electric flux density, Gauss's law, divergence and divergence theorem. The book continues to explain the concept of elementary work done, conservative property, electric potential and potential difference and the energy in the electrostatic fields. The detailed discussion of current density, continuity equation, boundary conditions and various types of capacitors is also included in the book. The book provides

the discussion of Poisson's and Laplace's equations and their use in variety of practical applications. The chapter on magnetostatics incorporates the explanation of Biot-Savart's law, Ampere's circuital law and its applications, concept of curl, Stoke's theorem, scalar and vector magnetic potentials. The book also includes the concept of force on a moving charge, force on differential current element and magnetic boundary conditions. The book covers all the details of Faraday's laws, time varying fields, Maxwell's equations and Poynting theorem. Finally, the book provides the detailed study of uniform plane waves including their propagation in free space, perfect dielectrics, lossy dielectrics and good conductors. The book uses plain, lucid language to explain each topic. The book provides the logical method of explaining the various complicated topics and stepwise methods to make the understanding easy. The variety of solved examples is the feature of this book which helps to inculcate the knowledge of the electromagnetics in the students. Each chapter is well supported with necessary illustrations and self-explanatory diagrams. The book explains the philosophy of the subject which makes the understanding of the concepts very clear and makes the subject more interesting.

Essays On The Formal Aspects Of Electromagnetic Theory

CD-ROM contains: Demonstration exercises -- Complete solutions -- Problem statements.

Classical Field Theory

Accompanying CD-ROM contains a MATLAB tutorial.

Field Computation by Moment Methods

Electromagnetic Fields

Electromagnetic Field Theory

Engineering Electromagnetics is a "classic" book that has been updated for electromagnetics in today's world. It is designed for introductory courses in electromagnetics or electromagnetic field theory at the junior-level, but can also be used as a professional reference. This widely respected book stresses fundamentals and problem solving and discusses the material in an understandable, readable way. Numerous illustrations and analogies are provided to the aid the reader in grasping difficult concepts. In addition, independent learning is facilitated by the presence of many examples and problems.

Electromagnetic Field Theory

This book aims to disseminate geometric algebra as a straightforward mathematical tool set for working with and understanding classical electromagnetic theory. It's target readership is anyone who has some knowledge of electromagnetic theory, predominantly ordinary scientists and engineers who use it in the course of their work, or postgraduate students and senior undergraduates who are seeking to broaden their knowledge and increase their understanding of the subject. It is assumed that the reader is not a mathematical specialist and is neither familiar with geometric algebra or its application to electromagnetic theory. The modern approach, geometric algebra, is the mathematical tool set we should all have started out with and once the reader has a grasp of the subject, he or she cannot fail to realize that traditional vector analysis is really awkward and even misleading by comparison. Professors can request a solutions manual by email: pressbooks@ieee.org

Fundamentals of Applied Electromagnetics

Electromagnetic Fields: For Anna University is an ideal textbook for the single-semester course on electromagnetic fields for electronic and communication students of Anna University. Written in a lucid and student-friendly style, this book uses many real-life examples and a simple, clear and concise presentation to explain fundamental concepts in electromagnetic field theory. The book also explains fundamental concepts in the field of electromagnetic field theory for students of electrical and electronic engineering. The chapters cover every aspect of the subject, from fundamentals such as electrostatics to advanced topics dealing with transmission lines.

Fundamentals of Electromagnetics with MATLAB

In this book, all known electromagnetic laws are proven to be derivable from the solution of a single quadratic equation. This governing equation, it is shown, generates precisely three complex fields in

4-space, but can itself be generated as a law of all even-dimensioned spaces in universes having "meaning," without need of a prior knowledge of physics. Provided for the first time are electromagnetic formulas applicable in a general Riemannian space: the fundamental field tensor with three complex components, the energy-momentum tensor and the force-power tensor. The Lorentz force, as currently known, is shown to be an approximate form of the derived Riemannian force-power tensor, which imbeds gravitational interactions inclusive of frame-dragging terms. Newly identified electro-gravitational interaction force and power-transfer mechanisms are provided as natural consequences of the reformulations. As a byproduct of the complex-field theory developed in this book, the mystery of missing magnetic monopoles in nature is fully resolved. Also clarified are classical duality, field superposition, and the origins of charge sign and chirality. The approach taken to include all spatial dimensionalities leads to the justifiable conclusion that infinitely many higher-dimensioned spaces likely exist, with their laws of operation able to be broadly generated from the material presented....

Electromagnetic Fields (Theory and Problems)

Development of the subject in the book follows an order of increasing complexity. It is useful for the undergraduate level students of electronics engineering as well as postgraduate level students of engineering physics wanting to take up problems in the interface of electromagnetism and quantum mechanics. It discusses: * Gauss' and Stokes' theorems. * Gauss' and Coulomb's laws of electrostatics developed in both integral and differential frameworks. * Computation of static electric and magnetic field for various situations. * Green's function method for the solution of boundary value problems. * Problems involving computation of the emf for conductors moving in magnetic fields. * Derivation of the 3-D wave equations and Snell's laws of reflection and refraction. * Schrodinger's wave mechanics.

Engineering Electromagnetics with CD

"Fundamental of Engineering Electromagnetics" not only presents the fundamentals of electromagnetism in a concise and logical manner, but also includes a variety of interesting and important applications. While adapted from his popular and more extensive work, "Field and Wave Electromagnetics," this text incorporates a number of innovative pedagogical features. Each chapter begins with an overview, which serves to offer qualitative guidance to the subject matter and motivate the student. Review questions and worked examples throughout each chapter reinforce the student's understanding of the material. Remarks boxes following the review questions and margin notes throughout the book serve as additional pedagogical aids. Back Cover Fundamentals of Engineering Electromagnetics is a shorter version of Dr. Cheng's best-selling Field and Wave Electromagnetics, Second Edition. Fundamentals has been written in summaries. Emphasizes examples and exercises that invite students to build their knowledge of electromagnetics by solving problems. Besides presenting electromagnetics in a concise and logical manner, the text covers application topics such as electric motors, transmission lines, waveguides, antennas, antenna arrays, and radar systems.

Understanding Geometric Algebra for Electromagnetic Theory

Electromagnetics is one of the fundamental disciplines of electronic engineering. The author explains the development of field theory in relation to common electrical circuits and components, as opposed to just circuit theory, thus giving the reader a broader perspective of electrical circuits. Essentially in two parts, this book will help students to gain an appreciation of the physical effects of electrical and magnetic fields. The first part covers the basic theory of electrostatics, electromagnetism and electro-conductive fields and applies the theory to different transmission lines. It culminates in a comparison of the basic relationships that lie behind all the field systems covered. The second part covers the physical effects of dielectrics and ferrous materials on capacitors and coils. It is truly introductory with very little prior knowledge assumed. The mathematical techniques required to manipulate the theory are introduced from basics and there are numerous worked examples and problems. Self-assessment questions are given at the end of each chapter to allow the student to check their understanding of material before moving onto further chapters. This is an accessible and self-contained introduction to a topic that all physical scientists and engineers must get to grips with before developing their knowledge further.

Electromagnetic Fields: For Anna University

This is a textbook on electromagnetics for undergraduate students in electrical engineering, information, and communications. The book contents are very compact and brief compared to other commonly

known electromagnetic books for undergraduate students and emphasizes mathematical aspects of basic electromagnetic theory. The book presents basic electromagnetic theory starting from static fields to time-varying fields. Topics are divided into static electric fields, static magnetic fields, time-varying fields, and electromagnetic waves. The goal of this textbook is to lead students away from memorization, but towards a deeper understanding of formulas that are used in electromagnetic theory. Many formulas commonly used for electromagnetic analysis are mathematically derived from a few empirical laws. Physical interpretations of formulas are de-emphasized. Each important formula is framed to indicate its significance. Primary Theory of Electromagnetics shows a clear and rigorous account of formulas in a consistent manner, thus letting students understand how electromagnetic formulas are related to each other.

Unified Field Theory: Mathematical Treatise

The flagship monograph addressing the spheroidal wave function and its pertinence to computational electromagnetics Spheroidal Wave Functions in Electromagnetic Theory presents in detail the theory of spheroidal wave functions, its applications to the analysis of electromagnetic fields in various spheroidal structures, and provides comprehensive programming codes for those computations. The topics covered in this monograph include: Spheroidal coordinates and wave functions Dyadic Green's functions in spheroidal systems EM scattering by a conducting spheroid EM scattering by a coated dielectric spheroid Spheroid antennas SAR distributions in a spheroidal head model The programming codes and their applications are provided online and are written in Mathematica 3.0 or 4.0. Readers can also develop their own codes according to the theory or routine described in the book to find subsequent solutions of complicated structures. Spheroidal Wave Functions in Electromagnetic Theory is a fundamental reference for scientists, engineers, and graduate students practicing modern computational electromagnetics or applied physics.

Electromagnetic Field Theory

Considered the most comprehensive account of electromagnetic theory and analytical methods for solving waveguide and cavity problems, this text is now in a new second edition that has been completely revised and thoroughly updated, with approximately forty percent new material. Packed with examples and applications Field Theory of Guided Waves provides solutions to a large number of practical structures of current interest. The book includes a complete discussion of scalar and dyadic Green's function. As a valuable source of basic information on applied mathematical topics and a hands-on guide to solution methods and techniques, this book belongs on the desk of all engineers working on microwave and antenna systems.

Fundamentals of Engineering Electromagnetics

Fundamentals of Applied Electromagnetics: Incl CDRom.

Introduction to Electromagnetism

Providing an ideal transition from introductory to advanced concepts, Electromagnetics, Second Edition builds a foundation that allows electrical engineers to confidently proceed with the development of advanced EM studies, research, and applications. This second edition of a popular text continues to offer coverage that spans the entire field, from electrostatics to the integral solutions of Maxwell's equations. The book provides a firm grounding in the fundamental concepts of electromagnetics and bolsters understanding through the use of classic examples in shielding, transmission lines, waveguides, propagation through various media, radiation, antennas, and scattering. Mathematical appendices present helpful background information in the areas of Fourier transforms, dyadics, and boundary value problems. The second edition adds a new and extensive chapter on integral equation methods with applications to guided waves, antennas, and scattering. Utilizing the engaging style that made the first edition so appealing, this second edition continues to emphasize the most enduring and research-critical electromagnetic principles.

Primary Theory of Electromagnetics

Spheroidal Wave Functions in Electromagnetic Theory

