

Chicago Lectures in Physics

Electrodynamics

Fulvio Melia

Electrodynamics is a branch of physics that deals with the study of electric and magnetic fields and their interactions with matter. It is a fundamental part of classical physics and is essential for understanding many phenomena in nature, from the behavior of atoms and molecules to the propagation of light and the structure of the universe. The theory of electrodynamics is based on the principles of electromagnetism, which were first formulated by James Clerk Maxwell in the mid-19th century. Maxwell's equations describe the relationship between electric and magnetic fields and how they change over time. These equations are the foundation of modern physics and have led to many important discoveries, including the development of radio, television, and the Internet.

In this book, Fulvio Melia provides a comprehensive introduction to the theory of electrodynamics. He begins with a discussion of the basic concepts of electromagnetism, such as electric charge, electric field, and magnetic field. He then moves on to a more detailed treatment of Maxwell's equations and their solutions. The book also covers the applications of electrodynamics to various fields of physics, including optics, quantum electrodynamics, and astrophysics.

The book is written in a clear and concise style, making it accessible to students and researchers alike. It is a valuable resource for anyone interested in the theory of electrodynamics and its applications. The book is available in both print and digital formats, and can be purchased from various online retailers.

Author: Fulvio Melia, a professor of physics at the University of Illinois at Chicago, has published numerous papers on electrodynamics and related topics. He is also the author of several books on physics, including *Electrodynamics*.

Editor: The book was edited by a team of experts in the field of electrodynamics, ensuring that the content is accurate and up-to-date. The editors also provided valuable feedback to the author throughout the writing process.

Reviewer: The book has been reviewed by several experts in the field of electrodynamics, who have praised its clarity and depth. They have also noted that the book is a valuable resource for students and researchers alike.

Keywords: Electrodynamics, electromagnetism, Maxwell's equations, electric field, magnetic field, optics, quantum electrodynamics, astrophysics.

Subject: Physics, Electrodynamics, Electromagnetism, Optics, Quantum Electrodynamics, Astrophysics.

Language: English.

Format: The book is available in both print and digital formats. The print version is a hardcover book, while the digital version is a PDF file that can be downloaded from various online retailers.

Price: The price of the book varies depending on the format and the retailer. The print version is typically priced between \$20 and \$30, while the digital version is typically priced between \$10 and \$15.

Availability: The book is available for purchase from various online retailers, including Amazon, BarnesandNoble, and Google Play. It is also available for purchase from local bookstores.

Recommendation: This book is highly recommended for anyone interested in the theory of electrodynamics and its applications. It is a comprehensive and accessible introduction to the subject, and it is a valuable resource for students and researchers alike.

Conclusion: *Electrodynamics* by Fulvio Melia is a well-written and informative book that provides a comprehensive introduction to the theory of electrodynamics. It is a valuable resource for students and researchers alike, and it is highly recommended for anyone interested in the subject.

CONTENTS

PREFACE	ix
1 INTRODUCTION	1
1.1 The Physical Basis of Maxwell's Equations	1
1.2 Maxwell's Equations in Matter	14
1.3 The Mathematical Structure of Electrodynamics	17
1.3.1 Electrostatic Phenomena	17
1.3.2 Magnetostatic Phenomena	18
1.3.3 Wave Phenomena	19
1.3.4 The General Case	21
1.3.5 The Mathematical Apparatus	21
2 TIME-INDEPENDENT FIELDS	25
2.1 Electrostatics	25
2.1.1 Method 1: Guesses and Symmetries	26
2.1.2 Method 2: The Green Function	28
2.1.3 Expansions with Orthonormal Functions	42
2.2 Magnetostatics	50
2.2.1 Method 1: The Magnetic Scalar Potential	52
2.2.2 Method 2: The Magnetic Vector Potential	57
2.2.3 Method 3: Hard Ferromagnets	58
3 GENERAL PROPERTIES OF MAXWELL'S EQUATIONS	61
3.1 Time-Varying Fields	61
3.2 The Time-Dependent Green Function	63

3.3	Conservation Laws	68
3.3.1	Field Energy Density and Poynting's Theorem	68
3.3.2	Conservation of Linear Momentum	71
3.3.3	The Maxwell Stress Tensor	73
3.3.4	Conservation of Angular Momentum	74
4	ELECTROMAGNETIC WAVES AND RADIATION	77
4.1	Electromagnetic Waves	77
4.2	Polarization and Stokes Parameters	80
4.3	Reflection and Refraction	83
4.4	Time Harmonic Fields in Matter	88
4.5	Wave Guides	93
4.6	Radiation	98
4.6.1	Point Currents and Liénard-Wiechert Potentials	98
4.6.2	The Radiation Fields	102
4.6.3	Simple Radiating Systems	107
5	A NEED FOR THE SPECIAL THEORY OF RELATIVITY	115
5.1	Basic Principles and Transformations	115
5.2	Mathematical Structure of Four-Dimensional Spacetime	124
5.3	Lorentz Transformation Properties of Physical Quantities	128
5.4	Lorentz Transformation of Macroscopic Electrodynamics	133
5.5	Stress-Energy Momentum Tensor and Conservation Laws	139
6	THE LAGRANGIAN FORMULATION OF ELECTRODYNAMICS	145
6.1	Action Principles in Classical Field Theories	145
6.2	Relativistic Lagrangians of Point-Charge Motions	150
6.3	The Field Lagrangian	153
6.4	Invariances and Conservation Laws (Noether's Theorem)	156

7	RELATIVISTIC TREATMENT OF RADIATION	161
7.1	The Green Function in Four-Dimensional Spacetime	162
7.2	Liénard-Wiechert Potentials and Fields for a Point Charge	169
7.3	Angular Distribution of the Emitted Radiation	173
7.4	Bremsstrahlung Radiation	176
7.5	Radiative Motions of a Point Charge	183
7.6	Radiation Damping and the Relativistic Lorentz-Dirac Equation	188
8	SPECIAL TOPICS	195
8.1	Time-Independent Multipole Fields	195
8.2	Multipole Expansion of Time-Dependent Fields	199
8.3	Collisions between Charged Particles	206
8.4	Magnetohydrodynamics	210
8.5	Alfvén Waves and Particle Acceleration	215
8.6	Synchrotron Emission	218
8.7	Echoes of the Big Bang	227
8.8	Cosmic Superluminal Sources	233
8.9	Polarized Radiation from the Black Hole at the Galactic Center	235
	REFERENCES	239
	INDEX	245