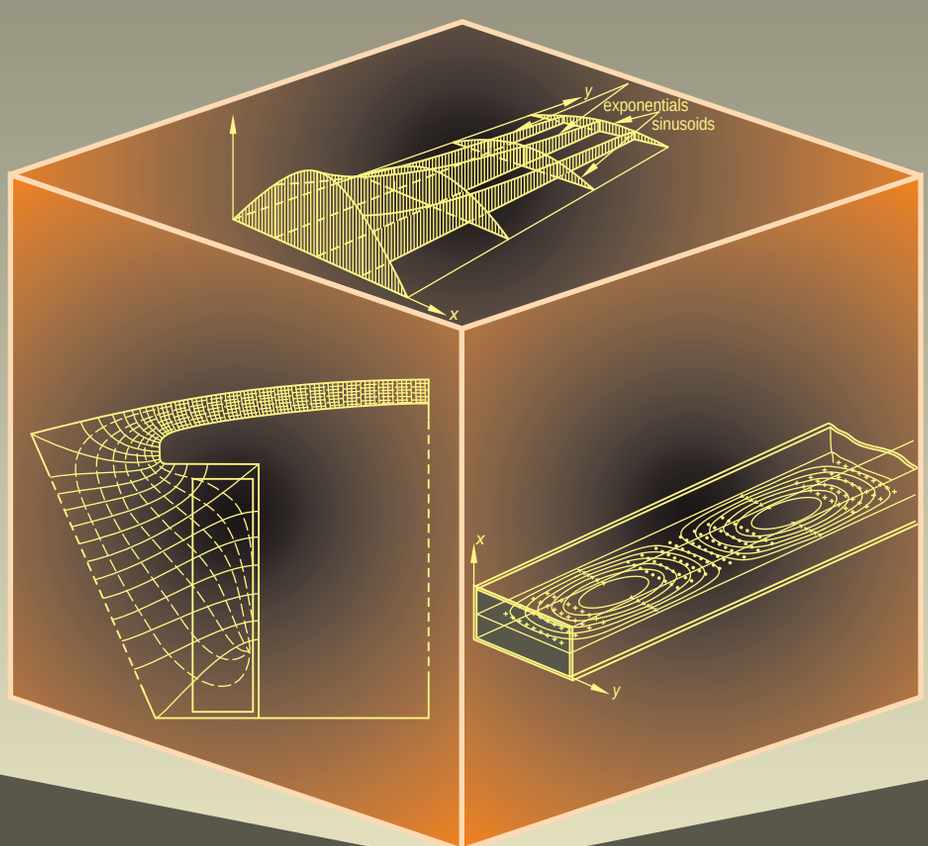
Eastern Economy Edition

Third Edition

Electromagnetism

Problems with Solutions



Ashutosh Pramanik

ELECTROMAGNETISM
Problems with Solutions

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Problems with Solutions

THIRD EDITION

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ELECTROMAGNETISM: Problems with Solutions, Third Edition
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To the revered memory of

my parents

Tarapada Pramanik and Renubala Pramanik

whose encouragement and support for my professional career made this book possible

and

to the memory of my two great teachers

J.G. Henderson

(*Department of Electronic and Electrical Engineering, The University of Birmingham*)

and

Professor G.W. Carter

(*Department of Electrical and Electronic Engineering, The University of Leeds*)

who were instrumental in developing my interest in Electromagnetism

and

thus made possible the writing of this book

Contents

Preface ..... *ix*
Preface to the Second Edition ..... *xi*
Preface to the First Edition ..... *xiii*
0 *Vector Analysis* *1*
1 *Electrostatics I* *52*
2 *Electrostatics II—Dielectrics, Conductors and Capacitance* *103*
3 *Electrostatic Field Problems* *189*
4 *Electric Currents (Steady)* *290*
5 *Magnetostatics I* *332*
6 *Electromagnetic Induction and Quasi-static Magnetic Fields* *423*
7 *Forces and Energy in Static and Quasi-static Magnetic Systems (with inductance calculations)* *520*
8 *Maxwell's Equations* *562*
9 *Vector Potentials and Applications* *590*
10 *Poynting Vector and Energy Transfer* *631*
11 *Magnetic Diffusion (Eddy Currents) and Charge Relaxation* *648*
12 *Electromagnetic Waves—Propagation, Guidance and Radiation* *717*
13 *Electromagnetism and Special Relativity* *855*
Appendix 1 Roth's Method *887*
Appendix 2 Solid Angles *894*
Appendix 3 Poynting Vector: A Proof *897*
Appendix 4 Magnetic and Electric Fields in Poynting Vector: A Proof *898*
Appendix 5 Bicylindrical Coordinate System and Associated Conformal Transformations ... *899*
Bibliography *905*

Preface

Since the main textbook *Electromagnetism—Theory and Applications*, Second Edition, is currently being significantly revised and enlarged, this companion text on problems and solutions has been revised first. Whilst the main philosophy of these books remains the same, the additions and modifications are fairly substantial. This has happened because it has now been realized that in spite of the very significant enhanced computing facilities, the progress in other associated fields is causing the revival of some of the classical techniques and methods, which initially were thought to be made obsolete by the "numerical methods" used in computers. A typical example is that of the applications of new permanent magnet materials (i.e. NdFeB) in the development of permanent magnet motors and generators of rotary as well as linear types. Design and development engineers are now using various methods of analysis of these devices by using the methods which had been nearly eliminated by the advent of modern powerful computers. Attempts have been made to provide information and knowledge of such topics in both the books. Examples of such topics are illustrated by the usage of topics such as Fröhlich's equations, Evershed criterion and similar other relations.

A very significant addition in the third edition has been made to the problems on electromagnetic induction (Chapter 6), covering nearly all aspects of applications of Faraday's law. This chapter now contains 61 problems instead of the original 43 problems, making it fully comprehensive for a sound understanding of the phenomenon of electromagnetic induction. Furthermore, none of the problems are of "formula substitution type" and, hence, they give a proper insight into the physics of the phenomenon. Regarding other chapters, problems have been added to all the main topics starting from vector analysis to Lorentz transformation in the last chapter titled Electromagnetism and Special Relativity. There have been additions to problems on eddy currents (i.e. magnetic diffusion) which illustrate the effects of a.c. resistance as well as the inductance of the devices in cylindrical geometry.

My thanks are due to the College of Engineering, Pune, for providing me with the necessary facilities for completing this third edition of the book. I would like to mention in particular the interest and help of Prof. B.N. Chaudhari, Head of the Department of Electrical Engineering in this connection. I must also acknowledge the help and meticulous work in bringing out this edition, of the staff of PHI Learning, with particular mention of Mr. Darshan Kumar, Executive Editor.

Last but not the least, I must acknowledge the encouragement of my daughter, Mrinmayee, at all stages of this work and the silent support of my wife, Lalita, in spite of her ill-health.

I have tried to eliminate the printing errors as far as possible, but it is likely there may be some missed out ones. I would greatly appreciate the kindness and interest of any readers who would point out such omissions, which can then be corrected in the subsequent printruns and editions.

A. PRAMANIK

Preface to the Second Edition

Along with the revision of the main textbook *Electromagnetism: Theory and Applications*, this opportunity is being taken to revise this 'companion' volume as well. There has been no change in the philosophy of this book. It was mentioned earlier that the problems had been so chosen that the main emphasis was on the 'inside physics' of them, and the associated mathematical manipulations remain as simple as possible. Hence the problems dealing with cylindrical and spherical geometries were kept to a minimum. But it has come to notice that these geometries are widely used in problems dealing with waveguides and antennae and hence they need the use of Bessel and Legendre functions. Hence a number of problems in these geometries have been added even at the initial stage of electrostatics and magnetostatics, so that the readers would develop familiarity with these important mathematical functions at an earlier stage. Though these problems are in electrostatics and magnetostatics, it is quite easy to modify and extrapolate them so as to convert such problems to electromagnetic problems. Also, some problems in antennae have been solved by using the Hertz vector and then their equivalence to the vector and the scalar potentials have been shown in these solutions. These intermediate steps are not essential integral parts of such solutions. This has been done just to show how the use of Hertz vector makes the solving of these problems easier. Such problems solved by using the Hertz vector directly would still be easier and more compact. Some problems on transmission lines requiring the use of Bicylindrical coordinate system have also been included. Nearly 40 new problems have been added to the original list of 440 problems.

Since the choice of the additional problems is based on my discussions with Prof. S.V. Kulkarni and Prof. R.K. Shevgaonkar of IIT Bombay, I express my thanks to them. Once again the staff members of PHI Learning deserve my thanks for their help and meticulous work in bringing out this edition and the names I would mention in this connection are Mr. S. Ramaswamy, Regional Sales Manager, Ms. Pushpita Ghosh, Managing Editor, and Mr. Darshan Kumar, Senior Editor.

Finally, I repeat my sincere thanks to my daughter Mrinmayee for her constant encouragement and support and my wife Lalita for her patience and forbearance during this long period.

I have tried to eliminate the printing errors and omissions as far as possible, but it is likely that some would have been missed out. I shall be grateful to all the readers who would kindly bring to my notice any such missed-out errors, which can then be eliminated in subsequent printruns and editions.

A. PRAMANIK

Preface to the First Edition

This book is a companion volume to the textbook on Electromagnetism (*Electromagnetism: Theory and Applications*). It presents the solutions to more than 400 problems covering the whole range of topics discussed in the main text. The present book follows the overall trend of the first book, though, of course, the sequence has not been followed rigorously because of a number of logical reasons.

Before going into the details of these points of discussion, it should be made absolutely clear that no originality whatsoever is being claimed regarding the origin and source of the problems in this book. These problems have been collected from various sources and through my colleagues in the academic world as well as in the industries during my professional life, and they have passed through so many stages that it has not been possible for me to identify correctly the original sources of all these problems. So, I have refrained myself from mentioning the sources of any of these problems. However, the solutions have been worked out by me, except for the problems on relativity which Late Prof. G.W. Carter of University of Leeds presented to me along with his all other papers on Electromagnetism and Relativity on the day of his retirement. A number of these solved problems have already been tried on various groups of design and development engineers in the industries during in-house refresher courses on Electromagnetism conducted by me during my stay in the industries, with somewhat non-uniform results and partial successes.

The arrangement of the solved problems in the book follows a similar trend of the topics as in the main textbook, i.e. Vector Analysis, Electrostatics (in free space, conductors and insulators, forces and energy in E.S. fields, and E.S. field problems), Electric Current, Magnetostatics, Quasi-static Magnetism and Electromagnetic Induction, Forces and Energy in Magnetic Fields and Magnetic Field Analysis, Maxwell's Equations, Vector Potentials and Applications, Electromagnetic Energy Transfer, Magnetic Diffusion and Eddy Currents and Charge Relaxation, Electromagnetic Waves (propagation with reflection, refraction and transmission, guidance, and radiation and reception), and finally Electromagnetism and Special Relativity. Though attempts have been made to follow the main themes of the textbook, it has not been always possible to maintain exactly the chapterwise distribution of the problems. This is because there are quite a number of problems which contain more than "single-chapter" topics and the relative location of such problems has been a matter of choice. For this reason, the number of the chapters in this book has been reduced while keeping in mind the overall classification of the topics and the problems. To give a specific example, a magnetostatic field problem requiring the concept of magnetic vector potential had to be located in the chapter on "Vector Potentials and Applications" and not in the chapter on the "Magnetostatic Fields" which preceded the chapter on Vector Potentials. However, the chapter dealing with the "Electromagnetic Induction" contains all the problems on induction including those requiring the

"moving media" concept which logically could have been located in the chapter on "Special Relativity" at the end of the book. This arrangement has been chosen because it would be more helpful for readers to have all the induction problems at the same place so that an integrated picture of the various facets of electromagnetic induction can be obtained for a better insight into all the aspects of this phenomenon. Next, all the wave problems have been included in a single chapter which consists of propagation, guidance, and radiation and reception of waves. The reasons for such unification have been that the problems contain more than one aspect of the waves in each and hence it was considered more effective to contain all wave problems in the same chapter.

Another topic which has been included in the chapter on vectors is that of the "Dirac-delta function". While the physicists (and the students of physics) are well aware of this function and are at ease with the handling of this function, the engineering students are, in general, at a comparative disadvantage in using this function (as well as the Kronecker delta function). So, in the first chapter itself, this function, along with some simple integration problems, has been introduced. Later, at various places in the book, the use of delta function has been illustrated in a number of problems dealing with point charges, line charges, and line currents. Such problems have been explained in Cartesian geometry only, to keep the associated mathematics as simple as possible. However, it should be noted that this is not a restriction on the usage of the delta function as it can also be used for problems in other coordinate systems such as cylindrical polar and spherical polar systems and so on. The main reason for not including problems in these coordinate systems is that while these problems require the use of more complicated mathematical functions like Bessel functions and Legendre functions, they do not illuminate any new physical concepts.

As mentioned in my previous book, a book like this can only be produced by the assistance of various people with whom I have been associated in my professional life. The two persons who have deeply influenced my study of electromagnetism and whom I freely acknowledge are Late Mr. J.G. Henderson of the University of Birmingham and Late Prof. G.W. Carter of the University of Leeds. It was Mr. Henderson who introduced me to the initial study of Roth's method and my association with Prof. Carter enabled me to approach the subject of electromagnetism with proper perspective and insight.

I would also like to express my sincere thanks to my daughter Mrinmayee and my wife Lalita for their help, support and encouragement during the preparation of this book. My daughter's active encouragement and inspiration helped me to complete this book in specified time. My wife's patience and forbearance has seen me through this arduous period of preparing the final manuscript and also the printing process.

It is no mean task turning a hand-written manuscript into a finished book. The efforts of my publishers are much appreciated. I would like to make a special mention of Ms. Pushpita Ghosh, Manager, Editorial and Marketing, for her overall supervision, Mr. Darshan Kumar, Editor, for his painstakingly editing the manuscripting and detailed checking of the typescript, and Mr. S. Ramaswamy, Sr. Marketing Executive for his support and help in smoothing the process of publishing.

Finally, I have tried to eliminate the printing errors and omissions as far as possible, but it is likely that some would have been missed out. I shall be grateful to all readers who would kindly bring to my notice any such missed-out errors, which can then be eliminated in subsequent printing and editions.

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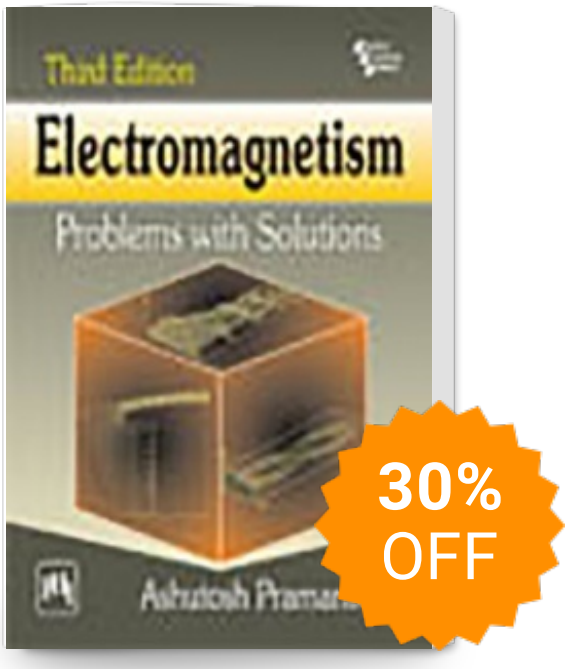

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