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Electromagnetic

Fields

R. V. Buckley

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Over many years the questions set by the various examination boards have improved the teaching of electromagnetic theory. Everyone interested in field theory realises that the subject is very basic to the teaching of electrical engineering as well as physics and owes a debt to the boards for the challenge that new examination questions bring to engineering education.

The author wishes to thank everyone who has helped in the preparation of this book and in particular to express her appreciation of her friend Mr D. H. Trevena, for making many constructive comments and for improving the presentation of the material.

The examination boards accept no responsibility whatsoever for the accuracy or method in the answers given in this book, to actual questions set by them. The answers are the entire responsibility of the author.

Introduction

Although most electrical and electronic engineering courses include the study of electric and magnetic field theory, it is usually recognised that on most courses much of the subject material can be and is separated out under special headings.

The ‘work out’ study covers the electromagnetic theory under seven major headings – electron ballistics is separated from electrostatics and electromagnetic field under steady state conditions, with a section on time-varying fields, Maxwell’s equations and their relations to each media property and finally a section on waveguide developments.

The problems here have been chosen to avoid repetition as far as possible in each of the worked examples and unworked problem sections; some questions require standard proofs, while others have been included to give a general picture of the type of questions asked in examinations.

The questions vary in their level of difficulty, and the author hopes that this will enable the book to be used at several stages of a degree or diploma course.

Examination Technique

No student can expect to pass examinations without a sound knowledge of the subject material to be examined, but he or she may improve their chances by attention to the following.

The Candidate’s Presentation

When a candidate is faced with an examination paper, he or she may avoid common errors (which can seriously prejudice the performance) and present the work most favourably by attention to the following advice.

(a) *Choice* Take time to read through the whole paper, decide on the questions to be answered, and mark them in order of preferences; note any rubric concerning compulsory questions on restricted choice from a sectional paper.

(b) *Timing* Do not spend too much time on a question (e.g. with five questions to answer in 3 hours, not more than 30–40 minutes should be spent on each). It is unwise to persist with complicated and laborious work that seems to be leading nowhere: the answer sought by the examiners is unlikely to involve several pages of analysis.

(c) *Interpretation* Carefully read each question before starting to answer it: answer the question set, not some alternative of your own; do not just ‘describe’ when the question states, compare; do not omit an essential part of the question.

(d) *Presentation* Either read each answer carefully after writing it or allow adequate time towards the end of the examination period, to revise and correct the work.

(e) *Formulae* Do not attempt to memorise extensive lists of formulae. A candidate is expected to know (by common usage and familiarity rather than by a conscious effort of memory) a few simple expressions directly based on fundamental laws and principles. Complex formulae will normally be quoted in the question, or the candidate will be asked to develop them from 'first principles'.

The Examiner's Requirements

In assessing a candidate's ability, the examiner looks particularly for:

(a) Sound knowledge of the appropriate fundamental principles; facility in the analysis of problems based thereon; and a clear and explicit understanding of the methods used and approximations legitimately made.

(b) Facility in numerical and graphical work in the solution of (in the examination sense) 'practical' engineering problems; logical layout of steps in the working; and an appreciation of practical orders of size and of numerical accuracy.

(c) Collective marshalling of logic and critical arguments for and against the choice of methods, equipment and lines of action.

(d) Some knowledge, derived from wider reading and professional motivation, of the general trend of modern developments.

(e) Ability to present descriptive answers legibly, concisely and grammatically; the use, where appropriate, of clear and neat freehand sketches.

Standard Data

Magnetic space constant: $\mu_0 = 4\pi \times 10^{-7}$ H/m

Electric space constant: $\epsilon_0 = \frac{1}{36\pi \times 10^9}$ F/m

Electron charge/rest mass ratio: $\frac{e}{m} = 1.76 \times 10^{11}$ C/kg

Velocity of electromagnetic radiation in free space: $= 3 \times 10^8$ m/s