REVIEWS

Continuum Electromechanics. By J. R. MELCHER. MIT Press, 1981. 605 pp. £38.25.

At first sight the study of this approximately 600 page book produced in a camera-ready 320 mm × 240 mm format appears a daunting prospect. How the reader feels subsequently will depend very much on his academic background and his ability and motivation to spend considerable effort and time digesting all that this learned work has to offer. Undoubtedly it has something for the applied mathematician. It provides an intriguing selection of physically and in general industrially relevant mathematical models of the interaction of electromagnetic fields and perfectly elastic isotropic solids and Newtonian fluids. For the engineer it provides an insight into the way mathematical modelling can be used to unify, by way of analogies, and at the same time clarify, by means of highlighting essential dissimilarities, branches of physics that have been developed independently and thought hitherto to have little or no common ground. I feel that a systematic reading of the text from beginning to end, which because of its level of detailed analysis and its many forward and backward references can be tough-going, is the only way to achieve the maximum benefit. Though a second perusal and an attempt at the numerous examples at the end of each of the eleven chapters is obviously recommended, I doubt whether many save the determined graduate student working in this area or the lecturer searching for material for his lecture courses will do so. Most readers will I suspect be highly selective and examine in detail only those sections that contain material of particular interest to them. However, unless they resist strongly, they will then be drawn inextricably into the other areas of the text by the elaborate cross-referencing system. Therein lies one of the many attractions of the book.

Professor Melcher has succeeded in defining a subject area that crosses the boundaries of several disciplines. There are few who would attempt to embrace classical fluid and solid mechanics, quasi-static electromagnetism, magnetohydrodynamics, thermodynamics and electrochemical phenomena in one volume. His experience in applying mathematical analysis in a wide variety of both academic and industrial contexts has placed him in an eminent position to do so. The very comprehensive nature of the material selected for inclusion in the text and the way in which the various electrical and magnetic interactions are juxtaposed under well-defined conceptual headings cannot fail but leave the reader impressed. A list of the chapter headings will give some idea of the scope of this text (number of pages in brackets):

1. Introduction to continuum electromechanics (6);
2. Electrodynamic laws, approximations and relations (54);
3. Electromagnetic forces, force densities and stress tensors (26);
4. Electromechanical kinematics: energy-conversion models and processes (60);
5. Charge migration, convection and relaxation (77);
6. Magnetic diffusion and induction interactions (39);
7. Laws, approximations and relations of fluid mechanics (50);
8. Statics and dynamics of systems having a static equilibrium (78);
9. Electromechanical flows (64);
10. Electromechanics with thermal and molecular diffusion (41);
11. Streaming interactions (79).

The work is almost completely self-contained. All the necessary mathematical techniques including Fourier and Laplace transforms, and vector and Cartesian tensor calculus are presented. The concept of quasi-static electromagnetics is introduced on the basis of the Chu formulation of the Maxwell equations. By means of appropriate non-dimensionalizations, the familiar field equations of magneto-hydrodynamics and electrohydrodynamics are obtained. The modern continuum-mechanics approach is utilised in that where possible control volumes are considered and the appropriate general principles are postulated in integral form, their pointwise differential equivalents subsequently being derived. In many instances an alternative reasoning from microscale considerations is included for comparison. The relevant constitutive equations are introduced, and the idea of defining models of particular regions of behaviour space by considering the relative magnitudes of the inherent non-dimensional parameters is a theme echoed throughout the text, as is the lumped-parameter approach to modelling.

One can see the depth and, at the same time, breadth of the treatment by considering just one of the specialized areas covered by this text. In electrohydrodynamics, for example, the discussion of bulk charge-transfer mechanisms in fluids follows from postulating quite general evolution and constitutive (flux) equations incorporating mobility concepts and diffusion processes for each contributing species (Chapter 5). By making explicit approximations on the relative sizes of the non-dimensional parameters, a wide range of models of both fundamental and industrial interest is developed. Unipolar and ambipolar models with dissociation and recombination are considered together with 'ohmic' conductivity models, thermal modifications being introduced later (Chapter 10). This background facilitates a discussion of ions in gases, electrolytes and highly insulating dielectric liquids together with macroscopic particle charging. The various interactions between fluid flow velocities and the 'electrical system' are illustrated by reference to an ion-drag anemometer and an electrostatic precipitator. In addition detailed and explicit studies are made of water droplet charging in the atmosphere and in a unipolar d.c. pump, generator or brake. The inclusion of thermal variations permits some mention to be made of thermally induced pumping and electrical augmentation of heat transfer in simple geometries.

As an aid to the student, each chapter contains a synopsis that serves as a study guide. Some in addition contain a final overview that helps to consolidate the more important aspects of the preceding argument. The examples at the end of each chapter are testing, though it is possible to obtain solutions from the author at the cost of reproduction. References in the form of footnotes to textbooks, educational films, reports and articles in research journals, together with a 10 page table of contents, a comprehensive 14 page index and numerous clear diagrams and photographs make this text a valuable addition to one's library. My only quibble concerns the somewhat inelegant production from camera-ready copy, although I can see the importance of keeping the price within reasonable bounds. I recommend the work to both students and researchers. It is the result of many years of study in the area, and should serve as a refreshing reminder of the rich and varied field of problems to be found in the world of electrical engineering of which the microchip is only a part.

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