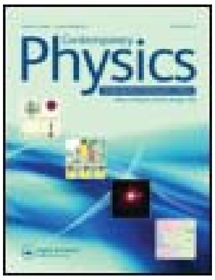

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Computational Methods for Electromagnetic Phenomena: Electrostatics in Solvation, Scattering and Electron Transport, by Cai Wei

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BOOK REVIEW

Computational Methods for Electromagnetic Phenomena: Electrostatics in Solvation, Scattering and Electron Transport, by Cai Wei, Cambridge, Cambridge University Press, 2013, 461 pp. + 19 pp., £80.00 (hardback), ISBN 978-1-107-02105-1. Scope: monograph. Level: postgraduate, researcher.

Electromagnetic phenomena are at the core of a huge range of physical phenomena, from the archetypal child's 'why is the sky blue?' through solvent effects on the conformation of molecules in solution to metamaterials and speculations about invisibility cloaks. The computational methods in this monograph are applicable to these problems, and many more. The book is written at quite an advanced level, for the reader who has reached the stage of wanting to arrive at numerical results for particular cases. Wei Cai has assembled an impressive summary of state-of-the-art numerical methods for solving problems in electrostatics, electromagnetics and transport, and draws on his own experience of modelling a wide range of systems. To cover such a wide field in one volume, though, introductory descriptions of the science and examples of results have both had to be cut to a bare minimum.

The book is divided, as the subtitle suggests, into three parts: electrostatics in solvation, electromagnetic scattering and electron transport. The first two chapters on dielectrics and the Poisson–Boltzmann equation are taken at a fairly easy pace, and with a more detailed explanation of the physics than in some later chapters. More detailed numerical methods for the Poisson–Boltzmann equation are covered next, in terms of boundary element, finite element and immersed interface methods. The descriptions are careful and mathematically rigorous. Finally in this section, a chapter is devoted to algorithms for dealing with the long-range (Coulomb) interactions which are so crucial in applying molecular dynamics simulations to solvation problems.

Moving to the scattering of electromagnetic waves, the problem of imposing appropriate boundary conditions for outward-travelling radiation is addressed. For harmonic waves, approaches to layered media through dyadic Green's functions and surface integral equations are explained, as well as finite element methods including edge elements. A chapter on time domain methods, which are useful for transient problems and for situations in which the materials are non-linear, draws useful comparisons between discontinuous Galerkin finite element formulations and the Yee finite difference approach. The special cases of periodic structures and surface plasmons are treated in detail.

The description of electron transport includes Wigner transport and non-equilibrium Green's functions. For the latter, interesting parallel discussions are given of finite difference and finite element methods for one-dimensional and two-dimensional devices. Practical issues in applying the Wigner transport equations are derived. After these quantum transport models, the text returns to semi-classical models, applying a variety of finite difference methods to the hydrodynamic equations derived from the Boltzmann transport equations. Finally, quite brief derivations are given of schemes for tackling transport in plasmas: a Boltzmann–Fokker–Planck solver, a particle-in-cell method, and a finite difference solver for the magnetohydrodynamic equations.

This is not a book for somebody who is unfamiliar with the science of the topics covered, but as a compendium of algorithms, with critical insights, it excels. It deserves a place on many reference shelves.

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