# In Search of the Ultimate Building Blocks

Gerard 't Hooft
*Cambridge U. P., New York, 1996.*
*203 pp. $39.95 hc*
*ISBN 0-521-55083-1*

Gerard 't Hooft is one of that handful of 20th-century physicists whose reputations were made by work completed while they were still in graduate school. Now, a quarter century later, he offers *In Search of the Ultimate Building Blocks*, his account of the great intellectual adventure in which he participated: the development of what has come to be known as the "standard model" in particle physics.

It is important to emphasize what this book is not. It is not, nor does it pretend to be, a comprehensive history of particle physics or even of particle theory. It is, rather, simply a highly personal account by an important participant who entered the chase fairly late in the game. And, as the author freely admits in his preface, it tends to exaggerate his personal role by focusing on those aspects of the development in which he was most active. One positive benefit of this idiosyncratic perspective is that it more fully documents the key role played in this story by 't Hooft's mentor, Martinius Veltman.

Though the book is written with some hope of reaching a general audience, it would be an extraordinarily difficult read for anyone without a strong background in modern physics. It is also a bit nationalistic, emphasizing the many important contributions to our contemporary physical worldview by physicists from the tiny nation of the Netherlands.

All of this said, it is also important to emphasize what this book does accomplish. It gives a remarkable account of what might be called the interior dialogue of particle theory, the ferment involving theorists and their ideas that is not readily apparent from reading the finished product—the published record. Even an experimenter who was active in the field and closely followed the theoretical literature is likely to have missed much of this story. This is particularly true because, while the standard model is a triumph of fundamental field theory, that line of development occupied only a small part of the theoretical community and did not always interact closely with experiment.

In retrospect, 't Hooft shows that the key step came in 1954, with the development of the Yang–Mills field theories. In their time, these were simply looked upon as a clever-but-failed effort to understand nuclear forces. Their triumph had to await the discovery of the proper elementary entities a decade later, followed by a heroic effort to construct theories that preserved symmetries and renormalizability while giving particles their mass.

The treatment of events prior to 't Hooft's arrival on the scene in 1970 shows that he is not always fully aware of the context of some of these early discoveries, although he does get most of the basic facts straight. And he garbles the celebrated story of Enrico Fermi's dismissal of particle nomenclature as "botany."

The book concludes with a valuable discussion of possible successors to the standard model, including grand unification, technicolor, supersymmetry and superstrings. It provides a lucid explanation of the motivations behind these theories and of their advantages and disadvantages, along with speculations about the possible form of a true "theory of everything." Here, 't Hooft reveals his philosophical bias, which includes a "neo-Einsteinian" hope that quantum theory may yet prove to have a deterministic substrate, a point of view nearly unique among contemporary theorists.

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# Computational Methods for Fluid Dynamics

Joel H. Ferziger
and Milovan Perić
*Springer-Verlag, New York, 1996.*
*356 pp. $49.50 pb*
*ISBN 3-540-59434-5*

At the mention of computational fluid dynamics, or CFD, one might think of the explosive growth of computer capabilities over the past 50 years. To illustrate: John von Neumann wrote in 1947 that one could make a start at the numerical simulation of turbulent fluid flow, but that a mesh of 8 points on a side would require a total of 512 mesh points and that there is no machine "in sight for several years to come" that could handle 20 points on a side, for a total of 8000. (There was one within two decades.) Actually, the use of 512 points on a side, or 134 million points, is possible on present-day large-scale parallel computers. Eight thousand points on a side will probably take another 15 to 20 years of growth in computer capability.

But CFD is more about getting the most out of the computational resources at hand, not what those resources are. It is also about transform-

ing the nonlinear continuum equations of fluid mechanics to an appropriate set of discretized equations and then determining tactics for solving these equations on a computer in an efficient manner. A complication is that fluid mechanics covers many diverse phenomena; strategies for this discretization process must be similarly diverse. This may be one reason that good books on CFD have been few and far between. However, in *Computational Methods for Fluid Dynamics* Joel H. Ferziger and Milovan Perić have provided an excellent reference and self-study text for practicing physicists and engineers who find themselves involved in the analysis of fluid flows, as users of commercial codes or as developers of new codes. It is also suitable as a graduate-level text in CFD.

Although their book covers finite-difference and spectral methods in some depth, Ferziger and Perić pay special attention to finite-volume methods, as these are the most versatile for complex geometries and are natural discretizations of the conservation laws of fluid mechanics. The authors strike a good balance in their presentation, avoiding oversimplification of the issues but also unnecessary complication. At the end of most chapters, they present sample results illustrating the successes and possible failure modes of the algorithms developed in those chapters. The discussions of the various approaches contain many caveats (giving the impression that Springer-Verlag's legal department had a hand in editing the manuscript). However, the reader does get a realistic picture of the many pitfalls that await the user.

The book contains a thorough discussion of various linear-equation solvers as a part of the arsenal to attack nonlinear CFD problems, from Gauss elimination and Jacobi and Gauss–Seidel iterative schemes to biconjugate gradient and multigrid methods. Also included are various approaches to constructing a grid system and their pros and cons, including the treatment of complex geometries and adaptive mesh refinement. The solution for the pressure field in an incompressible flow is covered in depth, while the coverage of methods for compressible effects and free surface flows is less thorough but is adequate for most purposes.

One difficulty encountered in most applications is the treatment of turbulence. One approach, called direct simulation, is to use a mesh sufficiently fine that all the important scales of turbulence are explicitly represented, including the energy dissipation range. However, this method is computationally intensive and limited to low Reynolds numbers. Alternatively, one

can model the stresses due to all the turbulent scales in the Reynolds-averaged Navier–Stokes equations, or one can compute the motions of the largest turbulent scales (large-eddy simulation) and model only the subgrid-scale stresses. All three approaches are astutely covered in the present volume, as the authors have many years of productive research in these areas.

All in all, this is an excellent book, eminently suitable as a graduate text and also valuable to those who need to get reliable results for difficult flows. A number of sample programs are available from the publisher on the Internet, at ftp.springer.de.

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## Empire of Light: A History of Discovery in Science and Art

Sidney Perkowitz
*Henry Holt, New York, 1996.*
*227 pp. $27.50 hc*
*ISBN 0-8050-3211-8*

The ambitious goal of Sidney Perkowitz's *Empire of Light* is to "weave together science and aesthetics, technology and art, to bring [the reader] a coherent sense of light that will transform [our] vision of the world." Whether the author achieves this lofty goal remains, in my opinion, questionable.

The discussion of light given by the author makes for pleasant enough reading. After a discussion of our understanding of vision, it follows the logical thread that would be expected from a physicist, discussing the classical view of light, its modern quantum mechanical description, ways to produce and manipulate light and finally some applications. Substantial space is given to historical perspectives, and many connections to the visual arts, mainly painting, are given throughout the text. Most of the key scientific players are mentioned, although P. A. M. Dirac somehow failed to make it. The author is clearly very enthusiastic about his topic, and he does a good job of communicating this enthusiasm to the reader. The writing is usually crisp, and I found the book easy to read.

But in the end, there is really no surprise. The discussion of the connection between the science of light and the visual arts remains quite superficial, never transcending the technical and mechanical levels. As such, it is quite obvious that the book was written by a physicist. It lacks the alternate, and similarly interesting, worldview that would be offered by an artist. Maybe that is an impossible task, since most artists do not benefit from the unified (although somewhat sterile) view of light offered by Maxwell's equations, but rather approach this subject in many very personal and vibrant ways that can't easily be summarized in a few hundred pages. But because this alternative view of light is not really represented in the book, my hope for a profound, larger picture that would "transform [my] vision of the world" never materializes. So maybe the problem is that the author's preface led me to expect too much.

Even within the more limited goal of raising some awareness of the connections between the physics and engineering of light and the visual arts, the book suffers from a major and possibly fatal flaw. It doesn't contain any illustrations: no reproduction of a painting discussed in the text, no picture of a laser or of a synchrotron source, no astronomical spectrum, no simple line drawing to help with an explanation.

The book is aimed at a large audience—not just physicists and artists, but also, one would hope, primarily other educated and inquisitive readers interested in gaining a better understanding of what light is all about and how important it is to us. To assume that such an audience would be familiar with, say, Edward Hopper's painting *Summer Evening* is, I believe, expecting much too much. And to assume that this same audience can visualize the Lawrence Livermore NOVA system from the ten-line description given by the author also requires a major leap of faith. I cannot comprehend why the author chose not to take advantage of the power of illustration, especially in a general-audience book concerned with light, colors and images. This just makes no sense to me. Finally, I cannot leave unmentioned the fact that I was occasionally quite annoyed when the author seemed carried away by his own prose. For instance, could anybody tell me what is meant by the following: "We create and carry fields of order through an enigmatic cosmos. If we do not yet understand light, our minds know how to assemble its wave-particles into comprehension." But this is a minor point, really, compared to what I consider to be the overwhelming problem with *Empire of Light*.

Summing up, my general view of this book is that, if only it had illustrations and some "truth in advertising," it would be a fine present to those brave souls who sometimes ask us what we spend our days doing after we leave home in the morning. It is