Statistical Dynamics (*à la* Maxwell) Homing on Coarse-Grained Continua

Granular Matter: An Interdisciplinary Approach

Edited by Anita Mehta
Springer-Verlag, New York, 1994. 306 pp. $89.00 hc
ISBN 0-387-94065-0

Reviewed by Robert W. Cahn

After examining this book, written by a motley mix of physicists, chemists, engineers and computer modelers, I am tempted to offer a new definition of a researcher: one whose inborn curiosity, unlimited but disciplined, leads him or her into ever more astonishing byways of investigation. *Granular Matter: An Interdisciplinary Approach* covers an extraordinary range of topics, which are united only by the fact that the solid matter being investigated consists of many grains rather than just one piece.

Any small child knows that dry sand flows; early clocks and egg timers depend upon it. Ask whether the rate of flow depends upon the "sandostatic" head, by analogy with a liquid, and you approach the core of this book, which makes it clear that a powder or sandpile does not behave exactly like a liquid.

The editor, Anita Mehta, starts off with a chapter on "Where It All Began," discussing the characteristics of sandpiles and what drives them to critical behavior when they can no longer remain at rest. She explains how the configurations of small groups of grains can be generalized to derive macroscopic properties. However, Mehta's claim that this kind of study is only a few years old is no more than partly true: The dynamics of sandpiles, as elegantly outlined in her introduction, may be new, but the use of sandpile stability is much older: A mechanical engineer, Arpad L. Nadai, in his seminal book on continuum plasticity, *Plasticity: A Mechanics of the Plastic State of Matter* (Engineering Society Monographs, 1931), described an extensive body of work in which the "plastic stress function" across a rod of irregular cross section that is subjected to torsion can be accurately simulated by measuring the height at each point of a critical sandpile resting on a flat surface that has been cut into the shape of the cross section. This function determines the way strain penetrates into the rod as the torsional moment is increased. (Another well established subdiscipline that receives no mention in this book is that of the fluidized bed—for example, a sandbath through which gas is bubbled to produce behavior like that of a true fluid.)

The various chapters in the book all cover, from different perspectives, the relationship between the behavior of small configurations and that of large assemblies of particles, which may be spheres of homogeneous size, mixtures of two size populations, or particles of irregular profile or elongated shape. Concern may focus on density of packing, on mobility under stress or on friction at the walls of the containing vessels. In a sense the book might be described as statistical dynamics (*à la* Maxwell) homing on "coarse-grained continua."

Much of the work discussed entails computer simulation. (It is not hard to watch a sandpile, but it is not at all easy to make significant measurements on it.) Whether a particular computer simulation accurately mirrors reality may be open to question, but in general, simulations certainly are more apt than actual experiments to produce quantitative distributions of various kinds.

For readers not actively engaged in any part of the field, two chapters stand out from the rest. One is a theoretical treatment of the compaction of powders, written by Sam Edwards of the Cavendish Laboratory in England. He convincingly introduces entropy considerations into the discussion of "compactivity" (which he defines accurately), and he even manages to identify a temperature analog that determines the "equality of powders in juxtaposition." This chapter is not easy to follow but amply repays the effort. The other fascinating chapter is by a chemist, Paul Bartlett of Bristol, England, and a physicist, William van Megen of Melbourne, Australia, about the "crystallography" of hard-sphere colloidal suspensions. (Much of the experimental work they describe was stimulated by a classic 1980 paper by an Australian, John V. Sanders, who showed by electron microscopy that natural opal consists of a regular array of colloidally sized silica spheres glued naturally into a stable assembly.) Bartlett and van Megen describe the formation of stable "crystalline" arrays from a mixture of hard colloidal spheres in suspension; the spheres have two populations of different size, and the crystalline structures formed depend on the size ratio and the relative volume fractions. This kind of research is in the process of creating an entirely new branch of crystallography.

Most readers will want to pick and choose what they read in this compilation, but it would be a dull physicist indeed who did not find something here to whet his or her appetite.

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Self-Assembling Amphiphilic Systems

Gerhard Gompper and Michael Schick
Academic, San Diego, Calif., 1994. 191 pp. $55.00 hc
ISBN 0-12-220316-X

Self-Assembling Amphiphilic Systems by Gerhard Gompper and Michael Schick is the 16th volume in the series Phase Transitions and Critical