Adding Weight to the Scanty Bookshelf on the Study of Granular Materials

Pattern Formation in Granular Materials

Gerald H. Ristow
Springer-Verlag, New York, 2000. $96.00 (161 pp.).
ISBN 3-540-66701-6

Sands, Powders, and Grains: An Introduction to the Physics of Granular Materials

Jacques Duran
(translated from French by Axel Reisinger)
Springer-Verlag, New York, 2000. $59.95 (214 pp.).
ISBN 0-387-98656-1

Reviewed by Robert P. Behringer

The study of granular materials was totally absent from the physics literature until little more than a decade ago. In the late 1980s, Per Bak, Chao Taug, and Kurt Wiesenfeld published a now famous paper in *Physical Review Letters*, volume 59, page 381, 1987, proposing the theory of self-organized criticality, in which they used sand piles as a paradigm for a large class of complex systems: earthquakes, avalanches, forest fires, epidemics—systems that might be expected to show self-similar behavior. In the next year or so, three additional papers appeared in the same journal: one on granular convection, one on sand-pile avalanches, and one—on wave phenomena in a simple granular flow—with a title very similar to that of Gerald H. Ristow's new book *Pattern Formation in Granular Materials*. I was coauthor of the last of these, and I remember well one referee's very serious comment that studies of granular materials were appropriate for engineering journals, not for *Physical Review Letters*.

In the intervening years, a deep fascination has developed within the physics community for the rich and complex phenomena that occur in all aspects of granular materials, from static systems to the rapid flow that occurs in real-life avalanches. Accompanying this growing interest has been a dramatic increase in contributions to the literature from authors within the physics community. The phenomena that have drawn this interest include complex spatiotemporal fluctuations that occur in static or nearly static systems (so-called stress chains); complex waves and flows that occur when granular materials are shaken; segregation, or separation, of differing types of materials that seems to defy our concepts of entropy; and instabilities in dilute, gaslike systems, leading to the formation of clusters that make granular "gases" distinct from their classical elastic-hard-sphere gas cousins. The list of unanswered questions is long. We have at best fledgling theories or models of a fundamental first-principle nature. Arguably, we are at the same stage with our models of granular materials as scientists were with Newtonian fluids one to two centuries ago.

Although there has been a flood of papers dealing with recent developments concerning granular materials, few monographs have been published on the topic—an exception being the book by Jacques Duran, (*Sables, Poudres et Grains*, Eyrolles, Paris, 1997) newly translated by Axel Reisinger and published as *Sands, Powders, and Grains*. Thus, Ristow's work is a welcome addition.

Ristow has chosen to review recent work in several sub-areas of granular materials, including flows induced by various types of shaking; stratification, mixing, and segregation; flows in hoppers; flows in rotating drums; and an appendix on numerical methods. There are also introductory and concluding chapters. For instance, in an early chapter, the author covers basic concepts such as dilatancy and angle of repose. He also provides a brief discussion of fluctuations and a useful table of some material properties. In two chapters on shaking, he discusses many of the recent experiments and molecular dynamics simulations for both vertical and horizontal shaking. Included are studies that describe compaction, surface patterns, and flows for vertically shaken systems, and that explore the fluid–solid transition (related to Mohr–Coulomb failure) in horizontally shaken systems. In a chapter on stratification, Ristow reviews experiments on avalanching, drum and hopper flows, and continuum and discrete models. He presents a brief section on fluctuations and flow properties for hoppers, and, in the most extensive chapter, he presents results on flow regimes and segregation phenomena in rotating drums. It is perhaps this last area that most represents the author's own area of research.

The style of these presentations is a straightforward review of results, which is particularly valuable to a reader who would like a broad description of much of the field. However, the descriptive approach does not always give insight into the relative importance of the topics that are discussed. Furthermore, some areas are left uncovered. For instance, the author does not describe recent work on granular gases or on microscopic models, such as the q model of Susan Coppersmith and colleagues, or the three-leg model of Jean-Philippe Bouchaud, Michael Cates, Philippe Claudin, and Joachim Wittmer. Similarly, he has not considered recent work on constitutive modeling that was stimulated by this microscopic modeling. Nor does he treat jamming and connections to jammed systems such as foams or colloids, or granular gases (including clustering). Nevertheless, there is a wealth of information in this work. In particular, the author provides an extensive bibliography that should be very useful to those with a relatively sophisticated interest in the field. The style of this work is actually much like that of a review article. Specifically, it provides brief summaries of various areas relevant to the subjects covered. The writing is clear and the organization sensible.

It is also interesting to compare this monograph to the comparably sized work by Duran. Ristow's work is written much more with the idea of

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providing a review of recent work. In contrast, Duran's book is didactic in style and provides an excellent starting point for an advanced student to enter the field. In Duran's work, there is considerable discussion of the physical principles involved and of simple models such as the Janssen model for stresses in a silo. There is a greater emphasis on models and mechanisms than in Ristow, but there is probably less of an attempt to be inclusive of all the recent work in this area. As with Ristow, the prose is clear. Both these volumes would be valuable additions for those with interest in the field.

Heavy Quark Physics

Aneesh V. Manohar
and Mark B. Wise
Cambridge U. Press, New York, 2000. $64.95 (191 pp.).
ISBN 0-521-64241-8

Intense experimental and theoretical studies of heavy quark systems have allowed for precise measurements of fundamental parameters of the Standard Model of electroweak interactions. The inherent difficulty in extracting these parameters is that the strongly interacting particles created in the laboratory, such as the B meson or the Λ_c baryon, are nonperturbative composites of the quark and gluon fields whose dynamics are defined by the Standard Model. The theoretical framework with which heavy quark systems are understood and described has evolved from the phenomenological models of the strong interaction of the early 1980s to that of the rigorous heavy quark effective field theory used today.

The monograph *Heavy Quark Physics*, by Aneesh V. Manohar and Mark B. Wise, is the first text devoted to the theoretical treatment of heavy quark systems. This is a detailed and well-thought-out presentation by two world-renowned experts on the theoretical techniques used to understand high-precision data on systems containing heavy quarks. The symmetries uncovered by Nathan Isgur and Wise (both recipients, along with Mikhail Voloshin, of the 2001 J. J. Sakurai Prize from the American Physical Society) that become manifest in the heavy quark limit form the backbone of this text and enable Manohar and Wise to move seamlessly among different aspects of heavy quark physics. With the introductory chapter providing a concise review of the Standard Model, loops, and effective field theory techniques, it can be considered self-contained. However, a firm background in field theory and particle phenomenology allows for a much more rewarding experience with this text. It is oriented toward those who wish to learn to calculate various quantities of importance in heavy quark systems and provides all the details necessary to do so. At the end of each chapter, problems are given that either develop a point discussed in the chapter or enable the reader to tackle issues beyond those discussed. References to important published papers relevant to the content of each chapter are also included.

After a thorough discussion of relations between observables that are a direct result of the spin and flavor symmetries existing in the heavy quark limit, such as those between matrix elements for $\mathrm{B}^{(*)} \to \mathrm{D}^{(*)} e \bar{\nu}_e$ decay, the text moves on to discuss the implementation of corrections to the heavy quark limit. These corrections allow a connection with the charm and bottom quark sectors. Considerations of the perturbative quantum-chromodynamic (QCD) corrections in $\alpha_s(M_Q)$, including matching for heavy–heavy and heavy–light currents, and of nonperturbative corrections in $\Lambda_{\mathrm{QCD}}/M_Q$, including discussions of Luke's theorem, culminate in the determination of the weak mixing angle V_{bc} from exclusive B meson decays.

The synthesis of heavy quark and chiral symmetry necessary to describe the low-momentum processes of baryons and mesons containing heavy quarks, such as strong decay widths and the radiative decays of the D^* mesons is detailed. A nice comparison is made here among the implications of the D^* widths for constants in the heavy quark chiral Lagrangian, results from lattice QCD, and predictions of the nonrelativistic quark model. However, the reader is left wanting more on this subject, as the discussion could have been somewhat more detailed and could have included heavy baryons.

The area of inclusive weak semileptonic decays, which developed somewhat after the initial work on the impact of heavy quark symmetries on exclusive decays and on meson spectroscopy, is discussed in great detail. After addressing important issues concerning the endpoint of the electron spectrum in $\mathrm{B} \to \mathrm{X}_c e\nu$ and $\mathrm{B} \to \mathrm{X}_u e\nu$, a determination of V_{bc} made possible by these tools is presented.

In recent years, much effort has been spent on understanding systems with more than one heavy quark. However, this text is clearly focused on detailing the accomplishments in systems with only one heavy quark, and discussion of nonrelativistic QCD is confined to only a brief outline.

To summarize, this is a wonderful text for graduate students in particle and nuclear physics who are interested in learning the tools of heavy quark physics from two of the experts in the field. This book is a must for both particle theorists and experimentalists who are currently researching heavy quark systems. In many ways, this text should be considered a sequel to Howard Georgi's *Weak Interactions and Modern Particle Physics* (Addison-Wesley, 1984).

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Iron, Nature's Universal Element: Why People Need Iron & Animals Make Magnets

Eugenie Vorburger Mielczarek
and Sharon Bertsch McGrayne
Rutgers U. Press, New Brunswick, N.J., 2000. $30.00 (204 pp.).
ISBN 0-8135-2831-3

Earth's living systems use nearly every element, but iron plays a particularly important role, and it is not clear that it could be replaced by other elements. Eugenie Mielczarek, a physicist, and Sharon McGrayne, a science writer, describe in their very readable *Iron, Nature's Universal Element* the importance of iron for life. The book is entertaining, amusing, and challenging and, despite the elementary level, contains some new information for most readers.

One could expect that a popular book, covering topics from the origin of life to bird migration and the ecosystem, would contain some mistakes. I did not find any; besides being very careful, the authors had the book reviewed for scientific accuracy by many of their friends. A brief description of some of the topics covered and some quotes will give an idea of the wide range covered and of the style of the authors.

In the first chapter, the authors describe the emergence of life, nearly four billion years ago. Life began without oxygen, and relics of this early time most likely survive deep in the oceans, in complete darkness and under immense pressure. The actual origin of life is not known with certainty, but the authors provide a balanced brief review of a conceivable beginning, in which iron is part of the