Book Review

Granular Media: Between Fluid and Solid by Bruno Andreotti, Yöel Forterre, and Olivier Pouliquen, Cambridge University Press, 2013; ISBN: 978-1-107-03479-2 (hardback), USD 110.00

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Granular media surrounds us: piles of snow accumulate in our driveways, we build sand castles at the beach, and we combine flour and sugar in baking. Despite its prevalence, the physics of both, static and dynamic granular media, is little more than an accumulation of phenomena. In *Granular Media: Between Fluid and Solid*, the authors strike a beautiful three-way balance between a research monograph, a historical description of the developments in the field, and a textbook introduction to the subject. They achieve all three simultaneously. For example, recent theoretical work on the rheology of granular flows by Ken Kamrin of MIT is included (Sect. 6.2) as well as a description of how Egyptians used granular media to erect statues (Sect. 1.3).

Granular media as a subject is fascinating in part because of counterintuitive behavior. An example is that the flowrate of sand out the bottom of a bucket is independent of the height of sand in the bucket, which was discovered by Jenssen in 1895 (Sect. 3.4). This is clearly in contrast to a fluid where the discharge scales with the square root of the height of water. Many interesting and counterintuitive phenomena are presented in boxes isolated from the text. The singing sand dunes, the most famous peculiarity of granular media, are presented in one such box in Sect. 3.5.

Another fascinating feature of granular flows is their wide applicability. Quantifying avalanche run-out (Sect. 9.1.2), drug administration, sediment

transport in rivers (Sect. 9.4), and food storage all depend heavily on the physics of granular media. A central difficulty in modeling these phenomena is the varied behavior of the granular media: in some cases, the grains behave as a solid (Sects. 3, 4), sometimes as a gas (Sect. 5) and still other times as a liquid (Sect. 6). Yet there is still no rheology or theory that unites all of these regimes. Hence, when modeling granular media, a case-by-case approach is required. In the last chapters, ANDREOTTI *et al.*, use the insight developed throughout the book to examine important applications of granular flows in geophysics. Topics include soil liquefaction (Sect. 7.3.2), Aeolian transport (Sect. 8.5), sand dune migration (Sect. 9.2), and the geomorphology of coastlines and deltas (Sects. 9.3.2, 9.4.2). The method of analysis is to describe the physics qualitatively, allowing the important features to not be lost in equations, and to draw connections between problems.

Granular Media: Between Fluid and Solid is a welcome step forward in its clarity of composition, descriptions of phenomena, and qualitative discussions and quantitative analysis of applications. The material is accessible for all graduate students in physics, chemistry, applied mathematics, and engineering. It would also serve well as a textbook for an advanced graduate course.

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