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# Book Review

**Suspension Acoustics, S. Temkin. Cambridge University Press (2005). xviii + 398pp., price £60, US$110 (hardback), ISBN: 0-52184-757-5**

What fluid, at normal temperature and pressure, has the same sound speed as air but 1000 times the density? The answer may be found by reading the first few pages of *Suspension Acoustics*. With the aid of graphic examples drawn from measurements in the literature—many of them from his own laboratory—the author introduces us to the intriguing world of two-phase media. Suspensions consist of particles (solid, liquid, or gas), which are dispersed in a host fluid (gas or liquid). Provided one considers the dynamics of the resulting composite medium on scales large compared with the inter-particle spacing $L$, the suspension can be considered as a homogeneous fluid. However, the acoustic properties of this equivalent fluid may be very different from those of its constituent phases.

Temkin provides a clear exposition of suspension acoustics at a level suitable for graduate students. Beginning with fundamentals, he leads the reader through a systematic account of the ways in which particles—mostly spherical, as a result of surface tension in bubbles, droplets and emulsions—interact with their host fluid under the influence of sound waves. The interaction processes are thermodynamic, as well as dynamic; that is, they involve inter-phase heat transfer, as well as momentum transfer via particle drag. The expository style is attractive, and the author's approach is reminiscent of Landau and Lifshitz in its tendency to emphasize fundamentals; for example, restrictive assumptions about equations of state are avoided, so the results obtained are of wide applicability. Insightful physical interpretations, along with numerical illustrations of key results, help to keep the reader's interest engaged.

The book's scope is broad, in the sense that a range of physical phenomena in suspensions is discussed: particle drag, particle heat transfer, volume and shape oscillations, particle interactions, and agglomeration. All these are dynamic phenomena, encountered when a suspension is acoustically excited. The reader will discover a number of limitations: not surprisingly, given the title, the book's emphasis is almost exclusively on small-amplitude motion. This allows the author access to all the tools of linearized theory, including an intriguing application of the Kramers–Kronig relations. However, even within this limitation, little is said about non-spherical particles. In fact the whole area of computer simulation, where the full equations for the constituent phases are solved numerically for a domain containing a large number of particles, is hardly touched on. It might be argued that the present book provides the fundamental starting point required for such numerical studies; on the other hand, a more modern treatment would probably give less weight to analytical solutions (and analytically-tractable models), preferring to use these as benchmarks rather than as the sole basis for interpreting measured data.

A second gap in the book's coverage is the topic of high-frequency scattering. Two length scales necessarily occur even in a monodisperse suspension (where the particles are all the same): the particle size $l$, and the inter-particle separation $L$. Interaction of a sound wave with suspended particles introduces at least two other length scales: the acoustic wavelength in the host fluid ($\lambda_0$) and the viscous penetration depth ($\delta_0$). The limiting case of scattering by an isolated particle ($L \gg \lambda_0$, $\delta_0$) is well understood; for simple shapes like spherical and cylindrical particles, analytical solutions are available. In particular, when $l/\lambda_0 \geqslant 1$, a significant fraction of the energy incident on the particle is scattered, that is, reradiated in other directions. However, Temkin focuses on absorption—the loss of acoustic energy due to fluid-particle interaction—and scattering in the sense of directional redistribution is hardly mentioned. The much more difficult problem of scattering by a sparse array of particles ($L/\lambda_0 \sim 1$), where one has to consider multiple scattering, is not touched

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on in the book; the analogous problem in optics has inspired much work on efficient numerical methods for this situation.

At frequencies sufficiently low that $L \ll \lambda_0$, on the other hand, the propagation of sound through a suspension can be modelled by treating the suspension as an equivalent homogeneous medium, whose properties follow from considering the particle–fluid interactions only at the lowest level of detail: namely the volume pulsation, heat transfer, and drag associated with the particles. It is this approach that Temkin exploits to great effect, in a systematic and powerful manner.

A book review might be expected to indicate competing titles and to briefly compare their merits, but I know of no comparable book on offer. *Suspension Acoustics* is a masterly survey based on a lifetime's work in the field. This reviewer is pleased to acknowledge that his own interest in sound propagation through bubbly liquids and dusty gases was sparked by Dr. Temkin 40 years ago, when they were colleagues at Bolt, Beranek and Newman Inc.; it has been instructive, and a pleasure, to review what has evidently been a labour of love on the author's part.

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