Book Reviews

A Problem in Dynamics

The Theory of Rotating Fluids. H. P. GREENSPAN. Cambridge University Press, New York, 1968. xii + 328 pp., illus. $15. Cambridge Monographs on Mechanics and Applied Mathematics.

The paradoxical way in which gyroscopes react to external influences is well known: the spinning mass of metal tends to twist not about the line of action of any newly applied torque but about a perpendicular axis; precessions result, which are of great importance for vehicular attitude control. The reactions of rotating fluids (liquids or gases) to external influences are even more tortuous and paradoxical. However, the intensive study to which they have been subjected in the past two decades did not have primarily technological motives: rotating fluids are still rather too unpredictable for use in engineering components, except in such relatively simple operations as centrifugal separation.

The motives, rather, have been mainly geophysical. The earth's great fluid masses—the liquid core, the ocean, and the atmosphere—are strongly influenced, in the way they react to the forces (of largely thermal origin) tending to move them, by the fact that they are in large-scale rotary motion with the angular velocity of the earth. Their motions relative to that large-scale rotation constitute the atmospheric weather and the ocean circulation, with their importance for the ecology of all kinds of living things, and the core eddies, with their geomagnetic importance. Scientists, motivated by these geophysical considerations, have increasingly sought clues to the basic dynamics of rotating masses of fluid by studying theoretically their motion under a great variety of external influences and comparing the results of those studies with laboratory experiments wherever possible.

The body of science so built up, laying emphasis on comparing theory and experiment for such movements of rotating masses of homogeneous liquid as can be realized in the laboratory, but referring often to specific geophysical phenomena that may be in part illuminated by individual studies of this kind, is excellently described in this well-written book. On the even more complicated subject of rotating stratified fluids, the book includes only a small amount of material, but enough to make the reader quite clearly aware of the possibility that particular phenomena may be grossly altered by stratification and of the need for careful scrutiny of this aspect in geophysical applications.

The central phenomena described, each from several points of view, are Ekman layers, Taylor columns, spin-up, inertial waves, Rossby waves, forced motions (and decaying disturbances) within a uniformly rotating container, and motion within a precessing container. Most of these important but complex and to some extent "unexpected" phenomena are first introduced in chapter 1 through simple experiments and elementary theoretical ideas. Their nature in certain limiting cases that possess considerable practical significance, while allowing simplification of theory through linearization, is described in the very long second chapter. The understanding so achieved is then used as a framework for explaining the meaning of various harder pieces of theory, valid in other (essentially nonlinear) cases, in chapter 3. Excitation of inertial waves (and of their limiting case, the Taylor columns) is the main theme of chapter 4. To balance the concentration on essentially laminar flow in most of the book, chapter 6 gives a good account of criteria for instability, including instability of Taylor vortices, Ekman layers, and vertical shear layers, as well as "baroclinic instability."

Discussions, in chapter 5 and elsewhere, concerning extensions of the book's central ideas into the enormous field of oceanography are for reasons of space somewhat slender. Stratification introduces more complexities even than those that are mentioned: it profoundly alters inertial waves; on a rotating spherical earth, it especially permits extra "baroclinic" modes, and does not bring about the "loss of effective stretching of vortex lines" that (in the context of flow in a cylinder) is noted on page 127. Again, "inertial boundary layers" are, possibly, of uncertain application to the depth-averaged equations for a real ocean, because the depth-averaged inertial terms are approximated in the theory in such a manner that their inaccuracy is both large and variable in form (depending on current distribution in depth).

The main section of the book, chapters 2 and 3 on contained rotating fluids, has many outstanding features, which include the making of several important distinctions. With the convention that the axis of rotation is vertical, containers whose curves of constant "height" (from top to bottom) are a set of closed contours behave in one way: "geostrophic" motions outside the Ekman boundary layers tend to be excited with flow around those curves. When, however, those curves are not closed but terminate on a vertical boundary, it is waves of generalized Rossby type that are excited in forced motions or disturbance decay. A quite different degenerate case is that of a container of uniform height, which would permit any geostrophic motion. Then it is the mass balance of flow in and out of Ekman layers that forces the geostrophic motion to be irrotational, and a further crucial distinction then depends on whether the fluid region is or is not simply connected. In these degenerate cases vertical shear layers are often present. The clear account of this complex topic is one more excellent feature of this permanently important book.

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Atmospheric Event

Lightning. MARTIN A. UMAN. McGraw-Hill, New York, 1969. xvi + 272 pp., illus. $13.50. McGraw-Hill Advanced Physics Monograph Series.

The subject matter covered by the title *Lightning* is so vast it is inconceivable that any single volume could do it justice. The phenomenon of lightning is of such impressive drama and power that it has an important