Fluid mechanics

PHYSICS

INTRODUCTION

Fluid mechanics, science concerned with the response of fluids to forces exerted upon them. It is a branch of classical physics with applications of great importance in hydraulic and aeronautical engineering, chemical engineering, meteorology, and zoology.

The most familiar fluid is of course water, and an encyclopaedia of the 19th century probably would have dealt with the subject under the separate headings of hydrostatics, the science of water at rest, and hydrodynamics, the science of water in motion. Archimedes founded hydrostatics in about 250 BC when, according to legend, he leapt out of his bath and ran naked through the streets of Syracuse crying “Eureka!”; it has undergone rather little development since. The foundations of hydrodynamics, on the other hand, were not laid until the 18th century when mathematicians such as Leonhard Euler and Daniel Bernoulli began to explore the consequences, for a virtually continuous medium like water, of the dynamic principles that Newton had enunciated for systems composed of discrete particles. Their work was continued in the 19th century by several mathematicians and physicists of the first rank, notably G.G. Stokes and William Thomson. By the end of the century explanations had been found for a host of intriguing phenomena having to do with the flow of water through tubes and orifices, the waves that ships moving through water leave behind them, raindrops on windowpanes, and the like. There was still no proper understanding, however, of problems as fundamental as that of water flowing past a fixed obstacle and exerting a drag force upon it; the theory of potential flow, which worked so well in other contexts, yielded results that at relatively high flow rates were grossly at variance with experiment. This problem was not properly understood until 1904, when the German physicist Ludwig Prandtl introduced the concept of the boundary layer (see below Hydrodynamics: Boundary layers and separation). Prandtl’s career continued into the period in which the first manned aircraft were developed. Since that time, the flow of air has been of as much interest to physicists and engineers as the flow of water, and hydrodynamics has, as a consequence, become fluid dynamics. The term fluid mechanics, as used here, embraces both fluid dynamics and the subject still generally referred to as hydrostatics.

One other representative of the 20th century who deserves mention here besides Prandtl is Geoffrey Taylor of England. Taylor remained a classical physicist while most of his contemporaries were turning their attention to the problems of atomic structure and quantum mechanics, and he made several unexpected and important discoveries in the field of fluid mechanics. The richness of fluid mechanics is due in large part to a term in the basic equation of the motion of fluids which is nonlinear—*i.e.,* one that involves the fluid velocity twice over. It is characteristic of systems described by nonlinear equations that under certain conditions they become unstable and begin behaving in ways that seem at first sight to be totally chaotic. In the case of fluids, chaotic behaviour is very common and is called turbulence. Mathematicians have now begun to recognize patterns in chaos that can be analyzed fruitfully, and this development suggests that fluid mechanics will remain a field of active research well into the 21st century. (For a discussion of the concept of chaos, see physical science, principles of.)
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Fluid mechanics is a subject with almost endless ramifications, and the account that follows is necessarily incomplete. Some knowledge of the basic properties of fluids will be needed; a survey of the most relevant properties is given in the next section.