Preface

These notes were prepared for a one-semester graduate course in introductory classical fluid mechanics. The fluid mechanics curriculum at the Courant Institute has traditionally consisted of a two-semester introductory sequence, followed by special topic courses. It was common to treat incompressible fluids, both ideal and viscous, in the first semester, and then to move to compressible flow, gas dynamics, and shock waves in the second. Because of the pressures of time and course scheduling, and the ever-expanding scope of the subject matter, a decision was made to offer instead a one-semester introductory course, which would include at least some of the material on compressible flow, to be followed by a second-semester special topic fluids course that could change from year to year depending upon faculty and student interests.

The present course was developed for students with a strong undergraduate mathematics background, but I have assumed no previous exposure to fluid mechanics. The selected material is fairly standard, but it was chosen to emphasize the mathematical methods that have their origin in fluid theory. A central problem of the classical theory is the subtle relation between an ideal fluid and a real fluid of small viscosity (or more precisely, a fluid flow with a large Reynolds number). Many of the crowning achievements of the fluid dynamicists of the nineteenth and twentieth centuries, certainly including Prandtl's boundary layer theory, airfoil theory, much of the theory of singular perturbations, and the recent developments surrounding triple-deck theory, are all motivated by this problem. I have tried to keep some of these issues front and center when presenting the classical results in potential flow and in models for the lift and drag of bodies in a flow. Some attention is paid to the problem of locomotion in fluids, since it provides an interesting example where both Eulerian and Lagrangian methods play a role.

As a course in a mathematics curriculum, fluid mechanics should, in my opinion, be presented as a beautiful, practical subject, involving a moving continuum whose deformations are determined by certain natural physical laws. But the mathematical complexity of the subject is legion; to take one of many examples, the global existence of solutions of the Navier-Stokes equations for an incompressible fluid remains an open question. In an introductory course we must be content with the relatively small number of model problems that convey the flavor of the subject without excessive analysis.

The choices made here leave out, or only touch upon, many interesting and important topics. Among these are turbulence, shallow-water theory, rotating fluids and associated geophysical models, water waves, hydrodynamic stability, surface tension phenomena, and, importantly, computational fluid dynamics. Nevertheless, it is hoped that these notes offer a fair introduction to the classical theory and a preparation for more specialized courses in fluid mechanics.

STEPHEN CHILDRESS