Preface

These lecture notes cover an advanced course in fluid dynamics at Stavanger University College.[1] Prerequisites corresponding to a standard basic course in fluid mechanics for BE students in fluid mechanics are assumed:

Properties of fluids
Fluid statics
Basics of fluid flow
Energy considerations (Bernoulli's equation)
The impulse-momentum principle
Basic hydrodynamics
The equations of Euler and Navier-Stokes
Similitude and dimensional analysis
Stationary incompressible flow in conduits

The emphasis of these lecture notes is on a study of the mathematical and physical aspects of selected topics in fluid dynamics. The original intention was to present physical principles which are usually not treated in basic courses of physics and fluid mechanics, as well as to treat physically interesting principles introduced in other courses in the BE/ME curriculum in petroleum technology without much explanation.[2] After the introduction of a ME study in technical physics and mathematics at SUC, the course was developed further: It gives an insight into mathematical methods and concepts which is at the base of a large part of classical theoretical physics. The lecturer as well as the students should therefore consider these notes less as 'fact sheets' about fluids, and more as an essay; a presentation of a cross-section through the methods of theoretical physics.

During the choice of topics, emphasis was on avoiding an overlap with other courses, compulsory as well as elective, in the ME curriculum at SUC. Therefore, there is less emphasis on potential flow and gas dynamics than usual; such topics are treated in courses in petroleum technology. Multiphase flow, non-Newtonian fluids, and the theory of hydraulic machinery are other examples of extensive and important but excluded fields; The first and partly the second are covered by separate courses. Flow in channels is included only to present an analogy with shock waves in compressible gases. In its present form the course covers mainly the dynamics of incompressible fluids, i.e., hydrodynamics.

At the outset the presentation was inspired by D. J. Tritton's textbook. That is still the case for the the empirical results and relations it was desirable to include (after all, fluids *are* wet). However, the treatment of the rest of the topics is different and of a more mathematical

[1] The Norwegian original served as the author's first LaTeXtraining.
[2] Thus, it may well have 'practical relevance' as a supporting course.

character, and a considerable body of other topics has been added. The list of references shows which books have been useful during the production of the compendium. The books by Acheson, Landau and Lifshitz, and Tritton can be recommended as supporting texts, although none of those excellent books are pedagogically suitable for the assumed audience of these notes. With problem solving added, a study of these notes ought to be sufficient as exam preparation. This compendium will hopefully lead the the students to a level where they are able to continue on their own with advanced texts of theoretical physics.

Depending on the students' initiative and energy, it may be that these notes contain more topics than it is possible to cover in a 5 study points course. The lecturer should then decide whether to prune uniformly throughout the included material, or to leave out some chapters or sections completely. In the latter case, parts of the chapters on shock ond lift, the derivation of the energy flow density for *compressible* flow, and the detailed treatment of some of the appendices, may for instance be omitted. (In particular, the derivations in Appendices A and B ought not be covered.) Water surface waves may be presented for the deep-water case only[3]. The presentation of hydraulic jumps in the chapter on shock waves will function best if the majority of the students are already familiar with the notion of shock waves, for instance from courses in applied gas dynamics. Moreover, the sections on solitary waves and on correlation functions in homogeneous isotropical turbulence are best suited for voraciously interested students. Generally, however, the introduction to turbulence ought to be as comprehensive as possible.

Thanks for reading through the manuscript, and for much good advice, goes to Rune W. Time. The author is solely responsible for eventual remaining errors and imprecise statements.

Stavanger, June 1992 J.F.

Some statements and derivations in the 1992 version have been improved. Observed misprints have been corrected.

The experience at SUC has been that time usually does not reach to cover Chapter 6 and much of Chapter 13, which would require more of the students than the rest of the compendium. Neither the appendices, with B as an exception: It has proved useful to treat the derivation of the Navier-Stokes equation more exhaustive than time allows in common basic courses in fluid mechanics. Chapters 5 and 7 might suitably be presented in an abridged version. However, gravity surface waves in a deep fluid, and Kutta-Joukowski's theorem as in Problem 7.1, should be counted among the topics in any course with an emphasis on fluid dynamics

The undersigned was originally introduces to fluid dynamics during Professor Harald Wergeland's lectures on theoretical physics at NTNU. Hopefully, this compendium has been as successful in presenting its physical basis.

Stavanger, February 1997 J.F.

This is a translation from the Norwegian language of the original version, without considerable changes.

Stavanger, fall semester 2003 J.F.

[3]The general case is presented here for completeness, since it is usually not found in textbooks.