Preface

Continuum physics is as old as science itself. The decision to write a textbook about this subject has not been easy, because of the feeling that everything has been said and written before. Many times! What prompted me to write this book was a one-semester non-obligatory course in which I had to teach the basic principles of continuum physics to students of physics, geophysics and astrophysics. The students had previously been taught mechanics and thermodynamics, and along with this course on continuum physics they were also learning electromagnetism. There is a certain parallelism in the use of partial differential equations in both of these subjects, but basically I could neither assume they knew much about the mathematical methods nor the physics in advance. In the end the book came to contain much more material than could be readily covered in one semester, but its modular layout still makes it fairly easy to select a subset of topics that fits the needs of a particular course.

The book is first and foremost an introduction to the basic ideas and the derivation of the equations of continuum mechanics from Newtonian particle mechanics. The field concept is introduced from the very outset and tensors are used wherever they are necessary. There is no call for shyness in this respect, here nearly 200 years after Cauchy. Although many examples — in particular in the first few chapters — are taken from geophysics and astrophysics, this does not mean that the book is designed only for students of these subjects. All physics students ought to be familiar with the description of the macroscopic world of apparently continuous matter.

Secondly, the necessary mathematical tools are developed along with the physics on a "need-to-know" basis in order to avoid lengthy and boring mathematical preliminaries seemingly without purpose. The disadvantage of this pedagogical line is of course that the general analytic methods and physical principles, so important later in a physics student's life, become scattered throughout the book. I have attempted to counteract this tendency by structuring the text in various ways and clearly marking out important results, sometimes repeating central material. The three short appendices also help in this respect.

The important thing to learn from this book is to reason about physics, both qualitatively and — especially — quantitatively. Numeric simulations may be fine for obtaining solutions to practical problems, but of very little aid in obtaining real understanding. Physicists must learn to think in terms of fundamental principles and generic methods. Solving one problem after another of similar kind seems unnecessary and wasteful. This does not mean that the physicist should not be able to reach a practical result through calculation, but the physical principles behind equations and the conditions underlying approximations must never be lost of sight. Nevertheless, numerical methods are used and explained in some detail whenever it seems natural, including two whole chapters on numeric simulation in elastostatics and fluid mechanics.

The book is divided into five parts: Introduction, hydrostatics, deformable solids, basic fluid mechanics, and special topics in fluid mechanics. I have made no attempt to balance the space allotted to fluid and solid mechanics; fluid mechanics clearly dominates the book because it is after all conceptually simpler than even the linear mechanics of isotropic solids. Although there may be a certain built-in logic in the way the fundamental equations of continuum physics are derived and presented, the subject of applications is so rich that there can be no canonical order of presentation. Apart from the bare-bone fundamentals, continuum physics appears as a huge collection of interconnected topics, or "stories". Any textbook of sufficiently broad scope is therefore necessarily colored by the interests, predilections, and idiosyncracies of its author.

The book should be useful at several levels of teaching. In an introductory second year course one would perhaps choose as curriculum chapters 1–5, 9–12, and 15–20. Later and more advanced course might wish to include most of the book. The level of difficulty is as much as possible sought to rise steadily within each chapter and in the book as a whole. The chapters are of fairly uniform length, and each chapter has a "soft" introduction making contact to everyday experience. Historical comments and microbiographies of the major players are sprinkled throughout the text without any attempt at systematics or completeness. Whenever feasible, the mutual interdependence of chapters has — at the cost of some repetition — been reduced in order to facilitate the exclusion of whole chapters in a curriculum. Certain sections and subsections have been marked with a star to indicate that they fall outside the main line of presentation either in subject or in level of difficulty, and may require more teacher support or simply be skipped in a first reading.

As an aid to the text the book has been provided with a large number of marginal vignettes, outlining the salient features of a physical system or a choice of coordinates. They are nothing but the simpleminded sketches that we all draw — or should draw — when trying to learn new physics. Larger figures are of course used whenever the margin turns out to be too narrow. At the end of each chapter there is a motley collection of problems with answers outlined in the back of the book. Some problems test the use of the formalism in practical settings, others the understanding of the theoretical concepts, and still others develop the theory presented in the chapter further. The system of units is as in any other modern text the international one (SI), although commonly used units strictly speaking outside of this system, for example bar or atm for pressure, are sometimes also employed, though never without a proper definition.

Writing this book over the course of several years I have benefitted from advice and support of many people of which I can only mention a few. First among them are those that have dared to use the earlier versions of the manuscript in their teaching: Tomas Bohr of the Technical University of Denmark, Predrag Cvitanovic of Georgia Tech, and Niels Kjær Nielsen of Odense University. For physics input, discussions, and criticism I also thank Anders Andersen, Andy Jackson, Alex Lande, Morten Olesen, Laurette Tuckerman, and all the students that have followed my course over the years. Special thanks go to Mogens Høgh Jensen without whose generosity I would not have been able to sustain my expensive habit of buying books. I am grateful to my institute and my colleagues for being patient with me, and finally I could not have finished this book without the daily and nourishing support of my wife Birthe Østerlund.

The book is written for adults with a serious intention to learn physics. I have selected for the readers, what I think are the interesting topics in continuum physics, and presented these as pedagogically as I can without trying to cover everything encyclopedically. The list of literature contains pointers to texts that deal with specialized subtopics, mostly the books that I have found useful. I sincerely hope that my own joy in understanding and explaining the physics shines through everywhere.

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