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 has changed to justify writing a new textbook on this subject?

What has changed is the teaching environment. The enormous expansion of physics in the last fifty years has put new demands on the texts that we present to our students. Physics keeps evolving, its history growing, and basically nothing can be thrown away. New conceptual structures are added on top of older structures, and only rarely if ever do we abandon well-developed theories, unless of course they are wrong and clash with experiment or other and better theories. This requires teaching to be highly selective and conscious of the modern needs, even in an introductory text on a subject as classical as continuum physics. Care must be exerted in providing the students with fine analytic instruments to deal efficiently with all aspects of the subject, and not to waste their time in endless mathematical analysis, special functions and special coordinates, painstaking numerical calculations, and rote learning of phenomenology.

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 makes it fairly easy to select a subset that fits.

The book is first and foremost an introduction to the basic concepts and phenomenology of continuous systems, and the derivation of the equations of continuum mechanics from Newtonian particle mechanics. The field concept is introduced from the very outset in such a way that the fundamental description of space and time will not be invalidated in more advanced courses. Although many generic examples — in particular in the first 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 basic description of the world of apparent continuous matter surrounding us.

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, but I have attempted to counteract this tendency by structuring the text in various ways and clearly marking out important results, sometimes repeating central material.

Thirdly, the weight has been laid squarely on generic methods and applications, because the students are assumed to be exposed to more realistic problems in later specialized courses.

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. Two whole chapters on numeric simulation in elastostatics and fluid mechanics are in fact included.

Another emphasis is on clarity and precision. The basic equations of fluid mechanics are surprisingly simple, but nevertheless so powerful that they contain all the richness of form seen in a waterfall. This is the deeper reason for us being so incompetent in solving them in general, but only capable of dealing with them in coarse approximations and highly constrained geometries, where most of the complexity has been thrown away. I have attempted everywhere to be clear about what has been thrown away, and what approximations have been made.

Throughout the book the aim has been to make intuition and formalism follow each other. Qualitative intuitive insight is often the only guide to approximation and conceptualization, but frequently we also learn from the quantitative equations that our intuition is off the track. Merging intuition and formalism is in my opinion not only the most important, but also the hardest thing to learn in physics. It is what our profession is really all about. It might be difficult to reach this goal in some areas of theoretical physics, but in continuum physics there is no excuse for not trying, because our daily experience, which is the basis for intuition, covers a wide range of properties of continuous systems.

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. The history of continuum physics is anyway so huge and contorted that only a thoroughly researched text will do it proper justice. 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, but 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. 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 for pressure, are sometimes also employed, though never without a proper definition.

The book is written for adults with a serious intention to learn physics. I have attempted not to chat my way around difficulties, but rather to expose them and deal with them, or even give up if too hard to handle. I have selected for the readers, what I think are the central topics in continuum physics, and presented these as pedagogically as I can without trying to cover everything encyclopedically. I sincerely hope that my own joy in understanding and explaining the physics shines through everywhere.

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Preface to draft number 7.6

This revision is a snapshot of the manuscript at a point where the first 29 chapters are essentially finished. More problems, more answers, a better index, several more chapters are to be added to the manuscript. The book is expected to appear in print in spring 2004.