

# Preface

This textbook is an introduction to the transport of the three quantities that are conserved in nature, namely mass, momentum, and energy (the transport of electric charge can be seen as a particular case of the transport of mass). It is the outgrowth of 30 years of teaching this material to students of chemical, mechanical, nuclear, and biomedical engineering, both in the U.S. and in Italy.

No transport phenomena textbook could be written without referring to the first modern book on this subject, namely *Transport Phenomena*, published by R.B. Bird, W.E. Stewart, and E.N. Lightfoot in 1960, which has constituted the gold standard for all textbooks that have been written after it. In that book, the authors intended to answer the “current demand in engineering education, to put more emphasis on understanding basic physical principles than on the blind use of empiricism.” To understand the meaning of this statement, one has only to look at the typical heat and mass transfer book of the 1940s: no mathematics is required beyond elementary algebra and no partial differential equations can be found in those texts. In fact, Bird, Stewart, and Lightfoot went the opposite way, as they first applied the mathematical framework of continuum mechanics to derive the fundamental governing equations at the microscopic level and only afterward, by integrating them, they obtain the macroscopic equations of mass, momentum, and energy balance. Therefore, microscopic balances precede any coarse-grained analysis: for example, the Navier-Stokes equation is derived in Chap. 3, while for the Bernoulli equation, one has to wait until Chap. 7.

This very rigorous approach is coupled to an extremely powerful idea: that of unifying all types of transport phenomena, describing them within a common framework, which is in terms of cause and effect, respectively, represented by the *driving force* and the *flux* of the transported quantity.

In this textbook we retain this basic idea. However, I decided to reverse the way this material is presented to students. Fifty-five years have passed since the appearance of Bird, Stewart, and Lightfoot’s textbook, and engineering students are now much more proficient in advanced mathematics. On the other hand, I feel, they have not been exposed enough to “common sense” physics. In fact, often I find myself presenting this subject to students who had no previous exposure to fluid

dynamics or heat and mass transfer and have no idea of what a pressure drop or a heat flux are. Therefore, I try to strike a balance between a rigorous explanation of the fundamental laws that govern these subjects and an intuitive approach that stresses where these laws come from. Presenting the Navier-Stokes equation before any basic macroscopic balance would be like explaining electromagnetism by deriving Maxwell's equation before showing the basic experimental results by Faraday and Ampere. This is why I think that, from a didactical point of view and in light of the type of students we are dealing with today, it is better to describe phenomena first from a macroscopic point of view, even at the expense of mathematical rigor, and only afterwards, more advanced treatments can be carried over.

This textbook has been written as a teaching tool for a two-semester course (or two one-semester courses) on transport phenomena. It is a modular teaching tool, though. So, for example, if transport phenomena are taught in a single one-semester course, one should follow only the macroscopic treatments, described in Chaps. 1–5, 9–11, 14–16, postponing the study of the material covered in the other chapters to a subsequent, more advanced course. In any case, the book offers an abundant resource in the sense that the material covered is much more than what one can hope to cover in two semesters. So, it is up to the instructor to choose which subjects should be favored, also based on the students' needs: mechanical engineering students will be more interested in turbulence, while biomedical engineering students will tend to prefer surface phenomena.

Special mention should be made of the problems that are proposed at the end of each chapter. First of all, their importance cannot be underestimated: a student cannot claim to understand a subject until she/he can solve problems. However, while in Anglo-Saxon universities, problem solving is part of the students' homework assignments, elsewhere, they are solved in class, and therefore, they become an integral part of the course. This is why here the solution of the problems are provided in the Appendix.

Finally, I would like to answer a common complaint that I heard from my students, namely that in this textbook, they cannot find all the physical properties that are required to solve some of the proposed problems. This deficiency is deliberate, being motivated by the fact that in this way the students are forced to look outside and find the missing data.

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