Aimed at beginning engineering students, this book presents the basic ideas of thermodynamics, fluid mechanics, heat transfer, and combustion through a real-world engineering situation. The engine is related to the atmosphere in which it moves and exhausts its waste products. In addition to the traditional thermal–fluid topics, the book includes a chapter on the atmosphere, with a particular focus on the greenhouse effect and atmospheric inversions. The social implications of engineering in a crowded world with increasing energy demands are also addressed. This novel approach will capture the reader's attention and set the stage for subjects that will be studied later in greater depth.

Students in mechanical, civil, agricultural, environmental, aerospace, and chemical engineering, as well as the physical sciences, will welcome this engaging, well-illustrated introduction to thermal–fluid engineering.

AN INTRODUCTION TO THERMAL–FLUID ENGINEERING

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THE ENGINE AND THE ATMOSPHERE

Z. WARHAFT
Cornell University

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For Zoe and Simon and to the memory of Sacha

Contents

Preface

Frequently, engineering students confront me with the question: "All of this math, physics, thermodynamics, and fluid mechanics is fine, but when are we going to study real engineering?" And then sometimes, after a pause: "Anyway, what *is* engineering?" My answer to these students, who are often well into their program, is usually an evasive mumble: "Wait a little longer. It will all come together. You will see." The students walk away none the wiser, and as the years go by I find my reply more and more dissatisfying. After all, law and medical students know what their subject is about, and so do upper-level physics and chemistry majors. What is wrong with the way we educate our engineers?

Consider for the moment the way we teach physics. By the end of their freshman year most students know what the landscape of physics looks like. Courses are connected in sequence, each building on the other: mechanics, electrodynamics, optics, and so on up to quantum and relativity theory. By the time physics students have reached their second or third year, they have a feeling for the progression of the subject and how the pieces fit together. They have also acquired technique in problem solving. Although they have not yet plumbed the depths, the first introductory overview provides them with substantial intellectual apparatus and hence a sound basis for a deeper second look later on. This progression is primarily due to a strong tradition of texts and elementary courses that cover the whole field at an introductory but nontrivial level. Engineering, like physics, is a discipline with a logical and coherent progression, yet my bookshelf is bereft of any introductory, unifying text. This lack, I suspect, is a major reason for the perplexity of many engineering students and provides much of the motivation for writing this book.

Engineering is difficult. Unlike the natural sciences, in which the major objective is to analyze the physical or biological world, engineering encompasses both analysis and synthesis (or design, as it is more often called). Moreover, engineering is a social activity: it does not progress as a purely intellectual or puzzle-solving pursuit. Airplanes, automobiles, and rockets change our environment and our social behavior; they make our wars more potent and devastating and affect our economy. No serious engineer can be oblivious to these issues. In writing this book, I have kept the social implications foremost in my mind. Apart from their intrinsic importance, they also provide the focus needed to unify the various topics.

My objective, then, is to provide an introduction to engineering by laying out the foundations in a coherent and connected way. Because engineering is a broad discipline, I cannot be completely general. I have confined myself to the thermal–fluids area of engineering, which constitutes about half of the mechanical engineering syllabus and a considerable portion of chemical, civil, aerospace, agricultural, and environmental engineering. So although this book is not as comprehensive as an introductory physics text, it is nevertheless broad enough to provide the overview that I believe is lacking.

My development of thermodynamics, fluid mechanics, heat transfer, and combustion is aimed at giving beginning students, at the first- and second-year college level, a firm foundation so they can do calculations and solve problems. When these topics are seen again later on, as separate subjects, students will be at home with their basic concepts and will not be bewildered by the details or how the subjects interrelate. I hope that this book may also be used by engineering nonmajors who wish to have a detailed overview, much in the spirit that physics nonmajors study introductory physics. The prerequisites for this book are concurrent first-year calculus and physics courses.

Teachers of the thermal and fluid sciences will see that some of my topics and the way they are developed are relatively standard, whereas others are not. Thus, the chapter on thermodynamics follows the familiar path first provided by Keenan, whereas the chapters on fluid mechanics and heat transfer depart considerably from the usual method of introduction. Here, at the outset, I accentuate the role of viscosity and flow losses. Turbulence, which is responsible for the major flow losses as well as for enhancing mixing and combustion, is discussed in some detail. Although not mathematical, the method of thinking is different and requires considerable patience. But so too does classical thermodynamics, a subject that has been dished up, without apology, to beginning students for decades. By discussing turbulence, I introduce the students to approximate methods of analysis as well as to the role of computers in engineering. Both these aspects play an ever increasing and important role in modern engineering. What I believe to be wholly new in the book, however, is the way I connect the subjects by relating the engine – its thermodynamics, fluid mechanics, heat transfer, and combustion – to the environment in which it moves and exhausts its waste products. To make this connection, I have included a chapter on the atmosphere, with particular focus on the greenhouse effect and atmospheric inversions. Here the student will also see that atmospheric science is really an application of engineering fluid mechanics, heat transfer, and so on to a particular system. So apart from showing that the engine is not an isolated object but must be studied in relation to the environment, I also show that the tools used to analyze the engine are indeed the same as we use to understand the atmosphere and its motion.

In summary, this book is a holistic introduction to the thermal–fluid side of engineering. Its aim is to lay out the foundations in a coherent manner, providing building blocks for further courses. Although written primarily for freshmen and sophomores, I hope it will also serve as a supplement to the upper-level courses. The book has the broader aim of showing that engineering is not merely technology but encompasses social and moral questions, making it perhaps the most fascinating profession of our age and one with the profoundest influence.

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