Thermodynamics and Energy Conversion

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Preface

This textbook grew out of lecture notes for the thermodynamics courses offered in the Department of Mechanical Engineering at the University of Victoria. Writing my own notes forced me to thoroughly consider how, in my subjective view, engineering thermodynamics should be taught. At the same time I aimed for a concise presentation, with the material of three courses delivered on about 600 pages.[1] My hope in publishing this book is that students of thermodynamics might find the chosen approach accessible, and maybe illuminating, and discover thermodynamics and its interesting applications for themselves.

Probably the biggest difference to standard texts is when and how the second law of thermodynamics and its central quantity, the entropy, are introduced. The second law describes irreversible processes like friction and heat transfer, which are related to a loss in work. For instance, work that is needed to overcome friction in a generator cannot be converted into electricity, hence there is a loss. Accordingly, it should be one of the main goals of a thermal engineer to reduce irreversibility as much as possible. Indeed, the desire to understand and quantify irreversible losses is one of the central themes of the present treatment, it is touched upon in almost all chapters.

The emphasis on irreversibilities requires the introduction of the second law as early as possible. The classical treatment, which is still used in most texts on engineering thermodynamics, is to derive the second law from discussion on thermal engines with and without losses. Obviously, this requires an extensive discussion of thermodynamic processes and thermal engines by means of the first law of thermodynamics—the law of conservation of energy—before the second law can even be mentioned. In the present treatment, entropy and

[1] The courses (13 weeks à 3 hours), and the relevant book chapters, as currently taught at the University of Victoria, are:

Thermodynamics (UVic Mech 240): Chapters 1-10

Energy Conversion (UVic Mech 390): Chapters 11-14, 18.1-18.9, 19, 23.1-23.5, 24

Advanced Thermodynamics (UVic Mech 443): Chapters 16-18, 20-26 the second law are introduced directly after the first law, based on observations of rather simple processes, in particular the trend of unmanipulated systems to approach a unique equilibrium state. With this, the complete set of thermodynamic laws is available almost immediately, and the discussion of all thermodynamic processes and engines relies on both laws from the start. All considerations on engines which are typically used to derive the second law, are now a result of the analysis of the engines by means of the first and second law.

As soon as the thermodynamic laws are stated we are in calmer waters. The discussion of property relations, processes in closed and open systems, thermodynamic cycles, mixtures and so on follows established practice, only, perhaps, with the additional emphasis on irreversibility and loss. Some elements that might not be found in other books on engineering thermodynamics concern the microscopic definition of entropy, the afore mentioned emphasis on thermodynamic losses, and the detailed discussion of a number of advanced energy conversion systems such as Atkinson engine, solar tower (updraft power plant), turbo-fan air engine, ramjet and scramjet, compressed air energy storage, osmotic power plants, carbon sequestration, phase and chemical equilibrium, or fuel cells. The principles of non-equilibrium thermodynamics are used to derive transport laws such as Newton's law of cooling, Darcy's law for flow through porous media, and activation losses in fuel cells.

There are about 300 end-of-chapter problems for homework assignments and exams. The problems were chosen in order to emphasize all important concepts and processes. They are accompanied by detailed solved examples in all chapters, and it is recommended to first study the examples and then tackle the problems. Many problems require the use of thermodynamic property tables, which are widely available in print and online.

Any presentation of a large topic such as thermodynamics can never be complete. The choice of topics in this book is a personal one, but I am confident that after studying this book the reader will find easy access to most other thermodynamics texts, be they written for mechanical engineers, chemical engineers, or scientists. *Thermodynamics and Energy Conversion* processes will remain an important part of modern civilization. High energy efficiency can only be obtained from a deep understanding of the Laws of Thermodynamics, which describe the interplay of *Energy, Entropy, and Efficiency.* It is my sincere hope that this book will contribute to this end.

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All chapters of this book went through several runs of the respective course, and each re-run led to additions and deletions, changes and adjustments, more examples and new problems. For feedback, corrections, and, sometimes, critical praise I would like to thank the countless students that went through these courses, as well as the graduate students that served as teaching assistants.

The Department of Mechanical Engineering at the University of Victoria provides a wonderfully collegial atmosphere for which I express my heartfelt thanks to my colleagues.

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