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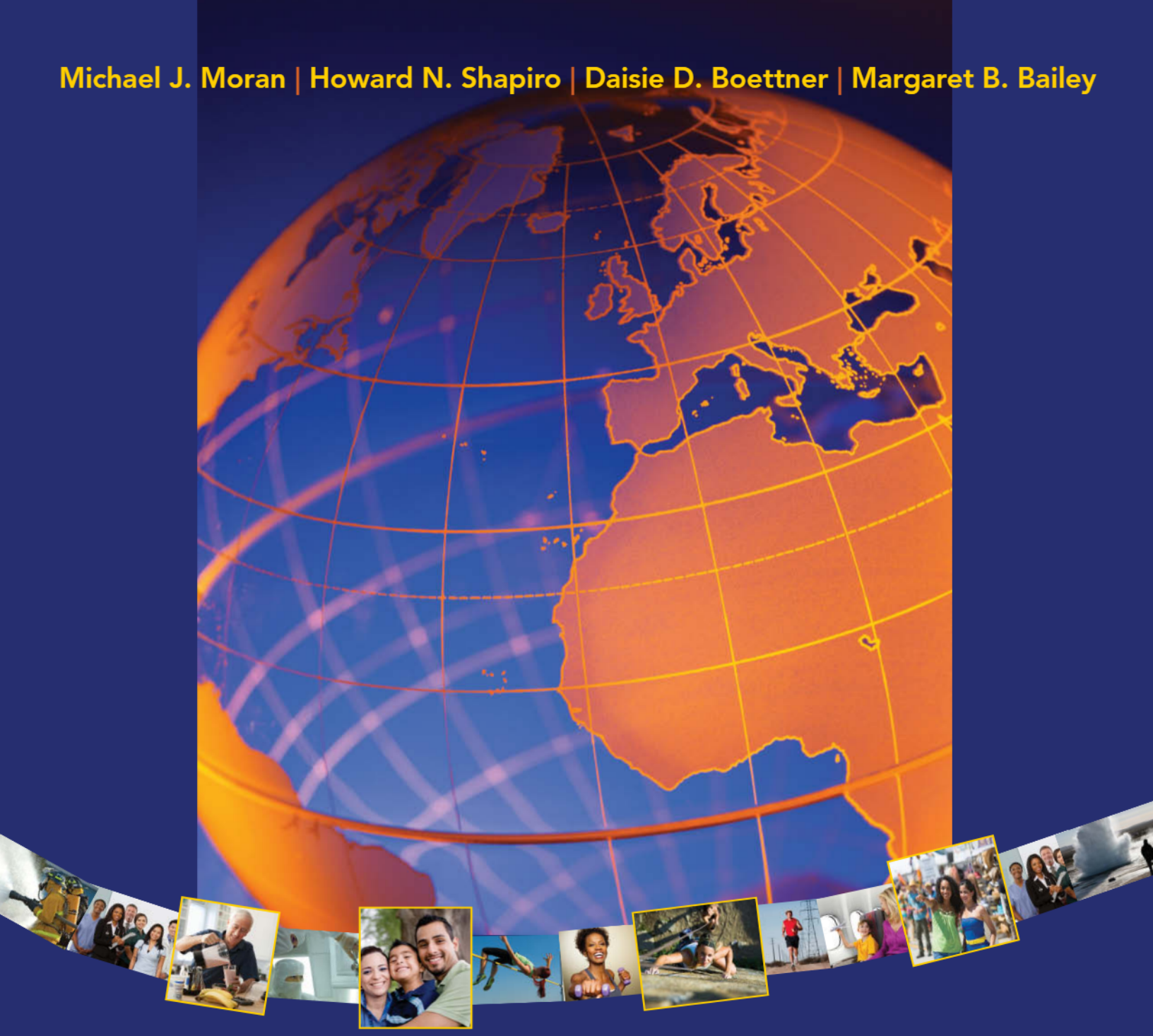

FUNDAMENTALS OF ENGINEERING THERMODYNAMICS

Eighth Edition

WILEY

How to Use This Book Effectively

This book is organized by chapters and sections within chapters. For a listing of contents, see pp. vii–xiv. Fundamental concepts and associated equations within each section lay the foundation for applications of engineering thermodynamics provided in solved examples, end-of-chapter problems and exercises, and accompanying discussions. **Boxed material** within sections of the book allows you to explore selected topics in greater depth, as in the boxed discussion of properties and nonproperties on p. 10.

Contemporary issues related to thermodynamics are introduced throughout the text with three unique features: **ENERGY & ENVIRONMENT** discussions explore issues related to energy resource use and the environment, as in the discussion of hybrid vehicles on p. 41. **BIOCONNECTIONS** tie topics to applications in bioengineering and biomedicine, as in the discussion of control volumes of living things and their organs on p. 7.

Horizons link subject matter to emerging technologies and thought-provoking issues, as in the discussion of nanotechnology on p. 15.

Other core features of this book that facilitate your study and contribute to your understanding include:

Examples

- Numerous annotated solved examples are provided that feature the **solution methodology** presented in Sec. 1.9 and illustrated in Example 1.1. We encourage you to study these examples, including the accompanying comments.
- Each solved example concludes with a list of the **Skills Developed** in solving the example and a **Quick Quiz** that allows an immediate check of understanding.
- Less formal examples are given throughout the text. They open with ▶ FOR EXAMPLE and close with ◀ ◀ ◀ ◀ ◀. These examples also should be studied.

Exercises

- Each chapter has a set of discussion questions under the heading ▶ EXERCISES: THINGS ENGINEERS THINK ABOUT that may be done on an individual or small-group basis. They allow you to gain a deeper understanding of the text material and think critically.
- Every chapter has a set of questions in a section called ▶ CHECKING UNDERSTANDING that provide opportunity for individual or small group *self-testing* of the fundamental ideas presented in the chapter. Included are a variety of exercises, such as matching, fill-in-the-blank, short answer, and true-and-false questions.
- A large number of end-of-chapter problems also are provided under the heading ▶ PROBLEMS: DEVELOPING ENGINEERING SKILLS. The problems are sequenced to coordinate with the subject matter and are listed in increasing order of difficulty. The problems are also classified under headings to expedite the process of selecting review problems to solve. Answers to selected problems are provided on the **student companion website** that accompanies this book at www.wiley.com/college/moran.
- Because one purpose of this book is to help you prepare to use thermodynamics in engineering practice, design considerations related to thermodynamics are included. Every chapter has a set of problems under the heading ▶ DESIGN & OPEN ENDED PROBLEMS: EXPLORING ENGINEERING PRACTICE that provide opportunities for practicing creativity, formulating and solving design and open-ended problems, using the Internet and library resources to find relevant information, making engineering judgments, and developing communications skills. See, for example, problem 1.10 D on p. 36.

Further Study Aids

- Each chapter opens with an introduction giving the **engineering context**, stating the **chapter objective**, and listing the **learning outcomes**.
- Each chapter concludes with a ▶ CHAPTER SUMMARY AND STUDY GUIDE that provides a point of departure to study for examinations.
- For easy reference, each chapter also concludes with lists of ▶ KEY ENGINEERING CONCEPTS and ▶ KEY EQUATIONS.
- Important terms are listed in the margins and coordinated with the text material at those locations.
- Important equations are set off by a color screen, as for Eq. 1.8.
- **TAKE NOTE...** in the margin provides just-in-time information that illuminates the current discussion, as on p. 8, or refines our problem-solving methodology, as on p. 12 and p. 22.
- A in the margin identifies an animation that reinforces the text presentation at that point. Animations can be viewed by going to the **student companion website** for this book. See **TAKE NOTE...** on p. 8 for further detail about accessing animations.
- in the margin denotes end-of-chapter problems where the use of appropriate computer software is recommended.
- For quick reference, conversion factors and important constants are provided on the next page.
- A list of symbols is provided on the inside back cover.

Conversion Factors

Mass and Density

$1\ \text{kg} = 2.2046\ \text{lb}$
$1\ \text{g/cm}^3 = 10^3\ \text{kg/m}^3$
$1\ \text{g/cm}^3 = 62.428\ \text{lb/ft}^3$
$1\ \text{lb} = 0.4536\ \text{kg}$
$1\ \text{lb/ft}^3 = 0.016018\ \text{g/cm}^3$
$1\ \text{lb/ft}^3 = 16.018\ \text{kg/m}^3$

Length

$1\ \text{cm} = 0.3937\ \text{in.}$
$1\ \text{m} = 3.2808\ \text{ft}$
$1\ \text{in.} = 2.54\ \text{cm}$
$1\ \text{ft} = 0.3048\ \text{m}$

Velocity

$1\ \text{km/h} = 0.62137\ \text{mile/h}$
$1\ \text{mile/h} = 1.6093\ \text{km/h}$

Volume

$1\ \text{cm}^3 = 0.061024\ \text{in.}^3$
$1\ \text{m}^3 = 35.315\ \text{ft}^3$
$1\ \text{L} = 10^{-3}\ \text{m}^3$
$1\ \text{L} = 0.0353\ \text{ft}^3$
$1\ \text{in.}^3 = 16.387\ \text{cm}^3$
$1\ \text{ft}^3 = 0.028317\ \text{m}^3$
$1\ \text{gal} = 0.13368\ \text{ft}^3$
$1\ \text{gal} = 3.7854 \times 10^{-3}\ \text{m}^3$

Force

$1\ \text{N} = 1\ \text{kg} \cdot \text{m/s}^2$
$1\ \text{N} = 0.22481\ \text{lbf}$
$1\ \text{lbf} = 32.174\ \text{lb} \cdot \text{ft/s}^2$
$1\ \text{lbf} = 4.4482\ \text{N}$

Pressure

$1\ \text{Pa} = 1\ \text{N/m}^2$
$= 1.4504 \times 10^{-4}\ \text{lbf/in.}^2$
$1\ \text{bar} = 10^5\ \text{N/m}^2$
$1\ \text{atm} = 1.01325\ \text{bar}$
$1\ \text{lbf/in.}^2 = 6894.8\ \text{Pa}$
$1\ \text{lbf/in.}^2 = 144\ \text{lbf/ft}^2$
$1\ \text{atm} = 14.696\ \text{lbf/in.}^2$

Energy and Specific Energy

$1\ \text{J} = 1\ \text{N} \cdot \text{m} = 0.73756\ \text{ft} \cdot \text{lbf}$
$1\ \text{kJ} = 737.56\ \text{ft} \cdot \text{lbf}$
$1\ \text{kJ} = 0.9478\ \text{Btu}$
$1\ \text{kJ/kg} = 0.42992\ \text{Btu/lb}$
$1\ \text{ft} \cdot \text{lbf} = 1.35582\ \text{J}$
$1\ \text{Btu} = 778.17\ \text{ft} \cdot \text{lbf}$
$1\ \text{Btu} = 1.0551\ \text{kJ}$
$1\ \text{Btu/lb} = 2.326\ \text{kJ/kg}$
$1\ \text{kcal} = 4.1868\ \text{kJ}$

Energy Transfer Rate

$1\ \text{W} = 1\ \text{J/s} = 3.413\ \text{Btu/h}$
$1\ \text{kW} = 1.341\ \text{hp}$
$1\ \text{Btu/h} = 0.293\ \text{W}$
$1\ \text{hp} = 2545\ \text{Btu/h}$
$1\ \text{hp} = 550\ \text{ft} \cdot \text{lbf/s}$
$1\ \text{hp} = 0.7457\ \text{kW}$

Specific Heat

$1\ \text{kJ/kg} \cdot \text{K} = 0.238846\ \text{Btu/lb} \cdot {}^\circ\text{R}$
$1\ \text{kcal/kg} \cdot \text{K} = 1\ \text{Btu/lb} \cdot {}^\circ\text{R}$
$1\ \text{Btu/lb} \cdot {}^\circ\text{R} = 4.1868\ \text{kJ/kg} \cdot \text{K}$

Others

1 ton of refrigeration = 200 Btu/min = 211 kJ/min
1 volt = 1 watt per ampere

Constants

Universal Gas Constant

$$\overline{R} = \begin{cases} 8.314\ \text{kJ/kmol} \cdot \text{K} \\ 1545\ \text{ft} \cdot \text{lbf/lbmol} \cdot {}^\circ\text{R} \\ 1.986\ \text{Btu/lbmol} \cdot {}^\circ\text{R} \end{cases}$$

Standard Acceleration of Gravity

$$g = \begin{cases} 9.80665\ \text{m/s}^2 \\ 32.174\ \text{ft/s}^2 \end{cases}$$

Standard Atmospheric Pressure

$$1\ \text{atm} = \begin{cases} 1.01325\ \text{bar} \\ 14.696\ \text{lbf/in.}^2 \\ 760\ \text{mm Hg} = 29.92\ \text{in. Hg} \end{cases}$$

Temperature Relations

$T(^\circ\text{R}) = 1.8\ T(\text{K})$
$T(^\circ\text{C}) = T(\text{K}) - 273.15$
$T(^\circ\text{F}) = T(^\circ\text{R}) - 459.67$

8/e

Fundamentals of Engineering Thermodynamics

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Preface

A Textbook for the 21st Century

In the twenty-first century, engineering thermodynamics plays a central role in developing improved ways to provide and use energy, while mitigating the serious human health and environmental consequences accompanying energy—including air and water pollution and global climate change. Applications in bioengineering, biomedical systems, and nanotechnology also continue to emerge. This book provides the tools needed by specialists working in all such fields. For non-specialists, this book provides background for making decisions about technology related to thermodynamics—on the job and as informed citizens.

Engineers in the twenty-first century need a solid set of analytical and problem-solving skills as the foundation for tackling important societal issues relating to engineering thermodynamics. The eighth edition develops these skills and significantly expands our coverage of their applications to provide

- current context for the study of thermodynamic principles.
- relevant background to make the subject meaningful for meeting the challenges of the decades ahead.
- significant material related to existing technologies in light of new challenges.

In the eighth edition, we build on the **core features** that have made the text the global leader in engineering thermodynamics education. We are known for our clear and concise explanations grounded in the fundamentals, pioneering pedagogy for effective learning, and relevant, up-to-date applications. Through the creativity and experience of our author team, and based on excellent feedback from instructors and students, we continue to enhance what has become the leading text in the field.

New in the Eighth Edition

In a major departure from all other texts intended for the same student population, in this edition we have introduced 700 new end-of-chapter problems under the heading, ▶ CHECKING UNDERSTANDING. The new problems provide opportunities for student *self-testing* of fundamentals and to serve instructors as *easily graded* homework, quiz, and exam problems. Included are a variety of exercises, such as matching, fill-in-the-blank, short answer, and true-and-false.

The eighth edition also features a **crisp new interior design** aimed at helping students

- better understand and apply the subject matter, and
- fully appreciate the relevance of the topics to engineering practice and to society.

Other Core Features

This edition also provides, inside the front cover under the heading How to Use This Book Effectively, an updated roadmap to core features of this text that make it so effective for student learning. To fully understand all of the many features we have built into the book, be sure to see this important element.

In this edition, several enhancements to improve student learning have been introduced or upgraded:

- The *p–h* diagrams for two refrigerants: CO_2 (R-744) and R-410A are included as Figs. A-10 and A-11, respectively, in the appendix. The ability to locate states on property diagrams is an important skill that is used selectively in end-of-chapter problems.
- **Animations** are offered at key subject matter locations to improve student learning. When viewing the animations, students will develop deeper understanding by visualizing key processes and phenomena.
- Special text elements feature important illustrations of engineering thermodynamics applied to our environment, society, and world:
  - *New* **ENERGY & ENVIRONMENT** presentations explore topics related to energy resource use and environmental issues in engineering.
  - *Updated* **BIOCONNECTIONS** discussions tie textbook topics to contemporary applications in biomedicine and bioengineering.
  - *Additional* **Horizons** features have been included that link subject matter to thought-provoking 21st century issues and emerging technologies.

  Suggestions for additional reading and sources for topical content presented in these elements provided on request.
- End-of-Chapter problems in each of the four modes: **conceptual, checking understanding, skill building, and design** have been extensively revised and hundreds of new problems added.

- New and revised class-tested material contributes to student learning and instructor effectiveness:
  - Significant new content explores how thermodynamics contributes to meet the challenges of the 21st century.
  - Key aspects of fundamentals and applications within the text have been enhanced.
- In response to instructor and student needs, class-tested changes that contribute to a more **just-in-time** presentation have been introduced:
  - **TAKE NOTE...** entries in the margins are expanded throughout the textbook to improve student learning. For example, see p. 8.
  - **Boxed material** allows students and instructors to explore topics in greater depth. For example, see p. 109.
  - **Margin terms** throughout aid in navigating subject matter.

Supplements

The following supplements are available with the text:

- Outstanding *Instructor* and *Student* companion web sites (visit www.wiley.com/college/moran) that greatly enhance teaching and learning:
  - Instructor Companion Site: Assists instructors in delivering an effective course with resources including
    - a new Steam Table Process Overview to assist students in mastering the use of the steam tables for retrieving data.
    - animations—with just-in-time labels in the margins.
    - chapter-by-chapter summary of Special Features, including
      - the subject of each solved example,
      - the topics of all **ENERGY & ENVIRONMENT**, **BIOCONNECTIONS**, and **Horizons** features,
      - the themes of the **DESIGN & OPEN ENDED PROBLEMS**
    - a complete solution manual that is easy to navigate.
    - solutions to computer-based problems for use with both *IT: Interactive Thermodynamics* as well as *EES: Engineering Equation Solver*.
    - image galleries with text images available in various helpful electronic formats.
    - sample syllabi on semester and quarter bases.
    - errata for both the text and problems.
    - chapter summary information, including Key Terms and Key Equations.
    - chapter learning outcomes.
    - correlation guides to ease transition between editions of this text and for switching to this edition from another book.
    - text Preface.
  - Student Companion Site: Helps students learn the subject matter with resources including
    - Steam Table Process Overview—new in this edition.
    - animations.
    - answers to selected problems.
    - errata for both the text and problems.
    - chapter summary information, including Key Terms and Key Equations.
    - chapter learning outcomes.
    - chapter-by-chapter summary of Special Features as listed in the Instructor Companion Site.
    - text Preface.
- *Interactive Thermodynamics: IT software* is available as a stand-alone product or with the textbook. *IT* is a highly-valuable learning tool that allows students to develop engineering models, perform "what-if" analyses, and examine principles in more detail to enhance their learning. Brief tutorials of *IT* are included within the text and the use of *IT* is illustrated within selected solved examples.
- Skillful use of tables and property diagrams is prerequisite for the effective use of software to retrieve thermodynamic property data. The latest version of *IT* provides data for CO_2 (R-744) and R-410A using as its source Mini REFPROP by permission of the National Institute of Standards and Technology (NIST).
- *WileyPLUS* is an online set of instructional, practice, and course management resources, including the full text, for students and instructors.

Visit www.wiley.com/college/moran or contact your local Wiley representative for information on the above-mentioned supplements.

Ways to Meet Different Course Needs

In recognition of the evolving nature of engineering curricula, and in particular of the diverse ways engineering thermodynamics is presented, the text is structured to meet a variety of course needs. The following table illustrates several possible uses of the textbook assuming a semester basis (3 credits). Courses could be taught using this textbook to engineering students with appropriate background beginning in their second year of study.

Type of course	Intended audience	Chapter coverage
Survey courses	Nonmajors	• Principles. Chaps. 1–6. • Applications. Selected topics from Chaps. 8–10 (omit compressible flow in Chap. 9).
	Majors	• Principles. Chaps. 1–6. • Applications. Same as above plus selected topics from Chaps. 12 and 13.
Two-course sequences	Majors	• First course. Chaps. 1–7. (Chap. 7 may be deferred to second course or omitted.) • Second course. Selected topics from Chaps. 8–14 to meet particular course needs.

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We continue to be extremely gratified by the reception this book has enjoyed over the years. With this edition we have made the text more effective for teaching the subject of engineering thermodynamics and have greatly enhanced the relevance of the subject matter for students who will shape the 21st century. As always, we welcome your comments, criticisms, and suggestions.

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