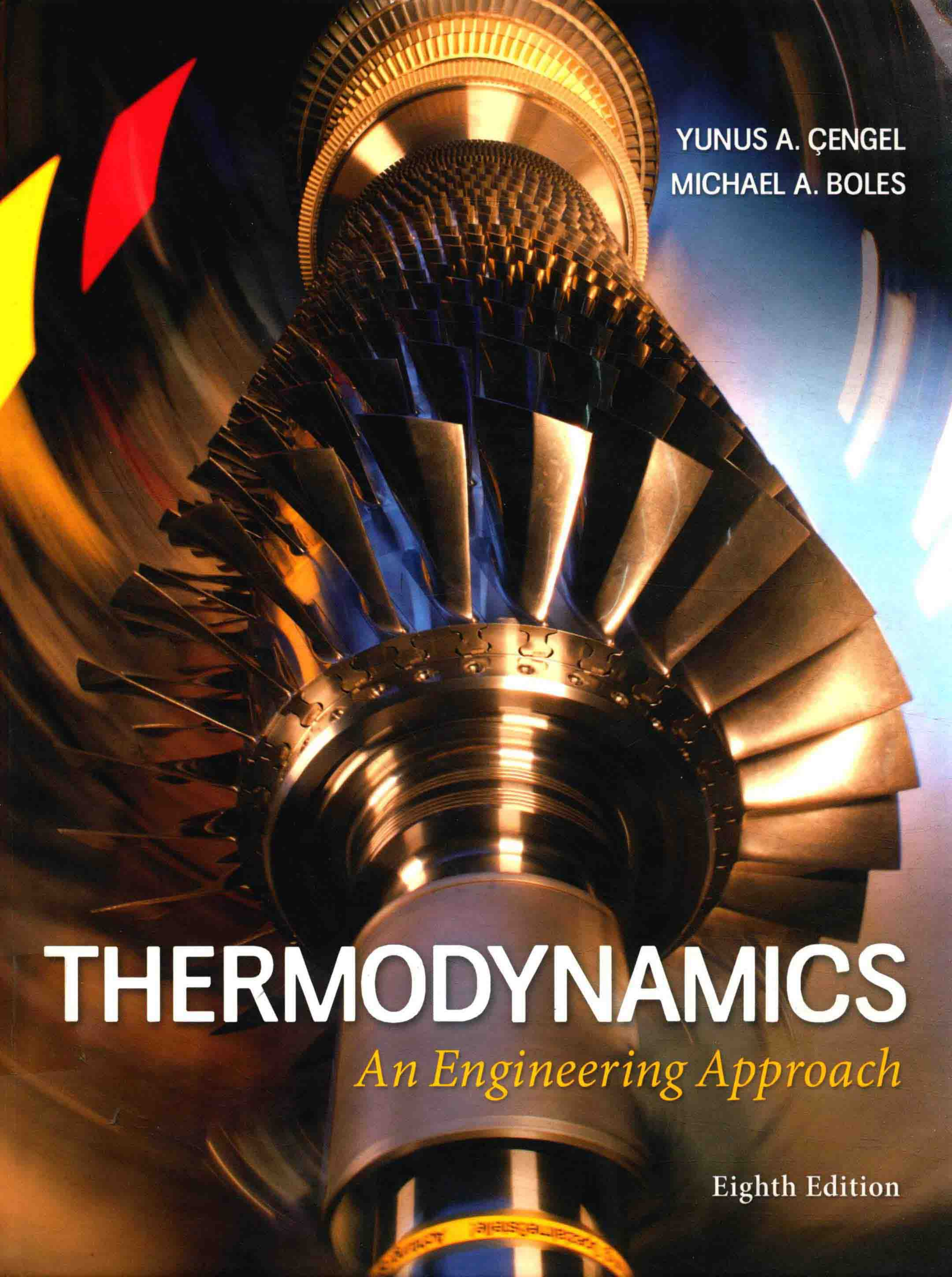

YUNUS A. ÇENGEL
MICHAEL A. BOLES

THERMODYNAMICS

An Engineering Approach

Eighth Edition

THERMODYNAMICS

AN ENGINEERING APPROACH

EIGHTH EDITION

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Mc Graw Hill Education

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NOMENCLATURE

a	Acceleration, m/s^2
a	Specific Helmholtz function, $u - Ts$, kJ/kg
A	Area, m^2
A	Helmholtz function, $U - TS$, kJ
AF	Air–fuel ratio
c	Speed of sound, m/s
c	Specific heat, kJ/kg·K
c_p	Constant pressure specific heat, kJ/kg·K
c_v	Constant volume specific heat, kJ/kg·K
COP	Coefficient of performance
COP_{HP}	Coefficient of performance of a heat pump
COP_{R}	Coefficient of performance of a refrigerator
d, D	Diameter, m
e	Specific total energy, kJ/kg
E	Total energy, kJ
EER	Energy efficiency rating
F	Force, N
FA	Fuel–air ratio
g	Gravitational acceleration, m/s^2
g	Specific Gibbs function, $h - Ts$, kJ/kg
G	Total Gibbs function, $H - TS$, kJ
h	Convection heat transfer coefficient, W/m^2·K
h	Specific enthalpy, $u + Pv$, kJ/kg
H	Total enthalpy, $U + PV$, kJ
$\bar{h}_C$	Enthalpy of combustion, kJ/kmol fuel
$\bar{h}_f$	Enthalpy of formation, kJ/kmol
$\bar{h}_R$	Enthalpy of reaction, kJ/kmol
HHV	Higher heating value, kJ/kg fuel
i	Specific irreversibility, kJ/kg
I	Electric current, A
I	Total irreversibility, kJ
k	Specific heat ratio, c_p/c_v
k_s	Spring constant
k_t	Thermal conductivity
K_p	Equilibrium constant
ke	Specific kinetic energy, $V^2/2$, kJ/kg
KE	Total kinetic energy, $mV^2/2$, kJ
LHV	Lower heating value, kJ/kg fuel
m	Mass, kg
$\dot{m}$	Mass flow rate, kg/s
M	Molar mass, kg/kmol
Ma	Mach number
MEP	Mean effective pressure, kPa
mf	Mass fraction
n	Polytropic exponent
N	Number of moles, kmol
P	Pressure, kPa
P_{cr}	Critical pressure, kPa
P_i	Partial pressure, kPa
P_m	Mixture pressure, kPa
P_r	Relative pressure
P_R	Reduced pressure
P_v	Vapor pressure, kPa
P_0	Surroundings pressure, kPa
pe	Specific potential energy, gz, kJ/kg
PE	Total potential energy, mgz, kJ
q	Heat transfer per unit mass, kJ/kg
Q	Total heat transfer, kJ
$\dot{Q}$	Heat transfer rate, kW
Q_H	Heat transfer with high-temperature body, kJ
Q_L	Heat transfer with low-temperature body, kJ
r	Compression ratio
R	Gas constant, kJ/kg·K
r_c	Cutoff ratio
r_p	Pressure ratio
R_u	Universal gas constant, kJ/kmol·K
s	Specific entropy, kJ/kg·K
S	Total entropy, kJ/K
s_{gen}	Specific entropy generation, kJ/kg·K
S_{gen}	Total entropy generation, kJ/K
SG	Specific gravity or relative density
t	Time, s
T	Temperature, °C or K
T	Torque, N·m
T_{cr}	Critical temperature, K
T_{db}	Dry-bulb temperature, °C
T_{dp}	Dew-point temperature, °C
T_f	Bulk fluid temperature, °C
T_H	Temperature of high-temperature body, K
T_L	Temperature of low-temperature body, K
T_R	Reduced temperature
T_{wb}	Wet-bulb temperature, °C
T_0	Surroundings temperature, °C or K
u	Specific internal energy, kJ/kg
U	Total internal energy, kJ

v	Specific volume, m^3/kg
v_{cr}	Critical specific volume, m^3/kg
v_r	Relative specific volume
v_R	Pseudoreduced specific volume
V	Total volume, m^3
$\dot{V}$	Volume flow rate, m^3/s
$\mathbf{V}$	Voltage, V
V	Velocity, m/s
V_{avg}	Average velocity
w	Work per unit mass, kJ/kg
W	Total work, kJ
$\dot{W}$	Power, kW
W_{in}	Work input, kJ
W_{out}	Work output, kJ
W_{rev}	Reversible work, kJ
x	Quality
x	Specific exergy, kJ/kg
X	Total exergy, kJ
x_{dest}	Specific exergy destruction, kJ/kg
X_{dest}	Total exergy destruction, kJ
$\dot{X}_{dest}$	Rate of total exergy destruction, kW
y	Mole fraction
z	Elevation, m
Z	Compressibility factor
Z_h	Enthalpy departure factor
Z_s	Entropy departure factor

Greek Letters

α	Absorptivity
α	Isothermal compressibility, 1/kPa
β	Volume expansivity, 1/K
Δ	Finite change in quantity
ε	Emissivity
ϵ	Effectiveness
η_{th}	Thermal efficiency
η_{II}	Second-law efficiency
θ	Total energy of a flowing fluid, kJ/kg
μ_{JT}	Joule-Thomson coefficient, K/kPa
μ	Chemical potential, kJ/kg
ν	Stoichiometric coefficient
ρ	Density, kg/m^3
σ	Stefan–Boltzmann constant
σ_n	Normal stress, N/m^2
σ_s	Surface tension, N/m
ϕ	Relative humidity
ϕ	Specific closed system exergy, kJ/kg
Φ	Total closed system exergy, kJ
ψ	Stream exergy, kJ/kg
γ_s	Specific weight, N/m^3
ω	Specific or absolute humidity, kg H_2O/kg dry air

Subscripts

a	Air
abs	Absolute
act	Actual
atm	Atmospheric
avg	Average
c	Combustion; cross-section
cr	Critical point
CV	Control volume
e	Exit conditions
f	Saturated liquid
fg	Difference in property between saturated liquid and saturated vapor
g	Saturated vapor
gen	Generation
H	High temperature (as in T_H and Q_H)
i	Inlet conditions
i	ith component
L	Low temperature (as in T_L and Q_L)
m	Mixture
r	Relative
R	Reduced
rev	Reversible
s	Isentropic
sat	Saturated
surr	Surroundings
sys	System
v	Water vapor
0	Dead state
1	Initial or inlet state
2	Final or exit state

Superscripts

˙ (over dot)	Quantity per unit time
¯ (over bar)	Quantity per unit mole
° (circle)	Standard reference state
* (asterisk)	Quantity at 1 atm pressure

THERMODYNAMICS

AN ENGINEERING APPROACH

EIGHTH EDITION

Quotes on Ethics

Without ethics, everything happens as if we were all five billion passengers on a big machinery and nobody is driving the machinery. And it's going faster and faster, but we don't know where.

—Jacques Cousteau

Because you're able to do it and because you have the right to do it doesn't mean it's right to do it.

—Laura Schlessinger

A man without ethics is a wild beast loosed upon this world.

—Manly Hall

The concern for man and his destiny must always be the chief interest of all technical effort. Never forget it among your diagrams and equations.

—Albert Einstein

Cowardice asks the question, 'Is it safe?' Expediency asks the question, 'Is it politic?' Vanity asks the question, 'Is it popular?' But, conscience asks the question, 'Is it right?' And there comes a time when one must take a position that is neither safe, nor politic, nor popular but one must take it because one's conscience tells one that it is right.

—Martin Luther King, Jr

To educate a man in mind and not in morals is to educate a menace to society.

—Theodore Roosevelt

Politics which revolves around benefit is savagery.

—Said Nursi

The true test of civilization is, not the census, nor the size of the cities, nor the crops, but the kind of man that the country turns out.

—Ralph W. Emerson

The measure of a man's character is what he would do if he knew he never would be found out.

—Thomas B. Macaulay

About the Authors

Yunus A. Çengel is Professor Emeritus of Mechanical Engineering at the University of Nevada, Reno. He received his B.S. in mechanical engineering from Istanbul Technical University and his M.S. and Ph.D. in mechanical engineering from North Carolina State University. His areas of interest are renewable energy, energy efficiency, energy policies, heat transfer enhancement, and engineering education. He served as the director of the Industrial Assessment Center (IAC) at the University of Nevada, Reno, from 1996 to 2000. He has led teams of engineering students to numerous manufacturing facilities in Northern Nevada and California to perform industrial assessments, and has prepared energy conservation, waste minimization, and productivity enhancement reports for them. He has also served as an advisor for various government organizations and corporations.

Dr. Çengel is also the author or coauthor of the widely adopted textbooks *Heat and Mass Transfer: Fundamentals and Applications* (5th ed., 2015), *Fluid Mechanics:Fundamentals and Applications* (3rd ed., 2014), *Fundamentals of Thermal-Fluid Sciences* (4th ed., 2012), *Introduction to Thermodynamics and Heat Transfer* (2nd ed., 2008), and *Differential Equations for Engineers and Scientists* (1st ed., 2013), all published by McGraw-Hill. Some of his textbooks have been translated into Chinese, Japanese, Korean, Thai, Spanish, Portuguese, Turkish, Italian, Greek, and French.

Dr. Çengel is the recipient of several outstanding teacher awards, and he has received the ASEE Meriam/Wiley Distinguished Author Award for excellence in authorship in 1992 and again in 2000. Dr. Çengel is a registered Professional Engineer in the State of Nevada, and is a member of the American Society of Mechanical Engineers (ASME) and the American Society for Engineering Education (ASEE).

Michael A. Boles is Associate Professor of Mechanical and Aerospace Engineering at North Carolina State University, where he earned his Ph.D. in mechanical engineering and is an Alumni Distinguished Professor. Dr. Boles has received numerous awards and citations for excellence as an engineering educator. He is a past recipient of the SAE Ralph R. Teetor Education Award and has been twice elected to the NCSU Academy of Outstanding Teachers. The NCSU ASME student section has consistently recognized him as the outstanding teacher of the year and the faculty member having the most impact on mechanical engineering students.

Dr. Boles specializes in heat transfer and has been involved in the analytical and numerical solution of phase change and drying of porous media. He is a member of the American Society of Mechanical Engineers (ASME), the American Society for Engineering Education (ASEE), and Sigma Xi. Dr. Boles received the ASEE Meriam/Wiley Distinguished Author Award in 1992 for excellence in authorship.

PREFACE

BACKGROUND

Thermodynamics is an exciting and fascinating subject that deals with energy, and thermodynamics has long been an essential part of engineering curricula all over the world. It has a broad application area ranging from microscopic organisms to common household appliances, transportation vehicles, power generation systems, and even philosophy. This introductory book contains sufficient material for two sequential courses in thermodynamics. Students are assumed to have an adequate background in calculus and physics.

OBJECTIVES

This book is intended for use as a textbook by undergraduate engineering students in their sophomore or junior year, and as a reference book for practicing engineers. The objectives of this text are

- To cover the *basic principles* of thermodynamics.
- To present a wealth of real-world *engineering examples* to give students a feel for how thermodynamics is applied in engineering practice.
- To develop an *intuitive understanding* of thermodynamics by emphasizing the physics and physical arguments that underpin the theory.

It is our hope that this book, through its careful explanations of concepts and its use of numerous practical examples and figures, helps students develop the necessary skills to bridge the gap between knowledge and the confidence to properly apply knowledge.

PHILOSOPHY AND GOAL

The philosophy that contributed to the overwhelming popularity of the prior editions of this book has remained unchanged in this edition. Namely, our goal has been to offer an engineering textbook that

- Communicates directly to the minds of tomorrow's engineers in a *simple yet precise* manner.
- Leads students toward a clear understanding and firm grasp of the *basic principles* of thermodynamics.
- Encourages *creative thinking* and development of a *deeper understanding* and *intuitive feel* for thermodynamics.
- Is *read* by students with *interest* and *enthusiasm* rather than being used as an aid to solve problems.

Special effort has been made to appeal to students' natural curiosity and to help them explore the various facets of the exciting subject area of thermodynamics. The enthusiastic responses we have received from users of prior editions—from small colleges to large universities all over the world—and the continued translations into new languages indicate that our objectives have largely been achieved. It is our philosophy that the best way to learn is by practice. Therefore, special effort is made throughout the book to reinforce material that was presented earlier.

Yesterday's engineer spent a major portion of his or her time substituting values into the formulas and obtaining numerical results. However, formula manipulations and number crunching are now being left mainly to computers. Tomorrow's engineer will need a clear understanding and a firm grasp of the *basic principles* so that he or she can understand even the most complex problems, formulate them, and interpret the results. A conscious effort is made to emphasize these basic principles while also providing students with a perspective of how computational tools are used in engineering practice.

The traditional *classical,* or *macroscopic,* approach is used throughout the text, with microscopic arguments serving in a supporting role as appropriate. This approach is more in line with students' intuition and makes learning the subject matter much easier.

NEW IN THIS EDITION

The primary change in this eighth edition of the text is the effective use of full color to enhance the learning experience of students and to make it more enjoyable. Another significant change is the addition of a new web chapter on Renewable Energy available via the Online Learning Center. The third important change is the update of the R-134a tables to make property values consistent with those from the latest version of EES. All the solved examples and end-of-chapter problems dealing with R-134a are modified to reflect this change. This edition includes numerous new problems with a variety of applications. Problems, whose solutions require parametric investigations and thus the use of a computer, are identified by a computer-EES icon, as before. Some existing problems from previous editions have been removed, and other updates and changes for clarity and readability have been made throughout the text.

The eighth edition also includes **McGraw-Hill's Connect®** Engineering. This online homework management tool allows assignment of algorithmic problems for homework, quizzes and tests. It connects students with the tools and resources they'll need to achieve success. To learn more, visit www.mcgrawhillconnect.com.

McGraw-Hill LearnSmart™ is also available as an integrated feature of McGraw-Hill Connect® Engineering. It is an adaptive learning system designed to help students learn faster, study more efficiently, and retain more knowledge for greater success. LearnSmart assesses a student's knowledge of course content through a series of adaptive questions. It pinpoints concepts the student does not understand and maps out a personalized study plan for success. Visit the following site for a demonstration: www.mhlearnsmart.com.

LEARNING TOOLS

EARLY INTRODUCTION OF THE FIRST LAW OF THERMODYNAMICS

The first law of thermodynamics is introduced early in Chapter 2, "Energy, Energy Transfer, and General Energy Analysis." This introductory chapter sets the framework of establishing a general understanding of various forms of energy, mechanisms of energy transfer, the concept of energy balance, thermo-economics, energy conversion, and conversion efficiency using familiar settings that involve mostly electrical and mechanical forms of energy. It also exposes students to some exciting real-world applications of thermodynamics early in the course, and helps them establish a sense of the monetary value of energy. There is special emphasis on the utilization of renewable energy such as wind power and hydraulic energy, and the efficient use of existing resources.

EMPHASIS ON PHYSICS

A distinctive feature of this book is its emphasis on the physical aspects of the subject matter in addition to mathematical representations and manipulations. The authors believe that the emphasis in undergraduate education should remain on *developing a sense of underlying physical mechanisms* and a *mastery of solving practical problems* that an engineer is likely to face in the real world. Developing an intuitive understanding should also make the course a more motivating and worthwhile experience for students.

EFFECTIVE USE OF ASSOCIATION

An observant mind should have no difficulty understanding engineering sciences. After all, the principles of engineering sciences are based on our *everyday experiences* and *experimental observations.* Therefore, a physical, intuitive approach is used throughout this text. Frequently, *parallels are drawn* between the subject matter and students' everyday experiences so that they can relate the subject matter to what they already know. The process of cooking, for example, serves as an excellent vehicle to demonstrate the basic principles of thermodynamics.

SELF-INSTRUCTING

The material in the text is introduced at a level that an average student can follow comfortably. It speaks *to* students, not *over* students. In fact, it is *self-instructive.* The order of coverage is from *simple* to *general.* That is, it starts with the simplest case and adds complexities gradually. In this way, the basic principles are repeatedly applied to different systems, and students master how to apply the principles instead of how to simplify a general formula. Noting that the principles of sciences are based on experimental observations, all the derivations in this text are based on physical arguments, and thus they are easy to follow and understand.

EXTENSIVE USE OF ARTWORK

Figures are important learning tools that help students "get the picture," and the text makes very effective use of graphics. This edition of *Thermodynamics: An Engineering Approach,* Eighth Edition features an enhanced art program done in four colors to provide more realism and pedagogical understanding. Further, a large number of figures have been upgraded to become three-dimensional and thus more real-life. Figures attract attention and stimulate curiosity and interest. Most of the figures in this text are intended to serve as a means of emphasizing some key concepts that would otherwise go unnoticed; some serve as page summaries.

LEARNING OBJECTIVES AND SUMMARIES

Each chapter begins with an *overview* of the material to be covered and chapter-specific *learning objectives.* A *summary* is included at the end of each chapter, providing a quick review of basic concepts and important relations, and pointing out the relevance of the material.

NUMEROUS WORKED-OUT EXAMPLES WITH A SYSTEMATIC SOLUTIONS PROCEDURE

Each chapter contains several worked-out *examples* that clarify the material and illustrate the use of the basic principles. An *intuitive* and *systematic* approach is used in the solution of the example problems, while maintaining an informal conversational style. The problem is first stated, and the objectives are identified. The assumptions are then stated, together with their justifications. The properties needed to solve the problem are listed separately if appropriate. Numerical values are used together with their units to emphasize that numbers without units are meaningless, and that unit manipulations are as important as manipulating the numerical values with a calculator. The significance of the findings is discussed following the solutions. This approach is also used consistently in the solutions presented in the instructor's solutions manual.

A WEALTH OF REAL-WORLD END-OF-CHAPTER PROBLEMS

The end-of-chapter problems are grouped under specific topics to make problem selection easier for both instructors and students. Within each group of problems are *Concept Questions,* indicated by "C," to check the students' level of understanding of basic concepts. The problems under *Review Problems* are more comprehensive in nature and are not directly tied to any specific section of a chapter—in some cases they require review of material learned in previous chapters. Problems designated as *Design and Essay* are intended to encourage students to make engineering judgments, to conduct independent exploration of topics of interest, and to communicate their findings in a professional manner. Problems designated by an "E" are in English units, and SI users can ignore them. Problems with the are solved using EES, and complete solutions together with parametric studies are included on the textbook's website. Problems with the are comprehensive in nature and are intended to be solved with a computer, possibly using the EES software. Several economics- and safety-related problems are incorporated throughout to promote cost and safety awareness among engineering students. Answers to selected problems are listed immediately following the problem for convenience to students. In addition, to prepare students for the Fundamentals of Engineering Exam (that is becoming more important for the outcome-based ABET 2000 criteria) and to facilitate multiple-choice tests, over 200 *multiple-choice problems* are included in the end-of-chapter problem sets. They are placed under the title *Fundamentals of Engineering (FE) Exam Problems* for easy recognition. These problems are intended to check the understanding of fundamentals and to help readers avoid common pitfalls.

RELAXED SIGN CONVENTION

The use of a formal sign convention for heat and work is abandoned as it often becomes counterproductive. A physically meaningful and engaging approach is adopted for interactions instead of a mechanical approach.

Subscripts "in" and "out," rather than the plus and minus signs, are used to indicate the directions of interactions.

PHYSICALLY MEANINGFUL FORMULAS

The physically meaningful forms of the balance equations rather than formulas are used to foster deeper understanding and to avoid a cookbook approach. The mass, energy, entropy, and exergy balances for *any system* undergoing *any process* are expressed as

Mass balance:

$$m_{\text{in}} - m_{\text{out}} = \Delta m_{\text{system}}$$

Energy balance:

$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\substack{\text{Net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{\text{system}}}_{\substack{\text{Change in internal, kinetic,} \\ \text{potential, etc., energies}}}$$

Entropy balance:

$$\underbrace{S_{\text{in}} - S_{\text{out}}}_{\substack{\text{Net entropy transfer} \\ \text{by heat and mass}}} + \underbrace{S_{\text{gen}}}_{\substack{\text{Entropy} \\ \text{generation}}} = \underbrace{\Delta S_{\text{system}}}_{\substack{\text{Change} \\ \text{in entropy}}}$$

Exergy balance:

$$\underbrace{X_{\text{in}} - X_{\text{out}}}_{\substack{\text{Net exergy transfer} \\ \text{by heat, work, and mass}}} - \underbrace{X_{\text{destroyed}}}_{\substack{\text{Exergy} \\ \text{destruction}}} = \underbrace{\Delta X_{\text{system}}}_{\substack{\text{Change} \\ \text{in exergy}}}$$

These relations reinforce the fundamental principles that during an actual process mass and energy are conserved, entropy is generated, and exergy is destroyed. Students are encouraged to use these forms of balances in early chapters after they specify the system, and to simplify them for the particular problem. A more relaxed approach is used in later chapters as students gain mastery.

A CHOICE OF SI ALONE OR SI/ENGLISH UNITS

In recognition of the fact that English units are still widely used in some industries, both SI and English units are used in this text, with an emphasis on SI. The material in this text can be covered using combined SI/English units or SI units alone, depending on the preference of the instructor. The property tables and charts in the appendices are presented in both units, except the ones that involve dimensionless quantities. Problems, tables, and charts in English units are designated by "E" after the number for easy recognition, and they can be ignored by SI users.

TOPICS OF SPECIAL INTEREST

Most chapters contain a section called "Topic of Special Interest" where interesting aspects of thermodynamics are discussed. Examples include *Thermodynamic Aspects of Biological Systems* in Chapter 4, *Household Refrigerators* in Chapter 6, *Second-Law Aspects of Daily Life* in Chapter 8, and *Saving Fuel and Money by Driving Sensibly* in Chapter 9. The topics selected for these sections provide intriguing extensions to thermodynamics, but they can be ignored if desired without a loss in continuity.

GLOSSARY OF THERMODYNAMIC TERMS

Throughout the chapters, when an important key term or concept is introduced and defined, it appears in **boldface** type. Fundamental thermodynamic terms and concepts also appear in a glossary located on our accompanying website (www.mhhe.com/cengel). This unique glossary helps to reinforce key terminology and is an excellent learning and review tool for students as they move forward in their study of thermodynamics. In addition, students can test their knowledge of these fundamental terms by using the flash cards and other interactive resources.

CONVERSION FACTORS

Frequently used conversion factors and physical constants are listed on the inner cover pages of the text for easy reference.

SUPPLEMENTS

The following supplements are available to users of the book.

ENGINEERING EQUATION SOLVER (EES)

Developed by Sanford Klein and William Beckman from the University of Wisconsin—Madison, this software combines equation-solving capability and engineering property data. EES can do optimization, parametric analysis, and linear and nonlinear regression, and provides publication-quality plotting capabilities. Thermodynamics and transport properties for air, water, and many other fluids are built in, and EES allows the user to enter property data or functional relationships.

EES is a powerful equation solver with built-in functions and property tables for thermodynamic and transport properties as well as automatic unit checking capability. It requires less time than a calculator for data entry and allows more time for thinking critically about modeling and solving engineering problems. Look for the EES icons in the homework problems sections of the text.

The Limited Academic Version of EES is available for departmental license upon adoption of the Eighth Edition of Thermodynamics: An Engineering Approach (meaning that the text is required for students in the course). You may load this software onto your institution's computer system, for use by students and faculty related to the course, as long as the arrangement between McGraw-Hill Education and F-Chart is in effect. There are minimum order requirements stipulated by F-Chart to qualify.

PROPERTIES TABLE BOOKLET (ISBN 0-07-762477-7)

This booklet provides students with an easy reference to the most important property tables and charts, many of which are found at the back of the textbook in both the SI and English units.

COSMOS

McGraw-Hill's COSMOS (Complete Online Solutions Manual Organization System) allows instructors to streamline the creation of assignments, quizzes, and tests by using problems and solutions from the textbook, as well as their own custom material. COSMOS is now available online at http://cosmos.mhhe.com/

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Yunus A. Çengel
Michael A. Boles

Online Resources for Students and Instructors

McGraw-Hill Connect® Engineering

McGraw-Hill Connect Engineering is a web-based assignment and assessment platform that gives students the means to better connect with their course-work, with their instructors, and with the important concepts that they will need to know for success now and in the future. With Connect Engineering, instructors can deliver assignments, quizzes, and tests easily online. Students can practice important skills at their own pace and on their own schedule.

Connect Engineering for *Thermodynamics: An Engineering Approach*, Eighth Edition is available via the text website at www.mhhe.com/cengel

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McGraw-Hill's COSMOS (Complete Online Solutions Manual Organization System) allows instructors to streamline the creation of assignments, quizzes, and tests by using problems and solutions from the textbook, as well as their own custom material. COSMOS is now available online at http://cosmos.mhhe.com/

WWW.MHHE.COM/CENGEL

This site offers resources for students and instructors.

The following resources are available for students:

- **Glossary of Key Terms in Thermodynamics**—Bolded terms in the text are defined in this accessible glossary. Organized at the chapter level or available as one large file.
- **Student Study Guide**—This resource outlines the fundamental concepts of the text and is a helpful guide that allows students to focus on the most important concepts. The guide can also serve as a lecture outline for instructors.
- **Learning Objectives**—The chapter learning objectives are outlined here. Organized by chapter and tied to ABET objectives.
- **Self-Quizzing**—Students can test their knowledge using multiple-choice quizzing. These self-tests provide immediate feedback and are an excellent learning tool.
- **Flashcards**—Interactive flashcards test student understanding of the text terms and their definitions. The program also allows students to flag terms that require further understanding.
- **Crossword Puzzles**—An interactive, timed puzzle that provides hints as well as a notes section.
- **Errata**—If errors should be found in the text, they will be reported here.

The following resources are available for instructors under password protection:

- **Instructor Testbank**—Additional problems prepared for instructors to assign to students. Solutions are given, and use of EES is recommended to verify accuracy.
- **Correlation Guide**—New users of this text will appreciate this resource. The guide provides a smooth transition for instructors not currently using the Çengel/Boles text.
- **Image Library**—The electronic version of the figures are supplied for easy integration into course presentations, exams, and assignments.
- **Instructor's Guide**—Provides instructors with helpful tools such as sample syllabi and exams, an ABET conversion guide, a thermodynamics glossary, and chapter objectives.
- **Errata**—If errors should be found in the solutions manual, they will be reported here.
- **Solutions Manual**—The detailed solutions to all text homework problems are provided in PDF form.
- **EES Solutions Manual**—The entire solutions manual is also available in EES. Any problem in the text can be modified and the solution of the modified problem can readily be obtained by copying and pasting the given EES solution on a blank EES screen and hitting the solve button.
- **PP slides**—Powerpoint presentation slides for all chapters in the text are available for use in lectures
- **Appendices**—These are provided in PDF form for ease of use.