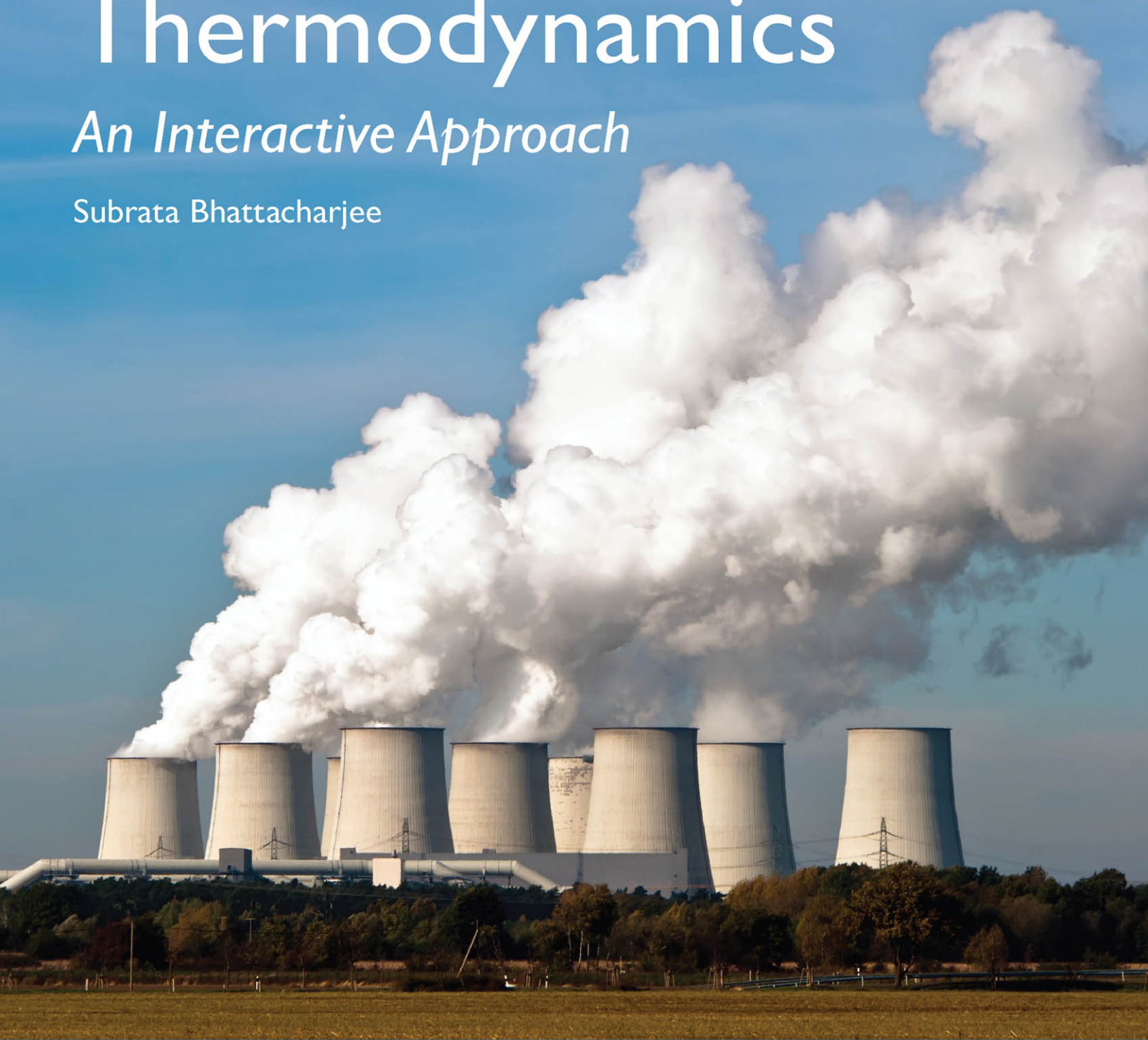
GLOBAL EDITION

Thermodynamics

An Interactive Approach

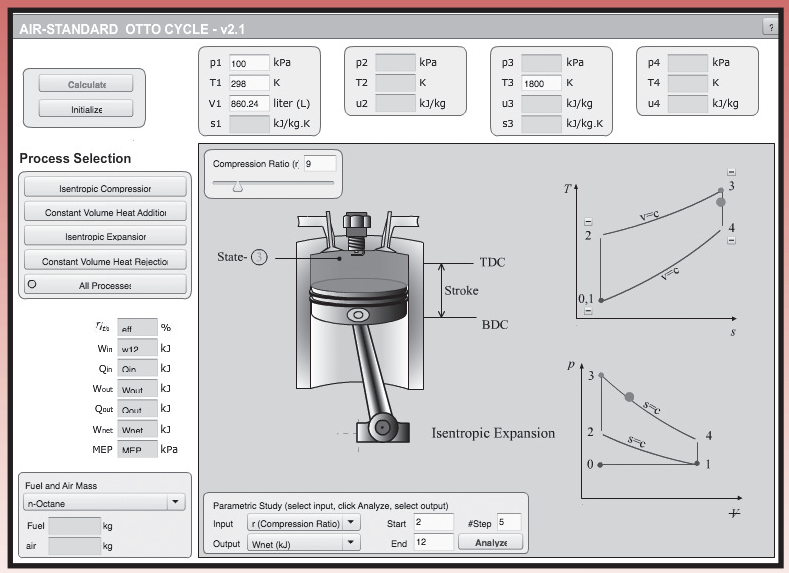
Subrata Bhattacharjee



ALWAYS LEARNING

PEARSON

TEST: The Expert System for Thermodynamics



The Expert System for Thermodynamics, or **TEST**, is an interactive website offering tools that enable you to analyze thermofluids problems and verify your calculations. With **TESTcalc**, **Interactive Animations**, **Property Tables**, **Animations**, and **Test Code** examples, you can also pursue what-if scenarios, and visualize complex thermal systems. Throughout the text, you will find problems and examples with references to **TEST** tools.

Redeem access to TEST at:
www.pearsonglobaleditions.com/Bhattacharjee

Use a coin to scratch off the coating and reveal your student access code.
Do not use a knife or other sharp object as it may damage the code.

IMPORTANT: The access code on this page can only be used once to establish a subscription. If the access code has already been scratched off, it may no longer be valid. If this is the case, visit the website above and select "Get Access" to purchase a new subscription. Please note that the access code does not include access to MasteringEngineering.

Technical Support is available at www.247pearsoned.com

Thermodynamics: An Interactive Approach, Global Edition

Table of Contents

Cover
Title Page
Copyright Page
Table of Contents
Preface
Introduction Thermodynamic System and Its Interactions with the Surroundings
- 0.1 Thermodynamic Systems
- 0.2 Test and Animations
- 0.3 Examples of Thermodynamic Systems
- 0.4 Interactions Between the System and Its Surroundings
- 0.5 Mass Interaction
- 0.6 Test and the TESTcalcs
- 0.7 Energy, Work, and Heat
  - 0.7.1 Heat and Heating Rate
  - 0.7.2 Work and Power
- 0.8 Work Transfer Mechanisms
  - 0.8.1 Mechanical Work
  - 0.8.2 Shaft Work
  - 0.8.3 Electrical Work
  - 0.8.4 Boundary Work
  - 0.8.5 Flow Work
  - 0.8.6 Net Work Transfer
  - 0.8.7 Other Interactions
- 0.9 Closure

Chapter 1 Description of a System: States and Properties
- 1.1 Consequences of Interactions
- 1.2 States
- 1.3 Macroscopic vs. Microscopic Thermodynamics
- 1.4 An Image Analogy

Pearson

Table of Contents

1.5 Properties of State

1.5.1 Property Evaluation by State TESTcalcs

1.5.2 Properties Related to System Size

1.5.3 Density and Specific Volume

1.5.4 Velocity and Elevation

1.5.5 Pressure

1.5.6 Temperature

1.5.7 Stored Energy

1.5.8 Flow Energy and Enthalpy

1.5.9 Entropy

1.5.10 Exergy

1.6 Property Classification

1.7 Evaluation of Extended State

1.8 Closure

Chapter 2 Development of Balance Equations for Mass, Energy, and Entropy: Application to Closed-Steady Systems

2.1 Balance Equations

2.1.1 Mass Balance Equation

2.1.2 Energy Balance Equation

2.1.3 Entropy Balance Equation

2.1.4 Entropy and Reversibility

2.2 Closed-Steady Systems

2.3 Cyclesa Special Case of Closed-Steady Systems

2.3.1 Heat Engine

2.3.2 Refrigerator and Heat Pump

2.3.3 The Carnot Cycle

2.3.4 The Kelvin Temperature Scale

2.4 Closure

Chapter 3 Evaluation of Properties: Material Models

3.1 Thermodynamic Equilibrium and States

3.1.1 Equilibrium and LTE (Local Thermodynamic Equilibrium)

3.1.2 The State Postulate

3.1.3 Differential Thermodynamic Relations

3.2 Material Models

3.2.1 State TESTcalcs and TEST-Codes

3.3 The SL (Solid/Liquid) Model

Table of Contents

3.3.1 SL Model Assumptions

3.3.2 Equations of State

3.3.3 Model Summary: SL Model

3.4 The PC (Phase-Change) Model

3.4.1 A New Pair of PropertiesQualities x and y

3.4.2 Numerical Simulation

3.4.3 Property Diagrams

3.4.4 Extending the Diagrams: The Solid Phase

3.4.5 Thermodynamic Property Tables

3.4.6 Evaluation of Phase Composition

3.4.7 Properties of Saturated Mixture

3.4.8 Subcooled or Compressed Liquid

3.4.9 Supercritical Vapor or Liquid

3.4.10 Sublimation States

3.4.11 Model SummaryPC Model

3.5 GAS MODELS

3.5.1 The IG (Ideal Gas) and PG (Perfect Gas) Models

3.5.2 IG and PG Model Assumptions

3.5.3 Equations of State

3.5.4 Model Summary: PG and IG Models

3.5.5 The RG (Real Gas) Model

3.5.6 RG Model Assumptions

3.5.7 Compressibility Charts

3.5.8 Other Equations of State

3.5.9 Model Summary: RG Model

3.6 Mixture Models

3.6.1 Vacuum

3.7 Standard Reference State and Reference Values

3.8 Selection of a Model

3.9 Closure

Chapter 4 Mass, Energy, and Entropy Analysis of Open-Steady Systems

4.1 Governing Equations and Device Efficiencies

4.1.1 TEST and the Open-Steady TESTcalcs

4.1.2 Energetic Efficiency

4.1.3 Internally Reversible System

4.1.4 Isentropic Efficiency

4.2 Comprehensive Analysis

Table of Contents

4.2.1 Pipes, Ducts, or Tubes
4.2.2 Nozzles and Diffusers
4.2.3 Turbines
4.2.4 Compressors, Fans, and Pumps
4.2.5 Throttling Valves
4.2.6 Heat Exchangers
4.2.7 TEST and the Multi-Flow, Non-Mixing TESTcalcs
4.2.8 Mixing Chambers and Separators
4.2.9 TEST and the Multi-Flow, Mixing TESTcalcs
4.3 Closure
Chapter 5 Mass, Energy, and Entropy Analysis of Unsteady Systems
5.1 Unsteady Processes
5.1.1 Closed Processes
5.1.2 TEST and the Closed-Process TESTcalcs
5.1.3 Energetic Efficiency and Reversibility
5.1.4 Uniform Closed Processes
5.1.5 Non-Uniform Systems
5.1.6 TEST and the Non-Uniform Closed-Process TESTcalcs
5.1.7 Open Processes
5.1.8 TEST and Open-Process TESTcalcs
5.2 Transient Analysis
5.2.1 Closed-Transient Systems
5.2.2 Isolated Systems
5.2.3 Mechanical Systems
5.2.4 Open-Transient Systems
5.3 Differential Processes
5.4 Thermodynamic Cycle as a Closed Process
5.4.1 Origin of Internal Energy
5.4.2 Clausius Inequality and Entropy
5.5 Closure
Chapter 6 Exergy Balance Equation: Application to Steady and Unsteady Systems
6.1 Exergy Balance Equation
6.1.1 Exergy, Reversible Work, and Irreversibility
6.1.2 TESTcalcs for Exergy Analysis
6.2 Closed-Steady Systems

Table of Contents

6.2.1 Exergy Analysis of Cycles

6.3 Open-Steady Systems

6.4 Closed Processes

6.5 Open Processes

6.6 Closure

Chapter 7 Reciprocating Closed Power Cycles

7.1 The Closed Carnot Heat Engine

7.1.1 Significance of the Carnot Engine

7.2 IC Engine Terminology

7.3 Air-Standard Cycles

7.3.1 TEST and the Reciprocating Cycle TESTcalcs

7.4 Otto Cycle

7.4.1 Cycle Analysis

7.4.2 Qualitative Performance Predictions

7.4.3 Fuel Consideration

7.5 Diesel Cycle

7.5.1 Cycle Analysis

7.5.2 Fuel Consideration

7.6 Dual Cycle

7.7 Atkinson and Miller Cycles

7.8 Stirling Cycle

7.9 Two-Stroke Cycle

7.10 Fuels

7.11 Closure

Chapter 8 Open Gas Power Cycle

8.1 The Gas Turbine

8.2 The Air-Standard Brayton Cycle

8.2.1 TEST and the Open Gas Power Cycle TESTcalcs

8.2.2 Fuel Consideration

8.2.3 Qualitative Performance Predictions

8.2.4 Irreversibilities in an Actual Cycle

8.2.5 Exergy Accounting of Brayton Cycle

8.3 Gas Turbine with Regeneration

8.4 Gas Turbine with Reheat

8.5 Gas Turbine with Intercooling and Reheat

Table of Contents

8.6 Regenerative Gas Turbine with Reheat and Intercooling

8.7 Gas Turbines For Jet Propulsion

8.7.1 The Momentum Balance Equation

8.7.2 Jet Engine Performance

8.7.3 Air-Standard Cycle for Turbojet Analysis

8.8 Other Forms of Jet Propulsion

8.9 Closure

Chapter 9 Open Vapor Power Cycles

9.1 The Steam Power Plant

9.2 The Rankine Cycle

9.2.1 Carbon Footprint

9.2.2 TEST and the Open Vapor Power Cycle TESTcalcs

9.2.3 Qualitative Performance Predictions

9.2.4 Parametric Study of the Rankine Cycle

9.2.5 Irreversibilities in an Actual Cycle

9.2.6 Exergy Accounting of Rankine Cycle

9.3 Modification of Rankine Cycle

9.3.1 Reheat Rankine Cycle

9.3.2 Regenerative Rankine Cycle

9.4 Cogeneration

9.5 Binary Vapor Cycle

9.6 Combined Cycle

9.7 Closure

Chapter 10 Refrigeration Cycles

10.1 Refrigerators and Heat Pump

10.2 Test and the Refrigeration Cycle TESTcalcs

10.3 Vapor-Refrigeration Cycles

10.3.1 Carnot Refrigeration Cycle

10.3.2 Vapor Compression Cycle

10.3.3 Analysis of an Ideal Vapor-Compression Refrigeration Cycle

10.3.4 Qualitative Performance Predictions

10.3.5 Actual Vapor-Compression Cycle

10.3.6 Components of a Vapor-Compression Plant

10.3.7 Exergy Accounting of Vapor Compression Cycle

10.3.8 Refrigerant Selection

10.3.9 Cascade Refrigeration Systems

Table of Contents

10.3.10 Multistage Refrigeration with Flash Chamber

10.4 Absorption Refrigeration Cycle

10.5 Gas Refrigeration Cycles

10.5.1 Reversed Brayton Cycle

10.5.2 Linde-Hampson Cycle

10.6 Heat Pump Systems

10.7 Closure

Chapter 11 Evaluation of Properties: Thermodynamic Relations

11.1 Thermodynamic Relations

11.1.1 The Tds Relations

11.1.2 Partial Differential Relations

11.1.3 The Maxwell Relations

11.1.4 The Clapeyron Equation

11.1.5 The Clapeyron-Clausius Equation

11.2 Evaluation of Properties

11.2.1 Internal Energy

11.2.2 Enthalpy

11.2.3 Entropy

11.2.4 Volume Expansivity and Compressibility

11.2.5 Specific Heats

11.2.6 Joule-Thompson Coefficient

11.3 The Real Gas (RG) Model

11.4 Mixture Models

11.4.1 Mixture Composition

11.4.2 Mixture TESTcalcs

11.4.3 PG and IG Mixture Models

11.4.4 Mass, Energy, and Entropy Equations for IG-Mixtures

11.4.5 Real Gas Mixture Model

11.5 Closure

Chapter 12 Psychrometry

12.1 The Moist Air Model

12.1.1 Model Assumptions

12.1.2 Saturation Processes

12.1.3 Absolute and Relative Humidity

12.1.4 Dry- and Wet-Bulb Temperatures

12.1.5 Moist Air (Ma) TESTcalcs

Table of Contents

12.1.6 More Properties of Moist Air

12.2 Mass and Energy Balance Equations

12.2.1 Open-Steady Device

12.2.2 Closed Process

12.3 Adiabatic Saturation and Wet-Bulb Temperature

12.4 Psychrometric Chart

12.5 Air-Conditioning Processes

12.5.1 Simple Heating or Cooling

12.5.2 Heating with Humidification

12.5.3 Cooling with Dehumidification

12.5.4 Evaporative Cooling

12.5.5 Adiabatic Mixing

12.5.6 Wet Cooling Tower

12.6 Closure

Chapter 13 Combustion

13.1 Combustion Reaction

13.1.1 Combustion TESTcalcs

13.1.2 Fuels

13.1.3 Air

13.1.4 Combustion Products

13.2 System Analysis

13.3 Open-Steady Device

13.3.1 Enthalpy of Formation

13.3.2 Energy Analysis

13.3.3 Entropy Analysis

13.3.4 Exergy Analysis

13.3.5 Isothermal CombustionFuel Cells

13.3.6 Adiabatic CombustionPower Plants

13.4 Closed Process

13.5 Combustion Efficiencies

13.6 Closure

Chapter 14 Equilibrium

14.1 Criteria for Equilibrium

14.2 Equilibrium of Gas Mixtures

14.3 Phase Equilibrium

14.3.1 Osmotic Pressure and Desalination

Table of Contents

- 14.4 Chemical Equilibrium
  - 14.4.1 Equilibrium TESTcalcs
  - 14.4.2 Equilibrium Composition
  - 14.4.3 Significance of Equilibrium Constant
- 14.5 Closure

Chapter 15 Gas Dynamics

- 15.1 One-Dimensional Flow
  - 15.1.1 Static, Stagnation and Total Properties
  - 15.1.2 The Gas Dynamics TESTcalc
- 15.2 Isentropic Flow of a Perfect Gas
- 15.3 Mach Number
- 15.4 Shape of an Isentropic Duct
- 15.5 Isentropic Table for Perfect Gases
- 15.6 Effect of Back Pressure: Converging Nozzle
- 15.7 Effect of Back Pressure: Converging-Diverging Nozzle
  - 15.7.1 Normal Shock
  - 15.7.2 Normal Shock in a Nozzle
- 15.8 Nozzle and Diffuser Coefficients
- 15.9 Closure

Appendix A

Appendix B

Answers to Key Problems

Index