Green Energy and Technology

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Energy

Production, Conversion, Storage, Conservation, and Coupling

Second Edition

Springer

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To Zuhal, Selçuk, and Can

Preface

This book is the second edition to fill the need for a comprehensive textbook on energy. Importance of energy and its effect on everyday life are undisputable. Consequently, many institutions today offer either energy minor or energy major programs. And 'Energy Engineering' is emerging as one of the recent engineering disciplines. Yet a suitable and general textbook for such programs is needed. This textbook is an undergraduate textbook for students with diverse backgrounds and interested to know more on energy and pursue a degree on energy. The new textbook covers many aspects of energy in systems with rate and transport processes.

The new textbook discusses five major aspects of energy in an introductory manner. These major aspects are: energy production, conversion, storage, conservation, and coupling in separate chapters. Before discussing these aspects of energy, the textbook starts with the Introduction: Basic Definitions in Chap. 1. In Chap. 2, the primary and the secondary energy sources are discussed. Chapter 3 discusses mechanical and electrical energies that are types of major energies other than heat and work. Chapter 4 discusses the internal energy and enthalpy, Chap. 5 discusses balance equations, heat of reaction, and heat transfer. After these chapters for introducing the basics and building the infrastructure of energy, Chap. 6 discusses energy production mainly using closed and open cycles. Chapter 7 discusses the energy conversion with an emphasis on the ways to improve the energy conversion efficiency. Chapter 8 emphasizes the energy storage by various means. Chapter 9 discusses the energy conservation and recovery. Chapter 10 briefly introduces energy coupling with examples from biological systems. Finally, newly introduced Chap. 11 focuses on sustainability and life cycle analysis in energy systems in order to emphasize the implications of the use of energy on the environment, society, and economy.

Each chapter contains fully solved example problems to support the easy understanding and applications of the topics discussed. At the end of each chapter, enough number of practice problems are listed to provide the students with opportunity toward deep understanding the concepts and aspects of energy. There

are a total of 140 fully solved example problems in the textbook and a total 648 practice problems listed at the end of 11 chapters.

It is obvious that the present textbook will mature further in reoccurring editions based on the technological developments and suggestions from the students and colleagues. I want to thank to those who helped me in preparing, developing, and improving the textbook. I especially thank Brad Hailey, Michael Matzen, Nghi Nguyen, Mahdi AlHajji, Hannah Evans, Xiaomeng Wang, and Dr. M.A. Abdel-Wahab for their help preparing this new textbook and checking the problems. I very much want to encourage those using this new textbook to contact me with suggestions and corrections for future editions.

Lincoln, NE, USA Yaşar Demirel
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Contents

Abbreviations

ADP	Adenosine diphosphate
ASHRAE	American society of heating, refrigerating and air conditioning engineers
ATP	Adenosine triphosphate
AUFE	Annual fuel utilization efficiency
CAES	Compressed air energy storage
COP	Coefficient of performance
DOE	Department of energy
EER	Energy efficiency ratio
EIA	Energy information administration
EPA	Environmental protection agency
ETB	Engineering toolbox
HP	Heat pump
HVAC	Heating, ventilation, and air conditioning
NREL	National renewable energy laboratory
PCM	Phase changing material
SEER	Seasonal energy efficiency ratio

Symbols

c_i	Molar concentration of component i
°C	Degrees Celsius
C_p	Constant-pressure heat capacities
D	Diameter
F	Faraday constant
°F	Degrees Fahrenheit
$\boldsymbol{F}$	Mass force
G	Gibbs free energy
h	Specific enthalpy, heat transfer coefficient
h_i	Partial specific enthalpy of component i
H	Enthalpy
I	Charge
$\boldsymbol{J}_i$	Flux of component i
J_q	Heat flux in the entropy balance equation
k_B	Boltzmann's constant, thermal conductivity
k	Thermal conductivity
m	Mass
M	Molar mass
n	Number of moles
P	Pressure
q	Degree of coupling
Q	Heat, volume flow
$\dot{Q}$	Heat flow rate
R	Universal gas constant
S	Entropy
t	Time
T	Absolute temperature
u	Specific internal energy
U	Internal energy
v	Specific volume
V	Volume

w_i Mass fraction of component i
W Work
X Ratio of forces
X_i Thermodynamic force
z valance

Greek Symbols

η Ratio of flows
λ Ratio of forces
μ_i Chemical potential of component i
ρ Density
v Stoichiometric coefficient
Ψ Dissipation function

Subscripts

e Effective
gen Generation
i,j,k Components
max Maximum
min Minimum
q Heat
r Chemical reaction