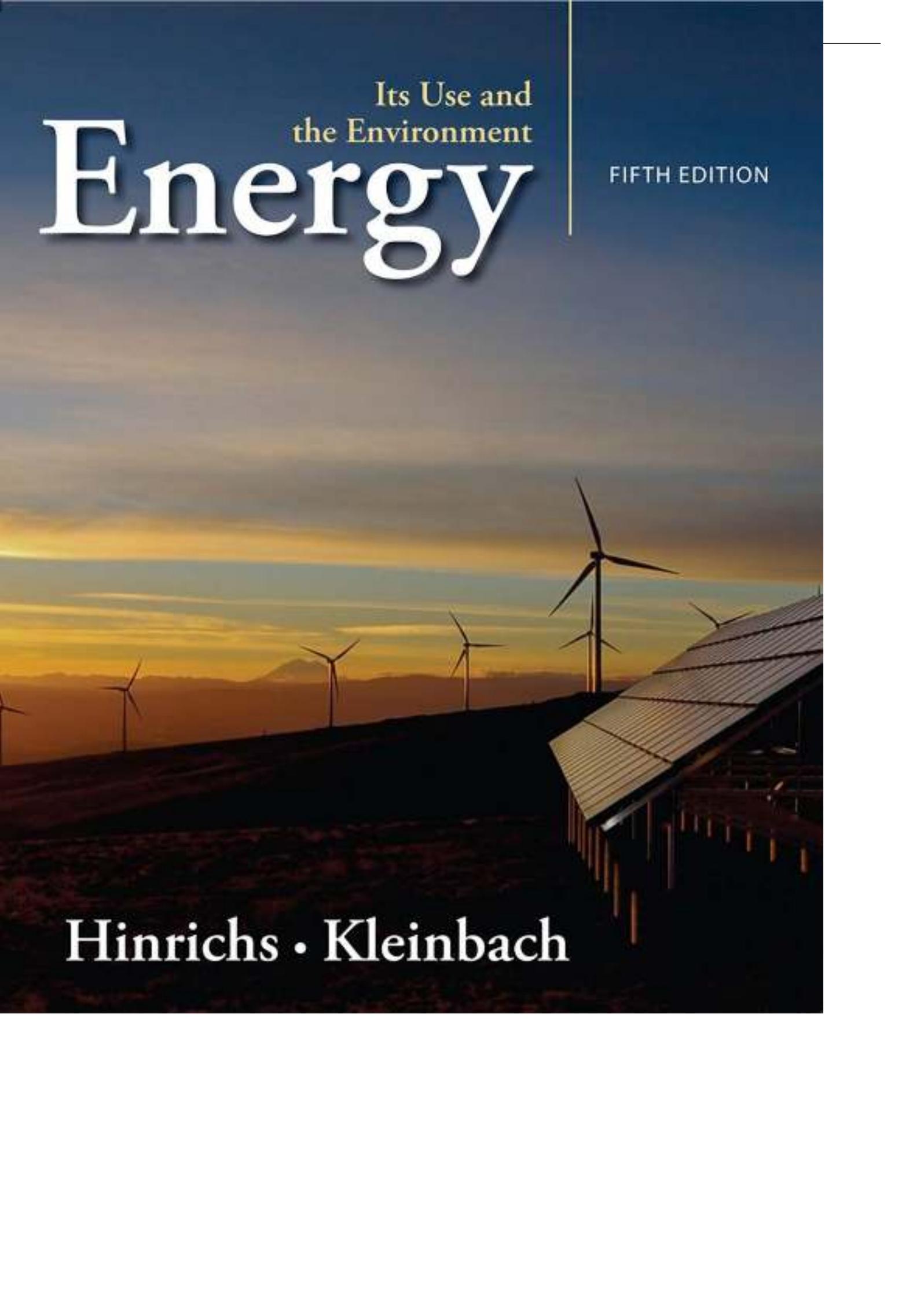


Its Use and
the Environment

Energy

FIFTH EDITION

The cover features a photograph of a landscape at sunset. In the foreground, a row of solar panels is visible, angled towards the right. In the background, several wind turbines are silhouetted against a sky with warm, orange and yellow hues. The overall scene is dark, with the sunset providing the primary light source.

Hinrichs • Kleinbach

Useful Websites

Because the science, technology, economics, and political atmosphere associated with the subject of energy are constantly changing, the Internet is a good source of current information. The ability of the Internet to constantly update its information makes it a valuable resource for locating up-to-date facts and figures as well as to receive information on new advancements and discoveries.

The website that accompanies this book contains a series of links to sites with content that can further help you understand the material presented in each chapter. The links are available at www.cengagebrain.com/shop/ISBN/9781111990831.

You can often locate useful and supplementary information through typical search engines like Google or Bing. The following list of standard sites can provide information on energy matters that you may find useful. The content is usually obvious from the name of the site. Most of these sites contain links to other sites—some have good educational materials and some will put you on useful email lists. Enjoy.

| | |
|---|--|
| eia.doe.gov | Energy Information Administration—official energy statistics from the United States government |
| eere.energy.gov | Energy efficiency and renewable energy information from the United States Department of Energy |
| epa.gov | United States Environmental Protection Agency |
| wri.org | World Resources Institute |
| iea.org | International Energy Agency |
| ashrae.org | American Society of Heating, Refrigeration, and Air-Conditioning Engineers |
| api.org | American Petroleum Institute |
| gasandoil.com | Portal site for gas and oil industry information |
| repp.org | Renewable Energy Policy Project and the Center for Renewable Energy and Sustainable Technology |
| aceee.org | American Council for an Energy-Efficient Economy |
| awea.org | American Wind Energy Association |
| ases.org | American Solar Energy Society |
| evworld.com | Electric vehicles information with a weekly email newsletter |
| worldwatch.org | Worldwatch Institute—publisher of State of the World annuals |
| eande.lbl.gov | Environmental Energy Technologies division of Lawrence Berkeley National Laboratory |
| fsec.ucf.edu | Florida Solar Energy Center at the University of Central Florida |
| nrc.gov | United States Nuclear Regulatory Commission |
| new.ans.org | American Nuclear Society |
| ucsusa.org | Union of Concerned Scientists |
| nrel.gov | National Renewable Energy Laboratory |

Energy

Its Use and the Environment

Fifth Edition

Roger A. Hinrichs

*Professor of Physics, Emeritus, State University of New York,
College at Oswego*

Merlin Kleinbach

*Professor of Technology Education, Emeritus, State University of
New York, College at Oswego*



Australia • Brazil • Japan • Korea • Mexico • Singapore • Spain • United Kingdom • United States



This is an electronic version of the print textbook. Due to electronic rights restrictions, some third party content may be suppressed. Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. The publisher reserves the right to remove content from this title at any time if subsequent rights restrictions require it. For valuable information on pricing, previous editions, changes to current editions, and alternate formats, please visit www.cengage.com/highered to search by ISBN#, author, title, or keyword for materials in your areas of interest.

Energy: Its Use and the Environment
Fifth Edition
Roger A. Hinrichs and Merlin Kleinbach

Publisher, Physics and Astronomy:
Charles Hartford

Development Editor: Ed Dodd

Associate Development Editor:
Brandi Kirksey

Editorial Assistant: Brendan Killion

Senior Media Editor: Rebecca Berardy
Schwartz

Marketing Manager: Jack Cooney

Marketing Coordinator: Julie Stefani

Marketing Communications Manager:
Darlene Macanan

Content Project Manager: Jill A. Quinn

Senior Art Director: Cate Rickard Barr

Senior Print Buyer: Diane Gibbons

Rights Acquisition Specialist:
Shalice Shah-Caldwell

Production Service/Compositor:
MPS Limited, a Macmillan Company

Text Designer: Joyce Weston

Cover Designer: Joyce Weston

Cover and Chapter Opener Image: photo
courtesy Puget Sound Energy, The Renewable
Energy Center at the Wild Horse Wind and
Solar Facility, Ellensburg, Washington,
www.pse.com

© 2013, 2006, 2002 Brooks/Cole, Cengage Learning

WCN: 02-200-203

ALL RIGHTS RESERVED. No part of this work covered by the copyright
herein may be reproduced, transmitted, stored, or used in any form or by
any means graphic, electronic, or mechanical, including but not limited to
photocopying, recording, scanning, digitizing, taping, Web distribution, in-
formation networks, or information storage and retrieval systems, except as
permitted under Section 107 or 108 of the 1976 United States Copyright Act,
without the prior written permission of the publisher.

For product information and technology assistance, contact us at
Cengage Learning Customer & Sales Support, 1-800-354-9706

For permission to use material from this text or product,
submit all requests online at www.cengage.com/permissions.

Further permissions questions can be emailed to
permissionrequest@cengage.com

Library of Congress Control Number: 2011933685

ISBN-13: 978-1-111-99083-1

ISBN-10: 1-111-99083-2

Brooks/Cole

20 Channel Center Street
Boston, MA 02210
USA

Cengage Learning is a leading provider of customized learning solutions with
office locations around the globe, including Singapore, the United Kingdom,
Australia, Mexico, Brazil and Japan. Locate your local office at
international.cengage.com/region

Cengage Learning products are represented in Canada by
Nelson Education, Ltd.

For your course and learning solutions, visit www.cengage.com.

Purchase any of our products at your local college store or at our preferred
online store www.cengagebrain.com.

Instructors: Please visit login.cengage.com and log in to access
instructor-specific resources.

Printed in the United States of America

1 2 3 4 5 6 7 15 14 13 12 11

Contents



Chapter 1. Introduction 1

- A.** Energy: An Initial Definition 1
- B.** Energy Use and the Environment 3
 - Focus on 1.1** Our Earth—Then and Now 4
- C.** Energy Use Patterns 7
- D.** Energy Resources 12
 - Focus on 1.2** Energy Use in China 15
- E.** Exponential Growth, Peak Oil, and Resource Depletion 17
- F.** Oil: A Critical Resource 21
- G.** Energy Conservation 24
- H.** Economic and Environmental Considerations 26
- I.** Future Scenarios 28
 - Focus on 1.3** The Kyoto Protocol on Climate Change 29

Chapter 2. Energy Mechanics 32

- A.** Introduction 32
- B.** Forms of Energy and Energy Conversions 34
- C.** Motion 38
- D.** Energy and Work 42
 - Focus on 2.1** Energy Losses in a Car 43
- E.** Examples of Work and Energy 46
- F.** Power 48
 - Focus on 2.2** Energy Use in India 51
- G.** Summary 53
 - Special Topic:** Newton's Laws of Motion 59

Chapter 3. Conservation of Energy 71

- A.** Introduction 71
- B.** Law of Conservation of Energy 72
- C.** Energy Conversion Examples 74
- D.** Energy Conversion Efficiencies 77
- E.** Energy Use in Developing Countries 79

- F. Energy Equivalencies: Barrels, Calories, and Btus** 83
 - Focus on 3.1** Sustainable Development 84
- G. Summary** 88

Chapter 4. Heat and Work 93

- A. Introduction** 93
- B. Heat and Work and the First Law of Thermodynamics** 94
- C. Temperature and Heat** 97
- D. Heat Transfer Principles** 101
- E. Heat Engines** 110
- F. The Second Law of Thermodynamics** 113
 - Direction and Disorder 113
 - Maximum Efficiency—Less than Perfect 116
 - The Ideal Case: Reversibility 117
 - Available Energy 117
- G. Summary** 118

Chapter 5. Home Energy Conservation and Heat-Transfer Control 123

- A. Introduction** 123
- B. Building Materials** 125
- C. House Insulation and Heating Calculations** 127
- D. Site Selection** 136
- E. Impact of Energy Conservation Measures** 138
- F. Cooling** 139
- G. Air Conditioners and Heat Pumps** 142
- H. Summary** 146

Chapter 6. Solar Energy: Characteristics and Heating 151

- A. Introduction** 151
- B. Characteristics of Incident Solar Radiation** 154
- C. History of Solar Heating** 161
 - Focus on 6.1** Early Twentieth-Century Egyptian Solar Power Plant 163
- D. Overview of Solar Heating Today** 167
- E. Solar Domestic Hot Water** 168
- F. Passive Solar Space Heating Systems** 174
- G. Active Solar Space-Heating Systems** 180
 - Solar Collectors 180

- H. Thermal Energy Storage 182
- I. Summary 184

Chapter 7. Energy from Fossil Fuels 193

- A. Introduction 194
- B. Resource Terminology 195
- C. Oil 198
 - Focus on 7.1 Pipeline Politics in Central Asia 204
- D. Natural Gas 207
 - Focus on 7.2 Oil Spills 208
 - Focus on 7.3 Oil From Alaska: Past, Present, and Future Dilemmas 211
- E. Coal: An Expanding Role 215
 - Types of Coal 216
 - Coal Production and Consumption Patterns 217
 - Strip Mining 218
 - Constraints to Coal Supply and Demand 220
- F. Future Sources of Oil 221
 - Synthetic Oil and Gas from Coal 221
 - Oil Shale and Tar Sands 221
- G. Summary 222
 - Special Topic: Physics of Oil and Gas Exploration 225

Chapter 8. Air Pollution and Energy Use 232

- A. Introduction 233
- B. Properties and Motion of the Atmosphere 233
 - Focus on 8.1 Eastern Europe and The Environment 234
 - Pressure 236
 - Buoyant Force and Air Temperature Profiles 239
 - Natural Dispersion of Air Pollutants; Temperature Inversions 241
- C. Air Pollutants and Their Sources 242
 - Carbon Monoxide 244
 - Sulfur Oxides 245
 - Particulates 247
 - Hydrocarbons or Volatile Organic Compounds 247
 - Focus on 8.2 Air Pollution and the Third World 248
 - Nitrogen Oxides, Photochemical Smog, and Ozone 250
 - Acid Rain 252
 - Indoor Air Pollution 256
- D. Air-Quality Standards 257
 - Focus on 8.3 1990 Clean Air Act Amendments 261

- E.** Automobile Emission-Control Devices 262
 - Focus on 8.4** Mass Transit 264
- F.** Stationary Source Air-Pollution-Control Systems 265
- G.** Summary 270

Chapter 9. Global Warming and Thermal Pollution 275

- A.** Introduction 276
- B.** Global Warming and the Greenhouse Effect: Observations 277
- C.** Global Warming: Possible Impacts 284
 - Focus on 9.1** Africa and Global Warming 289
- D.** Global Warming: Possible Actions 290
 - Focus on 9.2** “You can’t go back to Kansas anymore”—Chinese Consumers and Global Warming 292
- E.** Thermal Pollution 293
- F.** Ecological Effects of Thermal Pollution 294
 - Aquatic Life 294
 - Lake Processes: Eutrophication 297
- G.** Cooling Towers and Ponds 298
- H.** Using Waste Heat 300
- I.** Summary 301

Chapter 10. Electricity: Circuits and Superconductors 305

- A.** Introduction to “Electrification” 306
- B.** Restructuring of the Electric Utility Industry 308
 - Focus on 10.1** Managing Energy Demand 310
- C.** Electrical Charges and Currents 310
- D.** Batteries and Electric Vehicles 313
 - Focus on 10.2** Common Batteries 314
- E.** Ohm’s Law 318
- F.** Superconductivity 320
- G.** Elementary Circuits 322
 - Series Connections 323
 - Parallel Connections 324
- H.** Electrical Power 325
 - Focus on 10.3** Edison Mazda Lamps, Circa 1925 327
- I.** Pricing Electrical Energy Use 327
- J.** Fuel Cells 332
 - Focus on 10.4** Hydrogen Economy 334
- K.** Summary 337
 - Special Topic:** Electrostatics 342

Chapter 11. Electromagnetism and the Generation of Electricity 346

- A. Magnetic Forces and Fields 347**
 - Simple Magnets 347
 - The Magnetic Field of a Current 349
 - Motion of Charged Particles in a Magnetic Field: Cosmic Rays, Magnetic Bottles 350
 - Electric Motors 351
- B. The Generation of Electricity 353**
- C. Transmission of Electrical Energy 355**
 - Transformers: Voltage Changers 356
 - Environmental and Health Impacts of High-Voltage Lines 359
 - Alternatives to Transmission Lines 362
- D. Standard Steam-Electric Generating Plant Cycle 363**
- E. Co-Generation 366**
- F. Summary 369**

Chapter 12. Electricity from Solar, Wind, and Hydro 374

- A. Introduction 375**
- B. Solar Cell Principles 377**
 - Focus on 12.1** PV Cars: Yesterday and Today 380
- C. Cell Manufacture 381**
- D. Photovoltaic Systems and Economics 382**
 - Focus on 12.2** PV Cottages 385
 - Focus on 12.3** Pumping Water 387
- E. Wind Energy 388**
 - History, Installed Capacity, and Recent Growth 388
 - Wind-Energy Systems 392
 - Wind-Energy Storage and Economics 397
- F. Hydropower 400**
 - History, Installed Capacity, and Recent Growth 400
 - Hydroelectric Energy Systems 403
 - Focus on 12.4** Small-Scale Hydroelectric Systems 405
- G. Solar-Thermal Electric Facilities—Concentrating Solar Power (CSP) 406**
- H. Summary 408**

Chapter 13. The Building Blocks of Matter: The Atom and Its Nucleus 413

- A.** The Atomic Hypothesis 414
- B.** Building Blocks of the Atom 415
- C.** Energy Levels 419
- D.** Nuclear Structure 421
- E.** Radioactivity 422
- F.** Nuclear Glue, or Binding Energy 426
- G.** The Joy of Atom-Smashing, or Nuclear Reactions 428
 - Focus on 13.1** Indoor Radon 430
- H.** Fission 431
- I.** Summary 432
 - Special Topic:** The Periodic Table 435

Chapter 14. Nuclear Power: Fission 437

- A.** Introduction 438
 - Focus on 14.1** Atoms From America 441
- B.** Chain Reactions 444
- C.** Assembling a Nuclear Reactor 447
- D.** Types of Light Water Reactors 449
- E.** The Nuclear Fuel Cycle 451
 - Mining 452
 - Fuel Enrichment 453
 - Fuel Reprocessing 454
- F.** Radioactive Wastes 456
- G.** Decommissioning 463
 - Focus on 14.2** Monuments for the Future 463
- H.** Radioactive Releases 464
 - Radiation from the Reactor Building: Normal Operation 465
 - Catastrophic Accidents 466
 - Nuclear Reactor Accidents: Some Examples 468
- I.** Probabilistic Risk Assessment and Nuclear Safety 473
- J.** Alternate Reactor Designs 476
- K.** Nuclear Proliferation 480
- L.** Environmental and Economic Summary of Nuclear Power 481
 - Focus on 14.3** Post–Cold War Proliferation 482
- M.** Summary 485

Chapter 15. Effects and Uses of Radiation 488

- A.** Introduction 489
- B.** Radiation Dose 489
- C.** Biological Effects of Radiation 490
- D.** Background Radiation, Including Radon 494
- E.** Radiation Standards 500
- F.** Medical and Industrial Uses of Radiation 500
 - Focus on 15.1** Food Irradiation 504
- G.** Radiation Protection 506
- H.** Summary 507
 - Special Topic:** Radiation Detection Instruments 511

Chapter 16. Future Energy Alternatives: Fusion 514

- A.** Potential for Fusion Power 515
- B.** Energy from the Stars: The Fusion Process 516
- C.** Conditions for Fusion 516
- D.** Magnetic Confinement Fusion Reactors 518
- E.** Laser-Induced Fusion 521
- F.** Cold Fusion 524
- G.** Summary and Outlook for Fusion 525

Chapter 17. Biomass: From Plants to Garbage 528

- A.** Introduction 528
- B.** Biomass Conversion 529
 - Focus on 17.1** Brazil's Ethanol Program 534
- C.** Food, Fuel, Famine 538
- D.** Municipal Solid Waste 542
 - Recycling 543
 - Incineration 545
 - Secure Landfills 546
- E.** Wood Combustion 547
 - Residential Wood Combustion and Stove Design 548
 - Wood-Burning Economics 550
 - Cooking Stoves in Developing Countries 552
- F.** Summary 555

Chapter 18. Tapping the Earth's Heat: Geothermal Energy 558

- A.** Introduction 558
- B.** Origin and Nature of Geothermal Energy 560
- C.** Hydrothermal Systems 562
 - Wet Steam Systems 562
 - Dry Steam Systems: The Geysers Power Plant 563
- D.** Geothermal Exploration and Resources 564
- E.** Low-Temperature Geothermal Resources 567
- F.** Environmental Impacts 568
- G.** Summary 569

Chapter 19. A National and Personal Commitment 571

Appendix A. Units of Measurement and Powers of Ten Notation A-1

Appendix B. Conversions and Equivalencies B-1

Appendix C. Home Heating Analysis Worksheet C-1

Appendix D. Insolation and Temperature Data
for Selected U.S. Cities D-1

Appendix E. World Energy Consumption, 2009 E-1

Appendix F. U.S. Consumption of Energy by Source, 1949–2010 F-1

Appendix G. U.S. Energy Intensity, 1970–2010 G-1

Appendix H. The Periodic Table of the Elements H-1

Glossary GL-1

Index I-1

Preface



Introduction to the Fifth Edition

Energy, Its Use and the Environment, is an introductory textbook that emphasizes the physical principles behind energy, its uses, and its effects on our environment. It can be used in physics, technology, physical science, and environmental science courses for nonscience majors. No math or other science prerequisite is necessary. Much of the pedagogy used herein comes from a one-semester general education course one of us (R.H.) has taught at State University of New York, College at Oswego, over the past 25 years. Both of us have been involved in conducting energy education workshops for New York State secondary school science and technology teachers for more than 25 years.

For this fifth edition, all the data on energy resources, energy use, and energy technologies have been updated. Since the fourth edition (only seven years ago), we have seen oil prices reaching all-time highs and a rapid growth in energy use by China and India. Concern over the large dependence of the U.S. transportation sector upon imported oil continues to grow. Will the peak in worldwide oil production be upon us soon? An economy based upon hydrogen and fuel cells seems closer, but there are many bumps in the road. Electric vehicles are starting to make small but substantial inroads into the marketplace. The world is also seeing an increasing interest in renewable energy. The use of wind energy grows at a rate of about 30% per year, yet renewables today only account for about 7% of the United States' energy supply, and about 14% of the world's total energy use. These trends are examined throughout the book. We continue to emphasize the environmental impact of fossil-fuel consumption, in part by putting chapters on fossil-fuel use, air pollution, and global warming material early in the text. Due to environmental concerns about global warming, extra material has been added. The possible rebirth of nuclear power is discussed in later chapters in light of the Japanese earthquake/tsunami catastrophe. The interdependence of the world economies and environments, especially when it comes to energy, have led us to add more examples dealing with energy use in other countries, both industrialized and developing. We include a "How Would You Choose?" question at the beginning of every chapter that will prompt the readers to examine their own opinions on a particular energy-related issue. This question is revisited at the end of the chapter and the reader is asked whether material learned in that chapter has changed their position on this issue.

Goals of This Book

Because the subject of energy is multifaceted, this book has several purposes. First and foremost, it seeks to explain the basic physical principles behind the different energy transformations that occur, including the study of mechanics, electricity and magnetism, thermodynamics, and atomic and nuclear physics. At the same time, the text covers crucial environmental questions arising from energy use that currently are receiving much public attention, such as global warming, radioactive waste, and municipal solid waste. The best way to understand the consequences of present and future energy alternatives, and the environmental, social, and economic tradeoffs that must be made, is to understand the scientific principles involved. These principles are presented with a minimal amount of math and with the help of everyday examples. Each chapter has a set of problems (mainly nonmathematical) that seeks to emphasize the basic principles and apply them to situations dealing with energy and the environment. Many of the standard topics found in introductory physics textbooks are included. As a consequence, this book can be used as the text in a conceptual physics or physical science course with energy as the central theme, as has been our practice.

Second, the book examines different aspects of each energy resource, including the principles involved and the environmental and economic consequences of its use. Renewable energy is treated early on, after heat transfer, and eventually everything from solar heating systems to photovoltaic devices to wind-turbine generators is covered. The principles of nuclear power and the debate over radioactive waste disposal are covered in depth. At the heart of most energy conversion schemes is the heat engine, so general principles in this area are developed early (Chapter 4). The environmental aspects of generating electricity and using it are also an underlying theme. Air pollution and global warming are treated early on, in separate chapters, as are some ways in which their impacts can be lessened.

Third, the textbook seeks to integrate the complex questions of energy policy and possible energy strategies. There are no simple answers or single alternatives that can provide all of our energy needs, preserve our economic prosperity, and protect our environment. As a consequence, questions (many unanswered) are brought up throughout the book to cause readers to critically think ahead and maybe even begin to develop their own solutions. The “How Would You Choose?” questions at the beginning of every chapter further encourage a critical approach. The important theme of energy conservation is emphasized with examples *throughout* the textbook, rather than in a separate chapter, because the efficient use of energy should be of utmost concern in every area—from energy mechanics to heat transfer to electricity use. Practical suggestions are given that we hope will cause the readers to evaluate their individual roles in using energy more effectively.

Many books have an energy theme, but few seek both to teach general physical principles and to cover the many alternatives of energy supply and conservation. These themes are presented in such a way that they will appeal to the growing audience of non-science majors, as well as provide information relevant to those interested in science and engineering careers.

Coverage

Although the material in this textbook is organized to follow a somewhat traditional sequence presented in a physics course, we have tried to order the topics in a way that touches the current interests of students. Solar heating is covered early (Chapter 6), but only after concepts of heat transfer (Chapter 4) and residential energy conservation (Chapter 5) have been discussed. Chapters 8 and 9 deal with the environmental aspects of energy use, namely air pollution (from both stationary and mobile sources), global warming, and thermal pollution. These topics follow Chapter 7 on fossil fuels. The physics of oil exploration and recovery is covered in Chapter 7 as a special topic. Photovoltaics and the rapidly growing area of wind energy follow Chapters 10 and 11 on electrical energy production. New automotive technologies incorporating fuel cells and hybrids and electric vehicles are treated within these two chapters. Nuclear fission is covered in Chapter 14, after a chapter on the fundamentals of atomic and nuclear physics. Chapter 17 covers the broad topic of biomass, from wood combustion to municipal solid waste to the production of alcohol fuels from corn.

Features

Many features in this text are designed to encourage students to understand the crucial role of energy in our society and implications stemming from their own consumption of energy. The textbook is designed to make physics and its applications relevant and interesting to nonscience majors. A description of features follows:

- **“How Would You Choose?”** questions start each chapter by describing a real-world situation in which the reader is asked to make a decision that utilizes the concepts in the chapter. The question is revisited at the end of each chapter to examine how applying the science learned in the chapter affects the decision made.
- **Hands-on activities** that students can perform in their home or dorm room with common items. These activities provide opportunities to experimentally reinforce the material covered. These are both integrated into the chapters and placed at their ends. Some examples are the construction of a simple shoebox model to examine solar heating, an experiment to study heat transfer from insulated soda pop cans, an investigation of atmospheric particulates. All of the activities have been tested, many of them in the summer workshops for secondary school science and technology teachers that we direct.
- **Residential use of energy**, which is emphasized through many examples that are relevant to the home. Analysis of heat losses in the home and ways to reduce them are covered in Chapter 5. A home energy audit (developed by the authors) is provided in Appendix C. New energy-efficient lighting fixtures are covered in Chapter 10 on electricity.
- **International perspectives on energy**, which are emphasized throughout the textbook. Although the book primarily focuses on the United States' use of energy, we are part of an interdependent global village. As we well know, political

events in other parts of the world can have important effects on our own economy. Attention is also focused on those people who live in developing countries, where energy plays a critical role. “Focus on” boxes, which highlight interesting applications or unusual facts about energy, help in this area. Both of us have had a number of years experience working in developing countries (Ethiopia, Kenya, Oman, Qatar, Palestine).



- **CengageBrain** offers a variety of free tools to help students (www.cengagebrain.com/shop/ISBN/9781111990831). Lists of up-to-date Internet reference sites organized by chapter provide current information about this rapidly changing field. Worksheets for the home heating analysis in Appendix C can be downloaded as a PDF file for easy printing. A glossary and flash cards help students to learn the material and prepare for exams.
- **Resources** available to qualifying instructors at the password-protected instructor site www.cengage.com/physics/hinrichs5e include downloadable **electronic files of text art** and a downloadable full **Instructor's Manual**. The expanded Instructor's Manual contains instructor's notes, answers to selected end-of-chapter questions, classroom demonstrations, a bank of test questions, and worksheets for complete mini-labs that can be printed and assigned.

Other features include appendixes that provide current information on energy use in the United States and the world, end-of-chapter summaries, questions and problems, worked examples, and a glossary.

Teaching Options

Because of the many facets of energy use and our environment, some sections and chapters could be deleted without any loss in continuity to produce a shortened course. For example, the section on heat engines in Chapter 4 could be deleted (especially for the non-science major); the Carnot efficiency could be introduced later for that part of Chapter 9 on thermal pollution. For a shorter course, you might wish to skip Chapter 15 on biological effects of radiation and Chapter 16 on fusion, and concentrate instead on biomass conversion in Chapter 17. While Chapters 7 and 8 provide some physics background on fluids and oil exploration technology, they could be skipped if the course wished to reduce coverage of some of the environmental aspects of energy use. The nontechnical style of the writing allows the instructor to assign sections in each chapter as outside reading, making it possible to cover more of the book than could be covered in class discussion alone. The authors have found that the importance of the topic of energy can be made more relevant by having students bring to class local or national newspaper articles dealing with energy for discussion.

Acknowledgments

To make a good textbook, we rely on the comments and suggestions of those teaching the course across the country. Their contributions are of great help in the construction and revision of this book. We thank Abdelkrim Boukahil (University

of Wisconsin-Whitewater), Patricia A Cleary (University of Wisconsin-Parkside), Steve Hnetkovsky (Wabash Valley College), John Katers (University of Wisconsin-Green Bay), Charles Nickles (University of Massachusetts-Dartmouth), Rahim Setoodeh (Milwaukee Area Technical College), and Edward Stermer (Illinois Central College) for their comments on the fourth edition and their suggestions for developing the new edition.

We also thank Abdelkrim Boukahil (University of Wisconsin-Whitewater), John Katers (University of Wisconsin-Green Bay), and Charles Nickles (University of Massachusetts-Dartmouth) for their assistance in accuracy reviewing chapters from the fifth edition.

We also appreciate the comments on previous editions from David Appenbrink (University of Chicago), James Boyle (Western Connecticut State University), Terry Carlton (Oberlin College), Richard W. Fox (Chicago State University), Patrick Gleeson (Delaware State University), Laurent Hodges (Iowa State University), Daniel Holland (Illinois State University), Joseph Katz (Johns Hopkins University), Philip Krasicky (Hamilton College), Wesley Lingren (Seattle Pacific University), Nebil Misconi (University of Central Florida), John Oughton (Century College), Jack Pinnix, (Chicago State University), Robert Poel (Western Michigan University), Daryl Prigmore (University of Colorado, Colorado Springs), Ljubisa R. Radovic (Pennsylvania State University), Don Reeder (University of Wisconsin, Madison), David Ruzic (University of Illinois, Champaign-Urbana), Peter Schroeder (Michigan State University), Karin Shen (Vanderbilt University), Sunil Somalwar (Rutgers University), Patricia Terry (University of Wisconsin, Green Bay), Carl Voiles (Michigan State University), and Thomas Weber (Iowa State University).

At Brooks/Cole Publishing, we have appreciated the encouragement and professional advice of Charles Hartford, Physics Publisher; Ed Dodd, Development Editor; and Jill Quinn, Content Project Manager, Education Production GPMS.

Roger Hinrichs and Merlin Kleinbach
Seattle, Washington and Oswego, New York
October, 2011

Introduction



Chapter

1

- A.** Energy: An Initial Definition
- B.** Energy Use and the Environment
 - Focus on 1.1** Our Earth—Then and Now
- C.** Energy Use Patterns
- D.** Energy Resources
 - Focus on 1.2** Energy Use in China
- E.** Exponential Growth, Peak Oil, and Resource Depletion
- F.** Oil: A Critical Resource
- G.** Energy Conservation
- H.** Economic and Environmental Considerations
- I.** Future Scenarios
 - Focus on 1.3** The Kyoto Protocol on Climate Change

A. Energy: An Initial Definition

Energy is one of the major building blocks of modern society. Energy is needed to create goods from natural resources and to provide many of the services we have come to take for granted. Economic development and improved standards of living are complex processes that share a common denominator: the availability of an adequate and reliable supply of energy. The modernization of the West and the East from rural societies to affluent, urban ones was made possible through the employment of modern technology based on a multitude of scientific advances—all of which are energized by fossil fuels. Political events, beginning with an oil embargo in 1973 and continuing through the Iranian revolution of 1979, the Persian Gulf War of 1991, and the Iraq invasion of 2003, made many people aware of how crucial energy is to the everyday functioning of our society. Long gasoline lines and cold winters with natural gas shortages in the 1970s are still unhappy memories for some people. Despite those unhappy memories, the energy crises of the 1970s were almost forgotten by the 1980s. However, that decade brought an increased awareness of our environment. Concerns about global warming, acid rain, and radioactive waste are still very much with us today, and each of these topics is related to our use of energy.

1

While an interest in being energy self-sufficient and producing one's own power was a strong desire of some in the 1970s and 1980s, during the second half of the 1990s, the entire public began to have another choice—that of being able to select their own provider of electricity. The electric power industry moved away from a traditional, highly regulated industry to one of deregulation and competition. Beginning in 1997, customers were given the chance to shop for their own supplier—and the bottom line (cost) was not the only criterion. Many people decided to buy from the producer who polluted least, so-called “green power” alternatives.

The tragic events of September 11, 2001, changed the world forever. Continuing threats and actions of terrorists have an effect upon energy issues as much as on public safety. The United States (and many other countries of the industrialized and developing world) imports over half of its oil. Many diverse groups are calling for action on this issue because such a large dependence on imported oil poses a risk to our homeland security and our economic well-being. Most of our imported oil goes for transportation, so increased automobile efficiency, alternate fuels, and conservation must be pursued. Changes take time, yet it didn't take long for oil prices to rise by nearly a factor of two, as the year 2008 showed.

Energy pervades all sectors of society—economics, labor, environment, international relations—in addition to our own personal lives—housing, food, health, transportation, recreation, and more. The use of energy resources has relieved us of much drudgery and made our efforts more productive. People once had to depend on their own muscles to provide the energy necessary to do work. Today muscles supply less than 1% of the work done in the industrialized world.

Energy supplies are key limiting factors to economic growth. We have become a very interdependent world, and access to adequate and reliable energy resources is central for economic growth. About 40% of the world's energy comes from oil, much of which is imported by the industrialized nations and much of which comes from the Persian Gulf. From this region, Japan imports 80% of its oil, and the United States imports 18% of its oil. While France imports almost all of its oil, only 15% comes from the Persian Gulf. If industrialized nations encounter any significant restriction to their sources of oil, through either reduced supplies or large price increases, their economies will suffer considerable damage.

Your own picture of energy might be colored in many ways by your experiences. You might think of the “energy” (or the lack of it) that a particular person possesses, or the kinetic energy that a stone gains as it drops, or the energy responsible for the movement of automobiles, or the energy used in the production of heat and light. One dictionary defines energy as the “capacity for vigorous action; inherent power; potential forces.” Energy is found in many forms, and one purpose of this book will be to identify them and study how they can be used. Energy is found in such forms as wind and flowing water, and stored in matter such as fossil fuels—oil, coal, natural gas—where it can be burned for “vigorous action.”

Energy might best be described in terms of what it can do. We cannot “see” energy, only its effects; we cannot make it, only use it; and we cannot destroy it, only waste it (i.e., use it inefficiently). Unlike food and housing, energy is not valued in itself but for what can be done with it.

Energy is not an end in itself. The fundamental goals we should have in mind are a healthy economy and a healthy environment. We have to tailor our energy policy as a means to those ends, not just for this country but in global terms as well.

—Richard Balzhiser, former president of Electric Power Research Institute

Energy is a basic concept in all science and engineering disciplines. As we will discuss in the next chapter, a very important principle is that energy is a conserved quantity; that is, the total amount of energy in the universe is a constant. Energy is not created or destroyed but just converted or redistributed from one form to another, such as from wind energy into electrical energy, or from chemical energy into heat. We will study the various forms of energy—chemical, nuclear, solar, thermal, mechanical, electrical—and the useful work that energy is capable of doing for us. We will explore both energy resources and energy conversion processes.

Understanding energy means understanding energy resources and their limitations, as well as the environmental consequences of their use. Energy, environment, and economic development are closely linked. Over the past three decades, global energy consumption has almost doubled while the United States' consumption increased by 25%. Much of this global growth has been in less developed countries. (In the next two decades, estimates are that energy consumption will rise by over 100% in developing nations, an increase of over 3% per year. Most of this growth will occur in the developing nations of Asia, mainly China and India.) With this growth has been a decline in urban air quality as well as serious land and water degradation. Because fossil fuels represent almost 90% of our consumption, we continue to increase carbon dioxide emissions, which may alter the earth's climate irreversibly. The proper use of energy requires consideration of social issues as well as technological ones. Sustained economic growth in this century, together with improvements in the quality of everyone's lives, may be possible only by the well-planned and efficient use of limited energy resources and the development of new energy technologies.

B. Energy Use and the Environment

We live in an age of environmental awareness. Politicians would have a hard time getting elected if they did not at least state they had a concern for the environment. Many changes in the environment have occurred in the forty years since the first Earth Day of April 22, 1970, and some are listed in the box “Our Earth—Then and Now.”

The twenty-fifth anniversary of Earth Day in 1995 focused on the progress made to our air and water quality. In air pollution, smog has declined nationally by about a third since 1970. In 1999, Los Angeles did not record one ozone reading high enough to trigger a smog alert; twenty years earlier, there were 120 smog alerts in a year. New cars in 1995 emitted about 1% of the pollution per mile of 1970 model cars! New emission standards, plus higher fuel efficiency standards (see Chapter 8 on increased mpg), made 2010 even better for reduced emissions. Sulfur dioxide emissions, the primary cause of acid rain, have fallen by a third since 1970. In 1970, only about a quarter of our rivers met federal standards for fishing and swimming; in 1995, about 60% did. These accomplishments did not come about without great efforts. Federal and state expenditures for pollution abatement

FOCUS ON 1.1 OUR EARTH—THEN AND NOW

| | 1970 | 1990 | 2010 |
|---|-------------|-------------|-------------|
| World population | 3.3 billion | 5.4 billion | 6.8 billion |
| 10³ Tons of lead emitted, United States | 204 | 5 | 1 |
| Tons of waste recycled | 8 million | 49 million | 83 million |
| Tons of garbage generated annually in United States | 121 million | 160 million | 250 million |
| Percentage of oil imported to United States | 23% | 51% | 53% |
| Percentage of federal budget spent for environment | 3% | 1.5% | 1.2% |
| Atmospheric CO₂ concentration (ppM) | 325 | 350 | 384 |
| World CO₂ emissions, 10⁹ tons/yr | 14 | 21 | 31 |

Source: eia.gov and epa.gov

and control have risen sharply since 1970. However, concerns over federal spending, the national debt, and the role of the federal government continue to prompt legislative drives for drastic environmental law reforms and modifications in regulations affecting clean air and water, toxic waste, pesticides, endangered species, and so on.

The use of our energy resources is one of the major factors affecting the environment. (Our use of chemicals is another.) Increased use of fossil fuels since the beginning of the industrial age has increased the carbon dioxide concentration in the atmosphere by 35% and has also increased the earth's temperature (Fig. 1.1). Warmer global temperatures can lead to a melting of the polar ice caps and higher ocean levels, which will force a movement of population away from low-lying land near the seas. It can also mean a shift of agricultural areas as precipitation patterns move northward as well as increased disease.

Besides the use of energy resources, the gathering of those resources can impact the environment. A recent case in point is the oil well blowout in the Gulf of Mexico in April 2010. Damage to a well 1 mile below the surface of the Gulf allowed oil to flow into the Gulf for 3 months, releasing 200 million gallons of crude oil—the largest oil spill disaster in the world (see Fig. 1.2).

Disposing of our garbage is also an increasingly serious environmental problem. Americans generate almost 4.5 pounds of garbage per person per day—that's more than 3 tons per family per year and twice the rate of generation by Europeans. We're running out of acceptable places to bury our garbage. We have gone from 14,000 landfills in 1970 to less than 1600 today, for more people. Do we deal with solid waste by

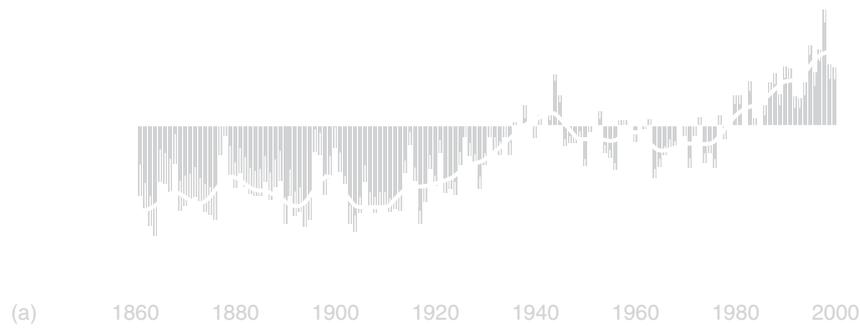


Figure 1.1 Correlation among global temperature change, atmospheric carbon dioxide, and methane concentrations displayed in order. (Intergovernmental Panel on Climatic Change—IPCC) A more convincing correlation between carbon dioxide concentrations and the earth's temperature over the past 400,000 years is shown in Figure 9.1 in Chapter 9. (Source: Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Figure 2-3, Figure 2-1. Cambridge University Press. Reproduced by permission.)

sample content of Energy: Its Use and the Environment

- [Project Antichrist pdf, azw \(kindle\)](#)
- [read online For Crying Out Loud! \(World According to Clarkson, Volume 3\) book](#)
- [read **The Companions \(Forgotten Realms: The Sundering, Book 1\) book**](#)
- [click **Fiddlehead \(The Clockwork Century, Book 6\)**](#)
- [read Max Weber: Collected Methodological Writings \(Weber in Translation\) pdf, azw \(kindle\), epub](#)
- [download online Bakhtinian Perspectives on Language, Literacy, and Learning online](#)

- <http://www.gateaerospaceforum.com/?library/Wings--Bromeliad-Trilogy--Book-3-.pdf>
- <http://www.freightunlocked.co.uk/lib/For-Crying-Out-Loud---World-According-to-Clarkson--Volume-3-.pdf>
- <http://test1.batsinbelfries.com/ebooks/The-Imprinted-Brain--How-Genes-Set-the-Balance-Between-Autism-and-Psychosis.pdf>
- <http://www.satilik-kopek.com/library/Air-Crashes-and-Miracle-Landings.pdf>
- <http://interactmg.com/ebooks/Untcigahunk--The-Complete-Little-Brothers.pdf>
- <http://thewun.org/?library/Nexus--The-Rosy-Crucifixion--Book-3-.pdf>