Energy: Insights from Physics

Philip DiLavore

Energy: Insights from Physics

Philip DiLavore
Indiana State University

John Wiley & Sons
New York • Chichester • Brisbane • Toronto • Singapore

Library of Congress Cataloging in Publication Data:

DiLavore, Philip, 1931–
Energy, insights from physics.

Bibliography: p.
Includes index.
1. Power resources. 2. Power (Mechanics)
3. Physics. I. Title.

TJ163.2.D54 1984 621.042 83-19840
ISBN 0-471-89683-7

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Energy: Insights from Physics

To Carmela

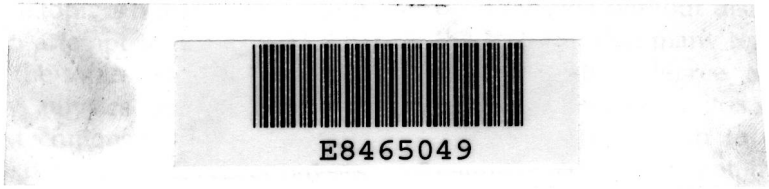
Whose yesterdays encouraged intellectual growth.

To Santa, Pam, Phil, and Teresa

Whose tomorrows are what this book is all about.

And, most of all, to Evelyn

Who makes every today worth the effort.



Preface

To the Teacher:

This book is intended for a one-semester course for students who have avoided science and mathematics and who are taking a physics course primarily to satisfy a general education requirement. The topic is frankly energy, and I have made no attempt to survey physics. Thus, many of the topics normally found in an introductory physics text are omitted. However, the techniques of physics and, especially, the experimental aspects of physics are presented in an elementary manner; students are thereby introduced to different ways of approaching a topic that is at least vaguely familiar to all of them and that certainly will affect their lives. Students need the opportunity, along with the motivation, to develop an analytical approach to important problems and to practice grappling with approximate numbers for insights that remain otherwise elusive. With this text, and the guidance of a skillful teacher, they will be given such an opportunity.

You might find that there is more material contained here than can be considered in depth in the usual one-semester course. As the teacher, you will therefore have to make judgments about what material to omit, cover lightly, or assign for out-of-class reading. I have included some material that might have been omitted without disrupting the flow of the text, but that many teachers will want to include to some degree. My philosophy has been that, in general, it is easier for a teacher to omit material than to add and face the plaintive cry, "it is not in the book." The physics presented provides a tool with which to tackle the applications at hand. For those teachers who are inclined to use it, the Teacher's Guide, available from Wiley, will assist you in developing a teaching strategy.

Decisions affecting the future use of energy by humankind will be crucial. If you and I can help the coming generations, objectively and rationally, to approach those decisions then a worthwhile purpose will have been served.

Philip DiLavore

Dear Student:

Energy may well turn out to be one of the most, if not the most, significant problems facing our society in the years to come. In your lifetime you will undoubtedly see enormous change, much of it caused by the availability, or lack, of energy sources. Careful planning for the future will require knowledge of the energy situation, past and present, and an understanding of future prospects.

As the title suggests, this book examines the present energy situation, using the methods of physics developed over a period of hundreds of years, and considers some possible avenues for the near future (say, the next 50 years). No text, unless it is a many volume encyclopedia, could examine every aspect of energy, so this book is limited to a few important ones. There is some emphasis on small-scale energy uses, such as home heating and solar energy, because each of us can have a very immediate effect on those uses. However, large-scale energy production and consumption, including nuclear power, are also considered, since those uses are certain to be of great consequence to us as well. More important, the methods of examination and analysis in this book may be extended to a wide range of problems not discussed here. In fact, you will soon forget the facts and figures presented (undoubtedly, immediately following the final exam). However, the problem-solving, inquisitive approach, once properly developed, endures: It will serve you well so I urge you to develop it as best as you can.

An extensive mathematics background will not be necessary in order to study this text; basic algebra at the high school or junior high school level is sufficient. Often, though, energy-related numerical calculations will be done, some involving very large numbers. If your algebra, computation, or graphing, is rusty the appendices at the back of the book will help you to review for the mathematics in this book. An inexpensive calculator will also assist you with the calculations.

The many "activities" scattered throughout the text could be the most beneficial aspect of this text for you. I urge you to complete as many of the activities as you possibly can—in the lab, at home, in your dorm room, wherever and whenever you have the opportunity. Don't be afraid to "get your hands dirty." You will find that you will better understand the physics principles and applications after you have seen them in action for yourself. The activities here may also suggest other activities that will help you gain insight into the workings of the surrounding world. You may be inspired, I hope, to invent some activities of your own.

Where will you be if you diligently study the material in this book? Certainly, you will be more informed about energy than you were at the outset. You will have had some experience with the techniques of problem solving and therefore be better able to evaluate statements about energy. You will more effectively interact with or respond to heating contractors, solar installers, wood stove salespeople, local utility representatives, newspapers, television, public service commissions, and even your congressmen, the state legislature, or local government. Above all, you may acquire an inquisitive attitude, be less likely to accept authoritative statements, and be prepared to objectively analyze any situation. If this book helps you to develop such an ability, then my efforts will have been worthwhile.

P.D.

Acknowledgments

I am grateful to Indiana State University, which generously permitted me a sabbatical and additional time for the preparation of this book.

I would like to express my thanks to many former teachers and mentors for guiding me into the field of physics and physics teaching. Foremost among them were Professors Peter A. Franken and Richard H. Sands, both talented physicists, dedicated teachers, and fine human beings.

During the preparation of this text, Professor Uwe J. Hansen was of invaluable help. He was the first to use an early version of the manuscript for a class, and his insights have been most helpful. In addition, as head of my department, he has provided assistance and encouragement in ways too numerous to mention. Professors L. Eugene Poorman and Vincent A. DiNoto have also used the manuscript on a trial teaching basis and have provided valuable suggestions. Norman L. Cooprider contributed technical assistance for many of the photographs and drew some of the original maps. Robert Lavette was the first to read the manuscript in an early draft, and he made numerous useful suggestions. Other colleagues who have contributed by reading and commenting on portions of the text are Professors John A. Swez, Carl O. Sartain, and Walter H. Carnahan. All of these people, and the several anonymous reviewers who so carefully and thoughtfully reviewed early manuscripts, have my gratitude. Additionally, I am grateful to Kathy Bendo, of John Wiley and Sons, who was quite helpful in locating hard-to-find photographs. By far, most constructive was the work of Ruth Greif, production supervisor for this text. The quality of the book and the sanity of the author owe much to her careful, knowledgeable, and ever-cheeful self. Finally, I would like to thank my good wife, who has suffered nearly three years of unmowed lawns, poor home maintenance, and shameful neglect on my part, but with not one word of complaint and with ever-ready encouragement when the going got tough. I'll try to fix those back steps now.

P.D.

TABLE D.1 *Conversion Table for Various Units of Energy*

	Joule (J)	Calorie (cal)	Kilocalorie (kcal)	Kilowatt-hour (kwh)	Megawatt-year (MW-yr)	British thermal unit (Btu)	Million British thermal unit (MBtu)
Joule (J)	1	0.239	2.39×10^{-4}	2.78×10^{-7}	3.17×10^{-14}	9.49×10^{-4}	9.49×10^{-10}
Calorie (cal)	4.184	1	10^{-3}	1.16×10^{-6}	1.33×10^{-13}	3.97×10^{-3}	3.97×10^{-9}
Kilocalorie (kcal)	4184	1,000	1	1.16×10^{-3}	1.33×10^{-10}	3.97	3.97×10^{-6}
Kilowatt hour (kWh)	3.6×10^{6}	8.6×10^{5}	860	1	1.14×10^{-7}	3,413	3.41×10^{-3}
Megawatt-year (MW-yr)	3.16×10^{13}	7.54×10^{12}	7.54×10^{9}	8.77×10^{6}	1	2.99×10^{10}	2.99×10^{4}
British thermal unit (Btu)	1,054	252	0.252	2.93×10^{-4}	3.34×10^{-11}	1	10^{-6}
Million British Thermalunit (MBtu)	1.05×10^{9}	2.52×10^{8}	2.52×10^{5}	293	3.34×10^{-5}	10^{6}	1
Quad (quad)	1.05×10^{18}	2.52×10^{17}	2.52×10^{14}	2.93×10^{11}	3.34×10^{4}	10^{15}	10^{9}
Q	1.05×10^{21}	2.52×10^{20}	2.52×10^{17}	2.93×10^{14}	3.34×10^{7}	10^{18}	10^{12}
Milli-Q (mQ)	1.05×10^{18}	2.52×10^{17}	2.52×10^{14}	2.93×10^{11}	3.34×10^{4}	10^{15}	10^{9}
Metric tons of oil equivalent (mtoe)	4.3×10^{10}	1.0×10^{10}	1.0×10^{7}	1.2×10^{4}	1.4×10^{-3}	4.1×10^{7}	41
Metric tons of coal equivalent (mtce)	3.0×10^{10}	7.1×10^{9}	7.1×10^{6}	8,100	9.4×10^{-4}	2.8×10^{7}	28
Barrels of oil equivalent (boe)	6.2×10^{9}	1.5×10^{9}	1.5×10^{6}	1,700	2.0×10^{-4}	5.9×10^{6}	5.9
Trillion cubic feet (TCF)	1.2×10^{18}	2.8×10^{17}	2.8×10^{14}	3.2×10^{11}	3.7×10^{4}	1.1×10^{15}	1.1×10^{9}
Teracalorie (Tcal)	4.184×10^{12}	10^{12}	10^{9}	1.2×10^{6}	0.13	4.0×10^{9}	4.0×10^{3}

Quad (quad)	Q	Milli-Q (mQ)	Metric tons of oil equivalent (mtoe)	Metric tons of coal equivalent (mtce)	Barrels of oil equivalent (boe)	Trillion cubic feet (TCF)	Teracalories (Tcal)
9.49×10^{-19}	9.49×10^{-22}	9.49×10^{-19}	2.3×10^{-11}	3.4×10^{-11}	1.6×10^{-10}	8.6×10^{-19}	2.4×10^{-13}
3.97×10^{-18}	3.97×10^{-21}	3.97×10^{-18}	9.6×10^{-11}	1.4×10^{-10}	6.7×10^{-10}	3.6×10^{-18}	10^{-12}
3.97×10^{-15}	3.97×10^{-18}	3.97×10^{-15}	9.6×10^{-8}	1.4×10^{-7}	6.7×10^{-7}	3.6×10^{-15}	10^{-9}
3.41×10^{-12}	3.41×10^{-15}	3.41×10^{-12}	8.3×10^{-5}	1.2×10^{-4}	5.8×10^{-4}	3.1×10^{-11}	8.6×10^{-7}
2.99×10^{-5}	2.99×10^{-8}	2.99×10^{-5}	730	1,100	5,100	2.7×10^{-5}	7.5
10^{-15}	10^{-18}	10^{-15}	2.4×10^{-8}	3.6×10^{-8}	1.7×10^{-7}	9.1×10^{-16}	2.52×10^{-10}
10^{-9}	10^{-12}	10^{-9}	0.024	0.036	0.17	9.1×10^{-10}	2.52×10^{-4}
1	10^{-3}	1	2.4×10^{7}	3.6×10^{7}	1.7×10^{8}	0.91	2.52×10^{5}
10^{3}	1	10^{3}	2.4×10^{10}	3.6×10^{10}	1.7×10^{11}	910	2.52×10^{8}
	10^{-3}	1	2.4×10^{7}	3.6×10^{7}	1.7×10^{8}	0.91	2.52×10^{5}
4.1×10^{-8}	4.1×10^{-11}	4.1×10^{-8}	1	1.47	7.0	3.7×10^{-8}	0.01
2.8×10^{-8}	2.8×10^{-11}	2.8×10^{-8}	0.68	1	4.76	2.7×10^{-8}	7.1×10^{-3}
5.9×10^{-9}	5.9×10^{-12}	5.9×10^{-9}	0.14	0.21	1	5.7×10^{-9}	1.5×10^{-3}
1.1	1.1×10^{-3}	1.1	2.7×10^{7}	3.8×10^{7}	1.9×10^{8}	1	2.8×10^{5}
4.0×10^{-6}	4.0×10^{-9}	4.0×10^{-6}	94	20	670	3.8×10^{-6}	1

Contents