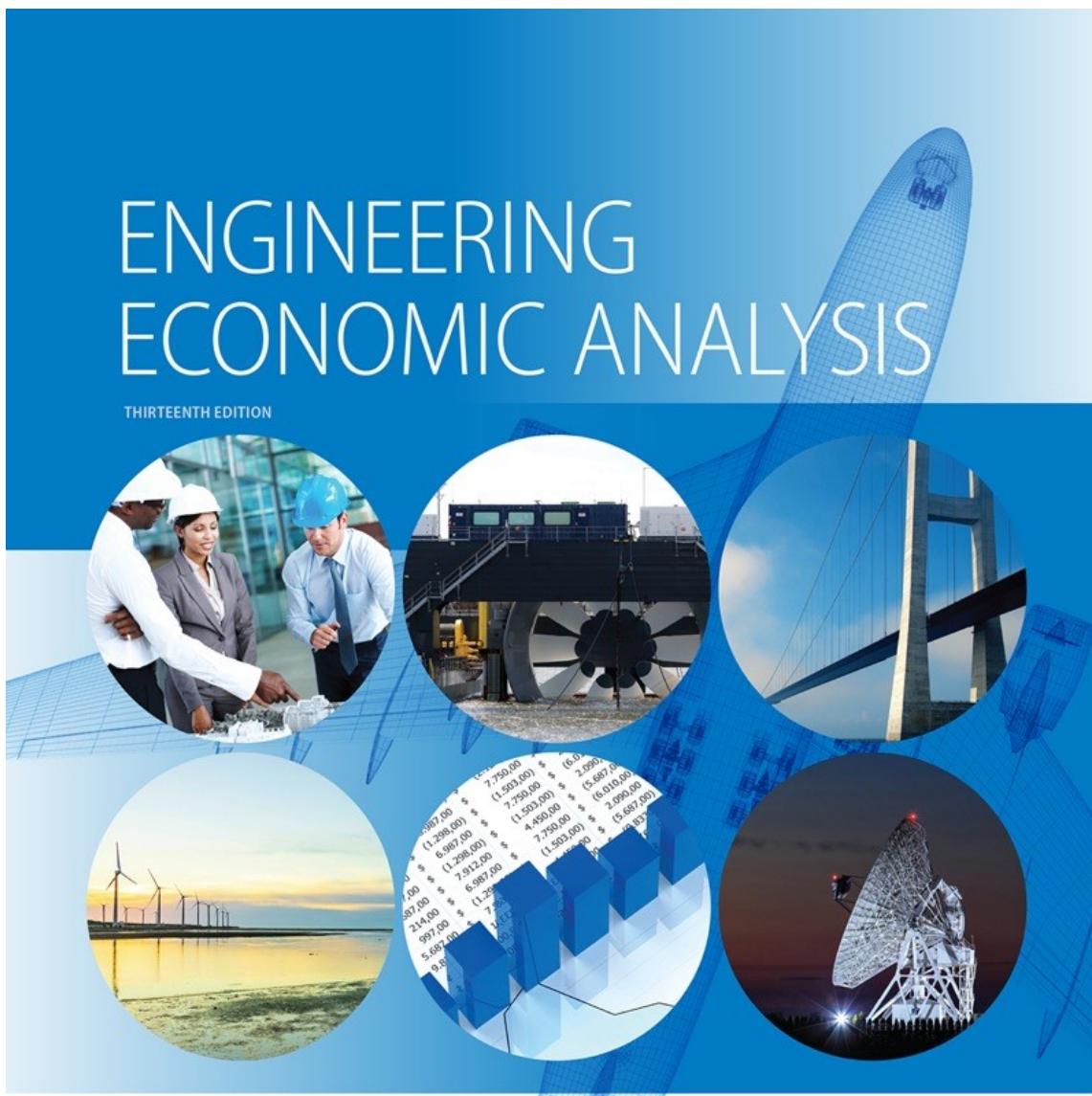


PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



OXFORD  
UNIVERSITY PRESS

Donald G. Newnan  
Ted G. Eschenbach  
Jerome P. Lavelle

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## ENGINEERING ECONOMIC ANALYSIS

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



# ENGINEERING ECONOMIC ANALYSIS

THIRTEENTH EDITION

**Donald G. Newnan**

*San Jose State University*

**Ted G. Eschenbach**

*University of Alaska Anchorage*

**Jerome P. Lavelle**

*North Carolina State University*

**Neal A. Lewis**

*University of New Haven*

New York Oxford  
OXFORD UNIVERSITY PRESS

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

Oxford University Press is a department of the University of Oxford. It furthers the University's objective of excellence in research, scholarship, and education by publishing worldwide. Oxford is a registered trade mark of Oxford University Press in the UK and certain other countries.

Published in the United States of America by Oxford University Press  
198 Madison Avenue, New York, NY 10016, United States of America.

Copyright © 2017, 2014, 2012, 2009, 2004 by Oxford University Press

For titles covered by Section 112 of the US Higher Education Opportunity Act, please visit [www.oup.com/us/he](http://www.oup.com/us/he) for the latest information about pricing and alternate formats.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, without the prior permission in writing of Oxford University Press, or as expressly permitted by law, by license, or under terms agreed with the appropriate reproduction rights organization. Inquiries concerning reproduction outside the scope of the above should be sent to the Rights Department, Oxford University Press, at the address above.

You must not circulate this work in any other form  
and you must impose this same condition on any acquirer.

CIP Data is on file at the Library of Congress

ISBN 978-0-19-029690-2

9 8 7 6 5 4 3 2 1  
Printed by Edwards Brothers Malloy, United States of America

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

*Brian Newnan, my chemical engineering nephew,*

*who helped guide this book forward*

*DN*

*Richard Corey Eschenbach, for his lifelong example  
of engineering leadership and working well with others*

*TE*

*To my lovely wife Christine  
and sweet daughters Gabrielle, Veronica,  
Miriam, Regina, and Magdalen,  
who all inspire me daily to be my best!*

*JL*

*My wife Joan,  
for her continued support*

*NL*

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

**CONTENTS IN BRIEF**

<b>1</b>	<b>MAKING ECONOMIC DECISIONS</b>	<b>2</b>
<b>2</b>	<b>ESTIMATING ENGINEERING COSTS AND BENEFITS</b>	<b>36</b>
<b>3</b>	<b>INTEREST AND EQUIVALENCE</b>	<b>80</b>
<b>4</b>	<b>EQUIVALENCE FOR REPEATED CASH FLOWS</b>	<b>110</b>
<b>5</b>	<b>PRESENT WORTH ANALYSIS</b>	<b>158</b>
<b>6</b>	<b>ANNUAL CASH FLOW ANALYSIS</b>	<b>198</b>
<b>7</b>	<b>RATE OF RETURN ANALYSIS</b>	<b>230</b>
	<b>APPENDIX 7A Difficulties in Solving for an Interest Rate</b>	<b>269</b>
<b>8</b>	<b>CHOOSING THE BEST ALTERNATIVE</b>	<b>282</b>
<b>9</b>	<b>OTHER ANALYSIS TECHNIQUES</b>	<b>306</b>
	<b>APPENDIX 9A Investing for Retirement and Other Future Needs</b>	<b>343</b>
<b>10</b>	<b>UNCERTAINTY IN FUTURE EVENTS</b>	<b>350</b>
	<b>APPENDIX 10A Diversification Reduces Risk</b>	<b>388</b>
<b>11</b>	<b>DEPRECIATION</b>	<b>394</b>
<b>12</b>	<b>INCOME TAXES FOR CORPORATIONS</b>	<b>434</b>
	<b>APPENDIX 12A Taxes and Personal Financial Decision Making</b>	<b>461</b>
<b>13</b>	<b>REPLACEMENT ANALYSIS</b>	<b>480</b>
<b>14</b>	<b>INFLATION AND PRICE CHANGE</b>	<b>518</b>
<b>15</b>	<b>SELECTION OF A MINIMUM ATTRACTIVE RATE OF RETURN</b>	<b>554</b>
<b>16</b>	<b>ECONOMIC ANALYSIS IN THE PUBLIC SECTOR</b>	<b>580</b>
<b>17</b>	<b>ACCOUNTING AND ENGINEERING ECONOMY</b>	<b>610</b>
	<b>APPENDIX A Introduction to Spreadsheets</b>	<b>628</b>
	<b>APPENDIX B Time Value of Money Calculations using Spreadsheets and Calculators</b>	<b>632</b>
	<b>APPENDIX C Compound Interest Tables</b>	<b>644</b>
	<b>APPENDIX D Fundamentals of Engineering (FE) Exam Practice Problems</b>	<b>675</b>
	<b>APPENDIX E Selected Answers to End-of-Chapter Problems</b>	<b>695</b>

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



## CONTENTS

### PREFACE xix

## 1 MAKING ECONOMIC DECISIONS 2

### Electric Vehicles 2

#### A Sea of Problems 4

Simple Problems 4 • Intermediate Problems 4 • Complex Problems 5

#### The Role of Engineering Economic Analysis 5

Examples of Engineering Economic Analysis 5

#### The Decision-Making Process 6

Rational Decision Making 7

#### Ethics 15

Ethical Dimension in Engineering Decision Making 15 • Importance of Ethics in Engineering and Engineering Economy 19

#### Engineering Decision Making for Current Costs 19

#### When More Than Economics Is Involved 23

SUMMARY 24

PROBLEMS 26

## 2 ESTIMATING ENGINEERING COSTS AND BENEFITS 36

### LightTUBE 36

#### Fixed, Variable, Marginal, and Average Costs 38

Sunk Costs 41 • Opportunity Costs 42 • Recurring and Nonrecurring Costs 43

• Incremental Costs 44 • Cash Costs Versus Book Costs 45

#### Considering All Costs 45

Life-Cycle Costs 45 • Design Changes and Cost Impacts 46 • Internal and External Costs 47

#### Estimating Benefits 49

#### The Estimating Process 49

Types of Cost Estimates 50 • Accuracy of Estimate 50 • Difficulties in Estimation 52

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**X CONTENTS****Estimating Models 53**

- Per-Unit Model 53 • Segmenting Model 55 • Cost and Price Indexes 57 • Power-Sizing Model 58  
• Triangulation 59 • Improvement and the Learning Curve 60

**Cash Flow Diagrams 63**

- Categories of Cash Flows 64 • Drawing a Cash Flow Diagram 64 • Drawing Cash Flow Diagrams with a Spreadsheet 66

**SUMMARY 66**

**PROBLEMS 67**

**TRUST ME, YOU'LL USE THIS 78****3 INTEREST AND EQUIVALENCE 80****A Prescription for Success 80****Computing Cash Flows 82****Time Value of Money 84**

- Simple Interest 84 • Compound Interest 85 • Repaying a Debt 86

**Equivalence 88**

- Difference in Repayment Plans 88 • Equivalence Is Dependent on Interest Rate 90 • Differences in Economically Equivalent Plans 91

**Single Payment Compound Interest Formulas 92****Nominal and Effective Interest 97**

**SUMMARY 103**

**PROBLEMS 105**

**4 EQUIVALENCE FOR REPEATED CASH FLOWS 110****Student Solar Power 110****Uniform Series Compound Interest Formulas 112****Cash Flows That Do Not Match Basic Patterns 120****Economic Equivalence Viewed as a Moment Diagram 125****Relationships Between Compound Interest Factors 127**

- Single Payment 127 • Uniform Series 128

**Arithmetic Gradient 129**

- Derivation of Arithmetic Gradient Factors 129 • Reality and the Assumed Uniformity of  $A$ ,  $G$ , and  $g$  135

**Geometric Gradient 135**

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**CONTENTS xi****Spreadsheets for Economic Analysis 138**

Spreadsheets: *The Tool for Engineering Practice* 138 • Spreadsheet Block Functions for Cash Flow Tables 139

**Compounding Period and Payment Period Differ 141**

**SUMMARY** 143  
**PROBLEMS** 145

**5 PRESENT WORTH ANALYSIS 158****The Present Value of 30 Years of Benefits 158****Assumptions in Solving Economic Analysis Problems 160**

End-of-Year Convention 160 • Viewpoint of Economic Analysis Studies 161 • Sunk Costs 161 • Borrowed Money Viewpoint 161 • Effect of Inflation and Deflation 161 • Income Taxes 162

**Economic Criteria 162****Time Period for Analysis 163**

Useful Lives Equal the Analysis Period 163 • Useful Lives Different from the Analysis Period 166 • Infinite Analysis Period: Capitalized Cost 170

**Multiple Alternatives 173****Applications and Complications 176**

Bond Pricing 181  
**SUMMARY** 183  
**PROBLEMS** 184

**6 ANNUAL CASH FLOW ANALYSIS 198****Are More Efficient Appliances Cost Effective? 198****Annual Cash Flow Calculations 200**

Resolving Cash Flows to an Annual Equivalent 200 • Capital Recovery Costs 201

**Annual Cash Flow Analysis 205****Analysis Period 208**

Analysis Period Equal to Alternative Lives 210 • Analysis Period a Common Multiple of Alternative Lives 210 • Analysis Period for a Continuing Requirement 210 • Infinite Analysis Period 211 • Some Other Analysis Period 213

**Analyzing Loans 214**

Building an Amortization Schedule 214 • Finding the Balance Due on a Loan 215 • How Much to Interest? How Much to Principal? 216 • Pay Off Debt Sooner by Increasing Payments 217

**Annuity Due 218**

**SUMMARY** 219  
**PROBLEMS** 220

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**xii CONTENTS****7 RATE OF RETURN ANALYSIS 230**

**Bar Codes Give a Number; RFID Codes Tell a Story and May Become the Spies You Buy 230**

**Internal Rate of Return 232**

**Calculating Rate of Return 234**

Plot of NPW Versus Interest Rate  $i$  239

**Interest Rates When There Are Fees or Discounts 242**

**Loans and Investments Are Everywhere 245**

**Incremental Analysis 250**

**Analysis Period 255**

GOAL SEEK 256

**XIRR 258**

SUMMARY 258

PROBLEMS 259

**APPENDIX 7A: DIFFICULTIES IN SOLVING FOR AN INTEREST RATE 269**

**What to Do If Cash Flow Diagram Has Two or More Sign Changes 270**

**Projects with Multiple Sign Changes 271**

**Modified Internal Rate of Return (MIRR) 275**

SUMMARY 277

PROBLEMS 278

**8 CHOOSING THE BEST ALTERNATIVE 282**

**Selecting the Best Pavement 282**

**Incremental Analysis 284**

**Graphical Solutions 284**

**Elements in Comparing Mutually Exclusive Alternatives 294**

**Doing a Set of Incremental Challenger-Defender Comparisons 295**

**Choosing an Analysis Method 297**

SUMMARY 297

PROBLEMS 298

**9 OTHER ANALYSIS TECHNIQUES 306**

**Clean and Green 306**

**Future Worth Analysis 308**

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**CONTENTS** **xiii**

<b>Benefit-Cost Ratio Analysis</b>	<b>310</b>
Variations on the Theme of the Benefit-Cost Ratio	314
<b>Payback Period</b>	<b>317</b>
<b>Sensitivity and Breakeven Analysis</b>	<b>322</b>
<b>Graphing with Spreadsheets for Sensitivity and Breakeven Analysis</b>	<b>326</b>
<b>Doing What-If Analysis with Spreadsheets</b>	<b>329</b>
SUMMARY	330
PROBLEMS	331
<b>APPENDIX 9A: INVESTING FOR RETIREMENT AND OTHER FUTURE NEEDS</b>	<b>343</b>
<b>Defined Contributions and Defined Benefit Plans</b>	<b>343</b>
<b>What Returns Are Reasonable to Expect and What Risks Go with Them</b>	<b>344</b>
PROBLEMS	348
<b>10 UNCERTAINTY IN FUTURE EVENTS</b>	<b>350</b>
<b>Video Game Development and Uncertainty</b>	<b>350</b>
<b>Estimates and Their Use in Economic Analysis</b>	<b>352</b>
<b>A Range of Estimates</b>	<b>352</b>
<b>Probability</b>	<b>355</b>
<b>Joint Probability Distributions</b>	<b>357</b>
<b>Expected Value</b>	<b>359</b>
<b>Economic Decision Trees</b>	<b>362</b>
<b>Risk</b>	<b>368</b>
Calculating the Standard Deviation	369
<b>Risk Versus Return</b>	<b>371</b>
Risk and Return as Multiple Objectives	372
<b>Simulation</b>	<b>374</b>
<b>Real Options</b>	<b>378</b>
SUMMARY	378
PROBLEMS	379
<b>APPENDIX 10A: DIVERSIFICATION REDUCES RISK</b>	<b>388</b>
<b>Portfolios of Stocks and Bonds</b>	<b>388</b>
<b>Making the Trade-Off Between Risk and Return</b>	<b>390</b>
PROBLEMS	392

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**xiv CONTENTS****11 DEPRECIATION 394****Depreciation and Intangible Property 394****Income, Depreciation, and Cash Flow 396****Basic Aspects of Depreciation 397**

Deterioration and Obsolescence 397 • Depreciation and Expenses 398 • Types of Property 399 • Depreciation Calculation Fundamentals 400

**Time-Based Depreciation Methods 401**

Straight-Line Depreciation 401 • Sum-of-Years'-Digits Depreciation 403 • Declining Balance Depreciation 404

**Modified Accelerated Cost Recovery System (MACRS) 406**

Cost Basis and Placed-in-Service Date 407 • Property Class and Recovery Period 407 • Percentage Tables 407 • Where MACRS Percentage Rates ( $r_i$ ) Come From 408 • MACRS Method Examples 412 • Comparing MACRS and Classic Methods 413

**Depreciation and Asset Disposal 414****Unit-of-Production Depreciation 418****Depletion 419**

Cost Depletion 419 • Percentage Depletion 420

**Spreadsheets and Depreciation 421**

Using VDB for MACRS 422

**SUMMARY 423****PROBLEMS 425****12 INCOME TAXES FOR CORPORATIONS 434****On with the Wind 434****A Partner in the Business 436****Calculation of Taxable Income 436**

Classification of Business Expenditures 436 • Taxable Income of Business Firms 437

**Income Tax Rates 438**

Corporate Tax Rates 438 • Combined Federal and State Income Taxes 440 • Selecting an Income Tax Rate for Economy Studies 441

**Economic Analysis Taking Income Taxes into Account 441**

Section 179 Deduction 445 • Investment Tax Credit 445 • Bonus Depreciation 445

**The After-Tax Rate of Return 446**

Estimating a Project's After-Tax IRR 446 • Firm's After-tax Minimum Attractive Rate of Return 446

**Capital Gains and Losses for Nondepreciated Assets 447**

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**CONTENTS xv****After-Tax Cash Flows and Spreadsheets 447****SUMMARY 449****PROBLEMS 449****APPENDIX 12A: TAXES AND PERSONAL FINANCIAL DECISION MAKING 461****Income Taxes for Individuals 461**

Calculating Taxable Income 461 • Individual Tax Rates 462 • Combined Federal and State Income Taxes 464 • Capital Gains/Losses for Individuals 465 • Tax Credits vs. Tax Deductions 465 • Student Loan Interest Deduction 465

**Student Loans 467****Retirement Accounts 469****Insurance 471**

Automobile Insurance 471 • Life Insurance 473

**Personal Budgeting 474****PROBLEMS 476****13 REPLACEMENT ANALYSIS 480****Aging Bridges 480****The Replacement Problem 482****Replacement Analysis Decision Map 483****Minimum Cost Life of a New Asset — The Challenger 485****Marginal Cost Calculations 489**

Do We Have Marginal Cost Data for the Defender? 491 • Are These Marginal Costs Increasing? 491

**Replacement Analysis Technique 1: Defender Marginal Costs Can Be Computed and Are Increasing 492****Replacement Repeatability Assumptions 494****Replacement Analysis Technique 2: Defender Marginal Costs Can Be Computed and Are Not Increasing 495****Replacement Analysis Technique 3: When Defender Marginal Cost Data Are Not Available 499****Complications in Replacement Analysis 500**

Defining Defender and Challenger First Costs 500

**Repeatability Assumptions Not Acceptable 502**

A Closer Look at Future Challengers 503

**After-Tax Replacement Analysis 504**

Marginal Costs on an After-Tax Basis 504 • Minimum Cost Life Problems 506 • Spreadsheets and After-tax Replacement Analysis 507

**SUMMARY 508****PROBLEMS 509**

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

**xvi CONTENTS**

---

**14 INFLATION AND PRICE CHANGE 518****Price Trends in Solar Technologies 518****Meaning and Effect of Inflation 520**

How Does Inflation Happen? 520 • Definitions for Considering Inflation in Engineering Economy 521

**Analysis in Constant Dollars Versus Then-Current Dollars 528**

Inflation and Uniform Flow Equivalence 531

**Price Change with Indexes 531**

What Is a Price Index? 532 • Composite Versus Commodity Indexes 534 • How to Use Price Indexes in Engineering Economic Analysis 536

**Cash Flows That Inflate at Different Rates 536****Different Inflation Rates per Period 538****Inflation Effect on After-Tax Calculations 538****Using Spreadsheets for Inflation Calculations 541**

SUMMARY 543

PROBLEMS 544

**15 SELECTION OF A MINIMUM ATTRACTIVE RATE OF RETURN 554****What's the Rate of Return on a Dam? 554****MARR for Individuals 556****Sources of Capital 556**

Money Generated from the Firm's Operation 556 • External Sources of Money 557 • Choice of Sources of Funds 557

**Cost of Funds 557**

Cost of Borrowed Money 557 • Cost of Capital 558 • Inflation and the Cost of Borrowed Money 559

**Investment Opportunities 560**

Opportunity Cost 560

**Selecting a Minimum Attractive Rate of Return 566****Adjusting MARR to Account for Risk and Uncertainty 567****Representative Values of MARR Used in Industry 569****Capital Budgeting or Selecting the Best Projects 570**

SUMMARY 572

PROBLEMS 573

**16 ECONOMIC ANALYSIS IN THE PUBLIC SECTOR 580****From Waste to Power and Money 580****Investment Objective 582**

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**CONTENTS xvii****Viewpoint for Analysis 583****Selecting an Interest Rate 585**

No Time-Value-of-Money Concept 585 • Cost of Capital Concept 585 • Opportunity Cost Concept 586 • Recommended Concept 586

**The Benefit-Cost Ratio 586****Incremental Benefit-Cost Analysis 590**

Elements of the Incremental Benefit-Cost Ratio Method 590

**Other Effects of Public Projects 595**

Project Financing 595 • Project Duration 596 • Quantifying and Valuing Benefits and Disbenefits 598 • Project Politics 600

**SUMMARY 601**

**PROBLEMS 602**

**17 ACCOUNTING AND ENGINEERING ECONOMY 610****A Tale of Three Engineers 610****The Role of Accounting 612**

Accounting for Business Transactions 613

**The Balance Sheet 613**

Assets 614 • Liabilities 614 • Equity 615 • Financial Ratios Derived from Balance Sheet Data 615

**The Income Statement 616**

Financial Ratios Derived from Income Statement Data 618 • Linking the Balance Sheet, Income Statement, and Capital Transactions 618

**Traditional Cost Accounting 619**

Direct and Indirect Costs 619 • Indirect Cost Allocation 620 • Problems with Traditional Cost Accounting 621 • Other Problems to Watch For 622

**PROBLEMS 622**

**APPENDIX A 628**

**APPENDIX B 632**

**APPENDIX C 644**

**APPENDIX D 675**

**APPENDIX E 695**

**PHOTOCREDITS 702**

**REFERENCES 703**

**INDEX 705**

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## PREFACE

**O**ur goal has been, and still is, to provide an easy-to-understand and up-to-date presentation of engineering economic analysis for today's students. That means the book's writing style must promote the reader's understanding. We humbly note that our approach has been well received by engineering professors—and more importantly, by engineering students through multiple editions.

### Hallmarks of this Book

Since it was first published, this text has become the market-leading book for the engineering economy course. It has always been characterized by

- **A focus on practical applications.** One way to encourage students to read the book, and to remember and apply what they have learned in this course, is to make the book interesting. And there is no better way to do that than to infuse the book with real-world examples, problems, and vignettes.
- **Accessibility.** We meet students where they are. Most don't have any expertise in accounting or finance. We take the time to explain concepts carefully while helping students apply them to engineering situations.
- **Superior instructor and student support packages.** To make this course easier to understand, learn, and teach, Oxford University Press has produced the best support package available. We offer more for students and instructors than any competing text.

### Strengths of the 13<sup>th</sup> Edition

- New to this edition is chapter appendix material on investing, diversification, and personal finance. This builds on the loans, savings, and other personal finance examples that have long been used to motivate students and engage them with engineering economy concepts. Our first goal is force the realization that engineering economy *really does matter*. Second, personal financial success contributes to success as a student, as an engineer, and most importantly in life.
- New to this edition is coverage of multiple objectives using simple additive models starting in Chapter 1. With this simple model students can incorporate the important nonmonetary factors found in many engineering economy applications.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

**xx PREFACE**

- Green engineering and ethics have more coverage with *new problem parts and icons* in every chapter. Ethics questions continue to be part of the Questions to Consider in the vignettes.
- Factor notation has long provided a clear way to describe and understand engineering economic calculations supported by tables—which is continued in this edition. Spreadsheet annuity functions with the same assumptions as tabulated factors are presented in a visual 5-BUTTON format. The two approaches are mutually reinforcing for faster and deeper student understanding. As detailed in Appendix B, students can also use a financial calculator or an HP 33s or 35s—which can be used on the FE exam.
- Over 500 problems are new or revised of the 1457 in the text. To minimize errors and typos, solutions in the *Instructor's Manual* were completed and text corrections were made *before* the book was finalized for printing.
  - Over 10% of these problems have been contributed by adopters with class-tested fresh examples and new question formats.
  - Problem headings link with chapter headings to assist faculty in choosing problems and students in studying similar problems. Problems are ordered from easy to hard within each heading.
  - There is an answer icon next to most even-numbered problems with answers in Appendix E.
    - Instructors can easily pick a preferred mix of problems with and without answers.
    - Students can work on assigned problems without knowing the answer until they are done (or stuck).
    - Students can do extra problems and check their own answers.
  - Each chapter opens with a list of *keywords*, which are **boldfaced** when first explained and indexed for later reference.
- Spreadsheet coverage has been designed to support student learning and engineering practice. Faculty can choose from no coverage to heavy reliance. In either case the text has been designed to support student self-directed learning.
  - Appendix A supports spreadsheet novices and demonstrates the use of data blocks and relative/absolute addresses.
  - Spreadsheet annuity functions are introduced beginning with Example 3–5; spreadsheet block functions are covered late in Chapter 4 after factor approaches for arithmetic and geometric gradients where annuity functions cannot be used. This structure allows a mutually reinforcing presentation of tabulated factors and spreadsheet annuity functions.
  - Other spreadsheet functions including XNPV, XIRR, SUMPRODUCT, and GOAL SEEK are presented when they will allow or speed solution in applications of engineering economy concepts.
  - Problems in Chapters 12, 13, and 14 on taxes, replacement analysis, and inflation tend to involve more calculations than other chapters so spreadsheets are particularly useful.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**PREFACE xxi**

- Renewed in this edition is a focus on selecting and revisiting examples with different economic measures, different tools, and increasing complexity.
- To support classes where some students rent or buy a used text, the 54 cases in *Cases in Engineering Economy 2<sup>nd</sup>* are now posted on the student website, their solutions on the instructor website, and each chapter concludes with a list of recommended cases.
- The chapter opening vignettes are replaced, revised, and updated to ensure they are up to date and relevant.

Changes in conceptual coverage are detailed by chapter.

- Chapter 1 (*Making Economic Decisions*) now introduces multiple objectives. The electric vehicle vignette is new to emphasize vehicle performance.
- Chapter 2 (*Estimating Engineering Costs and Benefits*) now includes coverage of internal and external costs with an emphasis on green engineering.
- Chapter 3 (*Interest and Equivalence*) reduces continuous compounding to coverage of the effective interest rate and drops coverage of the almost never used continuous compounding factors.
- Chapter 4 (*Equivalence for Repeated Cash Flows*) has reordered the factor and spreadsheet annuity function coverage to be mutually reinforcing. It drops coverage of the almost never used continuous compounding factors.
- Chapter 5 (*Present Worth Analysis*) now includes XNPV for cash flows that occur on specific dates rather than evenly spaced periods.
- Chapter 7 (*Rate of Return Analysis*) now includes XIRR for cash flows that occur on specific dates rather than evenly spaced periods.
- Chapter 9 (*Other Analysis Techniques*) now includes discounted payback period and Appendix 9A (*Investing for Retirement and Other Future Needs*) has been added to prepare students for likely retirement saving environments.
- Chapter 10 (*Uncertainty in Future Events*) now includes balancing risk and return using multiple objectives. Appendix 10A (*Diversification Reduces Risk*) has been added so that students can apply it when investing.
- Chapter 12 (*Income Taxes for Corporations*) now includes bonus depreciation and demonstrates how multiple depreciation methods can be used together. Appendix 12A (*Taxes and Personal Financial Decision Making*) has added coverage of insurance and personal budgeting. As in every edition, this material has been updated for changes in the tax code.
- Chapter 13 (*Replacement Analysis*) now matches the replacement map to real-world applications of replacement analysis. Formal equations for replacement analysis are now included.
- Chapter 14 (*Inflation and Price Changes*) has a new vignette on price trends in solar technologies.
- Chapter 15 (*Selection of a Minimum Attractive Rate of Return*) adds a new section on the MARR for individuals.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**xxii PREFACE**

- Chapter 16 (*Economic Analysis in the Public Sector*) adds design to cost and compares it with minimizing life cycle costs.
- "Trust Me: You'll Use This" (between chapters 2 and 3) focuses on applications to the lives of students and graduates.

**The Superior Newnan Support Package**

The supplement package for this text has expanded with each edition, and it has been updated and expanded even further for this edition. No competing text has a more extensive support package. The package features the following:

- A Study Guide by Ed Wheeler of the University of Tennessee, Martin (ISBN 978-0-19-029702-2) is available for individual purchase and is also available free of charge when packaged with the textbook.
- The book is accompanied by an extensive set of materials that are presented, free of charge, at [www.oup.com/us/newnan](http://www.oup.com/us/newnan). These include:
  - A set of tutorials on engineering economy applications of Excel by Julie L. Fortune of the University of Alabama in Huntsville.
  - A set of 54 cases provides realistic, complex problems for further study. These cases, written by William Peterson and Ted Eschenbach, also include three chapters on case analysis and an example case solution.
  - Spreadsheet problem modules, written by Thomas Lacksonen of the University of Wisconsin Stout.
  - Interactive multiple-choice problems, written by Paul Schnitzler of the University of South Florida and William Smyer of Mississippi State University.
  - Additional practice FE Exam problems, authored by Karen Thorsett, University of Phoenix.

Instructors will find an updated and expanded set of resources available on Oxford's Ancillary Resource Center. Please contact your Oxford University Press representative for access.

- An exam file written and edited by Meenakshi Sundaram of Tennessee Technological University.
- PowerPoint lecture notes for all chapters by Neal Lewis of the University of New Haven.
- An Instructor's Manual by John M. Usher of Mississippi State University and Lawrence Samuelson of Tri-State University and the authors, with complete solutions to all end-of-chapter problems.
- The compound interest tables from the textbook are available for adopting professors who prefer to give closed-book exams. The tables are on the website as PDF files that can be printed in part or in total.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**PREFACE xxiii**

### Acknowledgments

Many people have directly or indirectly contributed to the content of the book. We have been influenced by our educations and our university colleagues, and by students who have provided invaluable feedback on content and form. We are particularly grateful to the following professors and students for their contributions in the form of insights, reviews, contributed problems, and contributed vignettes to this and previous editions: Kate D. Abel, Stevens Institute of Technology; Francisco Aguirre, Texas A&M University-Kingsville; Magdy Akladios, University of Houston-Clear Lake; Yasser Alhehawi, University of Evansville; Benjamin Armbruster, Northwestern University; Baabak Ashuri, Georgia Institute of Technology; M. Affan Badar, Indiana State University; Kailash Bafna, Western Michigan University; Biswanath Bandyopadhyay, University of North Dakota; Robert Baston, University of Alabama-Tuscaloosa; Richard H. Bernhard, North Carolina State University; Marsha Berry, U.S. Army Research, Development & Engineering Command; Edgar Blevins, Southern University; Rebeca Book, Pittsburg State University; William Brown, West Virginia University at Parkersburg; Patrick Brunese, Purdue University; Mark Budnik, Valparaiso University; Karen M. Bursic, University of Pittsburgh; Peter A. Cerenzio, Cerenzio & Panaro Consulting Engineers; Linda Chattin, Arizona State University; Lijian Chen, University of Louisville; Steven Chiesa, Santa Clara University; Tracy Christoforo, Marshall University; Paul Compton, University of Texas at Arlington; Jennifer Cross, Texas Tech University; Gene Dixon, East Carolina University; Emmanuel Donkor, George Washington University; Colin Drummond, Case Western Reserve University; Julie Drzymalski, Western New England University; John Easley, Louisiana Tech University-Ruston; David Elizandro, Tennessee Technological University; Alberto Garcia, University of Tennessee; Mostafa Ghandehari, University of Texas at Arlington; Dolores K. Gooding, University of South Florida; Johnny R. Graham, University of North Carolina at Charlotte; Tarun Gupta, Western Michigan University; Safwat H. Shakir Hanna, Prairie View A&M University; Craig Harvey, Louisiana State University; Oliver Hedgepeth, American Public University; Morgan E. Henrie, University of Alaska Anchorage; Joseph R. Herkert, North Carolina State University; Hamed Kashani, Georgia Institute of Technology; Paul Kauffmann, East Carolina University; Khoiat Kengskool, Florida International University; Adeel Khalid, Southern Polytechnic State University; David Kieser, Indiana University-Purdue University at Indianapolis; Changhyun Kwon, SUNY Buffalo; Marcial Lapp, University of Michigan; Tony Lima, CSU East Bay; Barry Liner, George Mason University; Daniel P. Loucks, Cornell University; Muslim Majeed, Carleton University; Louis Manz, University of Texas, San Antonio; Jessica Matson, Tennessee Technological University; Brooke Mayer, Arizona State University; Paul R. McCright, University of South Florida; Dale McDonald, Midwestern State University; Nina Miville, University of Miami; Gary Moynihan, University of Alabama; David W. Naylor, UNC Charlotte; Kim LaScola Needy, University of Arkansas; Gillian M. Nicholls, Southeast Missouri State University; Charles Nippert, Widener University; Benedict N. Nwokolo, Grambling State University; John O'Haver, University of Mississippi; Darren Olson, Central Washington University; Jani Macari Pallis, University of Bridgeport & Cislunar Aerospace, Inc.; Renee Petersen, Washington State University; William Peterson, Minnesota State University, Mankato; Letitia M. Pohl, University of Arkansas; Md. Mamunur Rashid, University of Massachusetts-Lowell; Kevin A. Rider,

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**xxiv PREFACE**

West Virginia University; Saeid Sadri, JSC Nazarbayev University; Thobias Sando, University of North Florida; Scott Schultz, Mercer University; Dhananjai B. Shah, Cleveland State University; Deepak Sharma, California State University–Fullerton; Michael Shenoda, University of North Texas; James Simonton, University of Tennessee Space Institute; Don Smith, Texas A&M University; William N. Smyer, Mississippi State University; Hansuk Sohn, New Mexico State University; Musaka E. Ssemakula, Wayne State University; John Stratton, Rochester Institute of Technology; Meenakshi R. Sundaram, Tennessee Technological University; Robert Swan, Drexel University; Walter Towner, Worcester Polytechnic Institute; William R. Truran, Stevens Institute of Technology; Francis M. Vanek, Cornell University; Ed Wheeler, University of Tennessee at Martin; John Whittaker, University of Alberta; Gregory Wiles, Southern Polytechnic State University; Nong Ye, Arizona State University; Xiaoyan Zhu, University of Tennessee–Knoxville.

The following individuals are new additions to our list of contributors of vignettes, text or solution reviews, problems, and insight: Eva Andrijcic, Rose-Hulman Institute of Technology; Biswanath Bandyopadhyay, University of North Dakota; Robert Batson, University of Alabama–Tuscaloosa; Edgar R. Blevins, Southern University; Emmanuel A. Donkor, George Washington University; Ona Egbue, University of Minnesota Duluth; Tarun Gupta, Western Michigan University; Safwat H. Shakir Hanna, Prairie View A&M University; Craig Harvey, Louisiana State University; Muslim A. Majeed, Carleton University; Hector Medina, Liberty University; Nina D Miville, University of Miami; Gana Natarajan, Oregon State University; Ean Ng, Oregon State University; Md. Mamunur Rashid, University of Massachusetts–Lowell; Michael Shenoda, University of North Texas; Hansuk Sohn, New Mexico State University; John Stratton, Rochester Institute of Technology; Robert H. Swan, Jr., Drexel University; Xiaoyan Zhu, University of Tennessee–Knoxville.

John Whittaker of the University of Alberta wrote a new Chapter 8 for the first Canadian edition and many improvements he made in the second and third Canadian editions have been incorporated. Neal Lewis of the University of New Haven has contributed significantly to the last two editions, but for this edition we were fortunate to add him to the team of coauthors. Thank you, Neal, from Ted and Jerome. Finally, we were helped by the professors who participated in the market survey for this book, and whose collective advice helped us shape this new edition.

Finally, our largest thanks go to the professors (and their students) who have developed the products that support this text: Julie L. Fortune, University of Alabama in Huntsville; Thomas Lacksonen, University of Wisconsin–Stout; Shih Ming Lee, Florida International University; David Mandeville, Oklahoma State University; William Peterson, Minnesota State University, Mankato; Lawrence Samuelson, Tri-State University; Paul Schnitzler, University of South Florida; William Smyer, Mississippi State University; Meenakshi Sundaram, Tennessee Technological University; Karen Thorsett, University of Phoenix; John M. Usher, Mississippi State University; Ed Wheeler, University of Tennessee at Martin.

Textbooks are produced through the efforts of many people. Dan Kaveney, Christine Mahon, Patrick Lynch, and Megan Carlson have worked to make this a timely and improved edition. Keith Faivre managed the text's design and production. Dorothy Bauhoff copyedited the manuscript, and Mary Anne Shahidi proofread the page proofs.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**PREFACE XXV**

The sales force at OUP has maintained the text's leading position and ensured the flow of adopter feedback to the authors.

This book remains the best text on the market in large part because of feedback from users. We would appreciate hearing comments about the book, including being informed of any errors that have snuck in despite our best attempts to eradicate them. We also look forward to adding problems and vignettes in the next edition that adopters have found effective for their students. Please write us c/o the Engineering Editor at Oxford University Press, 198 Madison Avenue, New York, NY 10016, or email us directly. Thanks for using the Newnan book!

Don Newnan  
Ted Eschenbach  
[tgeschenbach@alaska.edu](mailto:tgeschenbach@alaska.edu)  
Jerome Lavelle  
[jerome\\_lavelle@ncsu.edu](mailto:jerome_lavelle@ncsu.edu)  
Neal Lewis  
[nlewis@newhaven.edu](mailto:nlewis@newhaven.edu)

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## ENGINEERING ECONOMIC ANALYSIS

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## CHAPTER

## 1

## MAKING ECONOMIC DECISIONS



### Electric Vehicles

In 2008 President Obama called for one million electric cars to be owned by Americans. However, by the end of 2015 only 300,000 were on the road. Why? The reasons included cost, battery range, and performance. Have the barriers changed?

In 2016, GM produced the Chevy Bolt EV, the first electric car under \$30,000. Given that the average price of a new vehicle in the U.S. is \$34,000, this class is large and ripe for competition. At introduction the Chevy Bolt EV had a 200-mile-per-charge electric battery, with an expected improvement of 30% by 2022. As the battery efficiency improves, sales of electric cars will increase. In turn,

higher sales will support lower manufacturing costs and reward technological improvements.

Can electric vehicles perform as well as gas-powered cars? Currently, fast automobiles can go from zero to 60 mph in under 6 seconds, while performance cars can do it in 3 to 4 seconds. The Tesla, with 2 electric motors, can go from zero to 60 mph in 2.8 seconds. The two quickest production cars are hybrids. Being the fastest might require electric motors.

These examples show that the electric car market seems ready for explosive growth. Andy Palmer, the CEO of Aston Martin, was quoted in *Auto News* as saying, "it's inevitable that the entire industry will shift over to electricity, if only because it's the most plausible way to deliver the power drivers expect."

The widespread adoption of electric vehicles would be a disruption to the current industry. Engineers who design electric vehicles will have different constraints. Electric motors and batteries will replace combustion engines, emission controls, fuel storage, and drive trains. This should reduce the weight and increase the available space in the vehicle,

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



making the electric car faster and more efficient. Design decisions will determine manufacturing costs and influence the sales price. In addition, the supply, production, and service chain will be affected by a conversion to electric vehicles.

The outlook for electric vehicles is positive for many reasons. As manufacturing experience increases, electric vehicles can be designed to surpass the performance of conventional cars, raising customer expectations. As economies of scale bring the price of electric vehicles down, more consumers can afford them and more manufacturers can profit from making them. All of this should be good news for the environment. ■■■

*Contributed by Kate D. Abel, Stevens Institute of Technology*

### QUESTIONS TO CONSIDER

1. What marketplace dynamics drive or suppress developing electric vehicles? What role should government play?
2. Develop a list of concerns and questions that consumers might have regarding the conversion to electric vehicles. Which are economic and which are non-economic factors?
3. From a manufacturer's viewpoint, what are the major concerns, potential problems, and overriding goals of producing an electric vehicle? How do these affect the price charged for the vehicle?
4. Are there ethical aspects in the shift from gasoline-powered vehicles to electric vehicles? List these and determine how they could be or should be resolved and by whom.

### After Completing This Chapter...

*The student should be able to:*

- Distinguish between simple and complex problems.
- Discuss the role and purpose of engineering economic analysis.
- Describe and give examples of the nine steps in the *economic decision-making process*.
- Select appropriate economic criteria for use with different types of problems.
- Describe common ethical issues in engineering economic decision making.
- Solve engineering problems with current costs.
- Solve problems that have multiple objectives.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

#### 4 CHAPTER 1: MAKING ECONOMIC DECISIONS

##### Key Words

absolute address	fixed input	resolving consequences
benefit	fixed output	shadow price
brainstorming	green engineering	societal costs
cost	maximizing profit	value engineering
criteria	model building	what-if analysis
data block	multiple objectives	
decision making	overhead	

This book is about making decisions. **Decision making** is a broad topic, for it is a major aspect of everyday human existence. This book develops the tools to properly analyze and solve the economic problems that are commonly faced by engineers. Even very complex situations can be broken down into components from which sensible solutions are produced. If one understands the decision-making process and has tools for obtaining realistic comparisons between alternatives, one can expect to make better decisions.

Our focus is on solving problems that confront firms in the marketplace, but many examples are problems faced in daily life. Let us start by looking at some of these problems.

#### A SEA OF PROBLEMS

A careful look at the world around us clearly demonstrates that we are surrounded by a sea of problems. There does not seem to be any exact way of classifying them, simply because they are so diverse in complexity and "personality." One approach arranges problems by their *difficulty*.

##### Simple Problems

Many problems are pretty simple, and good solutions do not require much time or effort.

- Should I pay cash or use my credit card?
- Do I buy a semester parking pass or use the parking meters?
- Shall we replace a burned-out motor?
- If we use three crates of an item a week, how many crates should we buy at a time?

##### Intermediate Problems

At a higher level of complexity we find problems that are primarily economic.

- Shall I buy or lease my next car?
- Which equipment should be selected for a new assembly line?
- Which materials should be used as roofing, siding, and structural support for a new building?
- Shall I buy a 1- or 2-semester parking pass?
- What size of transformer or air conditioner is most economical?

Some numeric examples of operational economics follow the section on ethics later in this chapter.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

### Complex Problems

Complex problems are a mixture of *economic*, *political*, and *humanistic* elements.

- Honda Motors in North America illustrates complex problems. In Alliston, Ontario, they employ 4000 workers and manufacture the Acura MDX, ZDX, CSX, and Civic. In Lincoln, Alabama, they employ 4000 workers and manufacture the Odyssey, Pilot, Ridgeline, and Acura MDX. Any decision allocating production must consider, along with economic aspects: reactions of the American, Canadian, Japanese, and Mexican governments; the North American Free Trade Agreement; labor unions in three countries; and the 2014 opening of a second Mexican plant in Celaya.
- The selection of a dating partner (who may later become a permanent partner) is obviously complex. Economic analysis can be of little or no help.
- A firm's annual budget allocates resources and all projects are economically evaluated. The budget process is also heavily influenced by noneconomic forces such as power struggles, geographical balancing, and impact on individuals, programs, and profits. For multinational corporations there are even national interests to be considered.

The chapter's final section presents one approach to more complex problems.

## THE ROLE OF ENGINEERING ECONOMIC ANALYSIS

Engineering economic analysis is most suitable for intermediate problems and the economic aspects of complex problems. They have these qualities:

1. The problem is *important enough* to justify our giving it serious thought and effort.
2. The problem can't be worked in one's head—that is, a careful analysis *requires that we organize* the problem and all the various consequences.
3. The problem has *economic aspects* important in reaching a decision.

When problems meet these three criteria, engineering economic analysis is useful in seeking a solution. Since vast numbers of problems in the business world (and in one's personal life) meet these criteria, engineering economic analysis is often required.

### Examples of Engineering Economic Analysis

Engineering economic analysis focuses on costs, revenues, and benefits that occur at different times. For example, when a civil engineer designs a road, a dam, or a building, the construction costs occur in the near future; but the benefits to users begin only when construction is finished and then continue for a long time.

In fact nearly everything that engineers design calls for spending money in the design and building stages, and only after completion do revenues or benefits occur—usually for years. Thus the economic analysis of costs, benefits, and revenues occurring over time is called *engineering economic analysis*.

Engineering economic analysis is used by firms and government agencies to answer many different questions.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 6 CHAPTER 1: MAKING ECONOMIC DECISIONS

---

- *Which engineering projects are worthwhile?* Has the mining or petroleum engineer shown that the mineral or oil deposit is worth developing?
- *Which engineering projects should have a higher priority?* Has the industrial engineer shown which factory improvement projects should be funded with the available dollars?
- *How should the engineering project be designed?* Has the mechanical or electrical engineer chosen the most economical motor size? Has the civil or mechanical engineer chosen the best thickness for insulation? Has the aeronautical engineer made the best trade-offs between (1) lighter materials that are expensive to buy but cheaper to fly and (2) heavier materials that are cheap to buy and more expensive to fly?

Engineering economic analysis can also be used to answer questions that are personally important.

- *How to achieve long-term financial goals:* How much should you save each month to buy a house, retire, or fund a trip around the world? Is going to graduate school a good investment—will your additional earnings in later years balance the cost of attending and your lost income while in graduate school?
- *How to compare different ways to finance purchases:* Is it better to finance your car purchase by using the dealer's low interest rate loan or by taking an available rebate and borrowing money from your bank or credit union?
- *How to make short- and long-term investment decisions:* Should you buy a 1- or 2-semester parking pass? Is a higher salary better than stock options?

## THE DECISION-MAKING PROCESS

---

Decision making may take place by default; that is, a person may not consciously recognize that an opportunity for decision making exists. This fact leads to our first element in a definition of decision making—there must be at least two alternatives available. If only one course of action is available, there is nothing to decide. The only alternative is to proceed with the single available course of action. (It is rather unusual to find that there are no alternative courses of action. More frequently, alternatives simply are not recognized.)

At this point we might conclude that the decision-making process consists of choosing from among alternative courses of action. But this is an inadequate definition. Consider the following situation.

At a race track, a bettor was uncertain about which horse to bet on in the next race. He closed his eyes and pointed his finger at the list of horses printed in the racing program. Upon opening his eyes, he saw that he was pointing to horse number 4. He hurried off to bet on that horse.

Does this racehorse selection represent decision making? Yes, (assuming the bettor had already ruled out the "do-nothing" alternative of placing no bet). But the particular method of deciding seems inadequate and irrational. We want to deal with rational decision making.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

### Rational Decision Making

Rational decision making is a complex process that contains nine essential elements, which are shown in Figure 1–1. Although these nine steps are shown sequentially, it is common for a decision maker to repeat steps, take them out of order, and do steps simultaneously. For example, when a new alternative is identified more data will be required. Or when the outcomes are summarized, it may become clear that the problem needs to be redefined or new goals established.

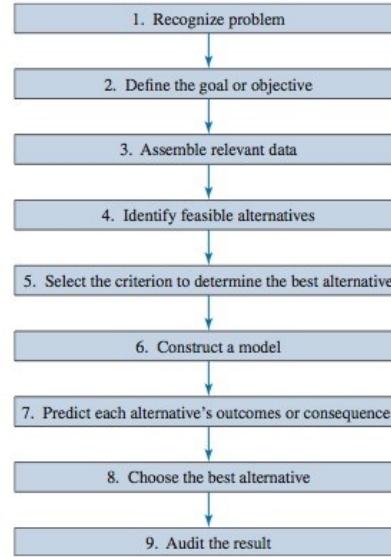
The value of this sequential diagram is to show all the steps that are usually required, and to show them in a logical order. Occasionally we will skip a step entirely. For example, a new alternative may be so clearly superior that it is immediately adopted at Step 4 without further analysis. The following sections describe the elements listed in Figure 1–1.

#### 1. Recognize the Problem

The starting point in rational decision making is recognizing that a problem exists.

Some years ago, for example, it was discovered that several species of ocean fish contained substantial concentrations of mercury. The decision-making process began with this recognition of a problem, and the rush was on to determine what should be done. Research revealed that fish taken from the ocean decades before and preserved in laboratories also contained similar concentrations of mercury. Thus, the problem had existed for a long time but had not been recognized.

**FIGURE 1-1** One possible flowchart of the decision process.



PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 8 CHAPTER 1: MAKING ECONOMIC DECISIONS

---

In typical situations, recognition is obvious and immediate. An auto accident, an overdrawn check, a burned-out motor, an exhausted supply of parts all produce the recognition of a problem. Once we are aware of the problem, we can solve it as best we can. Many firms establish programs for total quality management (TQM) or continuous process improvement (CPI) that are designed to identify problems so that they can be solved.

### ***2. Define the Goal or Objective***

The goal or objective can be an overall goal of a person or a firm. For example, a personal goal could be to lead a pleasant and meaningful life, and a firm's goal is usually to operate profitably. The presence of multiple, conflicting goals is often the foundation of complex problems.

But an objective need not be an overall goal of a business or an individual. It may be quite narrow and specific: "I want to pay off the loan on my car by May," or "The plant must produce 300 golf carts in the next 2 weeks," are more limited objectives. Thus, defining the objective is the act of exactly describing the task or goal.

### ***3. Assemble Relevant Data***

To make a good decision, one must first assemble good information. In addition to all the published information, there is a vast quantity of information that is not written down anywhere but is stored as individuals' knowledge and experience. There is also information that remains ungathered. A question like "How many people in your town would be interested in buying a pair of left-handed scissors?" cannot be answered by examining published data or by asking any one person. Market research or other data gathering would be required to obtain the desired information.

From all this information, what is relevant in a specific decision-making process? Deciding which data are important and which are not may be a complex task. The availability of data further complicates this task. Published data are available immediately at little or no cost; other data are available from specific knowledgeable people; still other data require surveys or research to assemble the information. Some data will be of high quality—that is, precise and accurate, while other data may rely on individual judgment for an estimate.

If there is a published price or a contract, the data may be known exactly. In most cases, the data is uncertain. What will it cost to build the dam? How many vehicles will use the bridge next year and twenty years from now? How fast will a competing firm introduce a competing product? How will demand depend on growth in the economy? Future costs and revenues are uncertain, and the range of likely values should be part of assembling relevant data.

The problem's time horizon is part of the data that must be assembled. How long will the building or equipment last? How long will it be needed? Will it be scrapped, sold, or shifted to another use? In some cases, such as for a road or a tunnel, the life may be centuries with regular maintenance and occasional rebuilding. A shorter time period, such as 50 years, may be chosen as the problem's time horizon, so that decisions can be based on more reliable data.

In engineering decision making, an important source of data is a firm's own accounting system. These data must be examined quite carefully. Accounting data focuses on past

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

information, and engineering judgment must often be applied to estimate current and future values. For example, accounting records can show the past cost of buying computers, but engineering judgment is required to estimate the future cost of buying computers.

Financial and cost accounting are designed to show accounting values and the flow of money—specifically **costs** and **benefits**—in a company's operations. When costs are directly related to specific operations, there is no difficulty; but there are other costs that are not related to specific operations. These indirect costs, or **overhead**, are usually allocated to a company's operations and products by some arbitrary method. The results are generally satisfactory for cost-accounting purposes but may be unreliable for use in economic analysis.

To create a meaningful economic analysis, we must determine the *true* differences between alternatives, which might require some adjustment of cost-accounting data. The following example illustrates this situation.

### EXAMPLE 1-1

A firm's printing department charges the other departments for its services to recover its monthly costs. For example, the charge to run 30,000 copies for the shipping department is:

Direct labor	\$228
Materials and supplies	294
Overhead costs	271
Cost to shipping department	\$793

The shipping department checks with a commercial printer, which would print the same 30,000 copies for \$688. The shipping department foreman wants to have the work done externally. The in-house printing department objects to this. The general manager has asked you to recommend what should be done.

### SOLUTION

Some of the printing department's output reveals the firm's costs, prices, and other financial information. Thus, the printing department is necessary to prevent disclosing such information to people outside the firm. The firm cannot switch to an outside printer for all needs.

A review of the cost-accounting charges reveals nothing unusual. The charges made by the printing department cover direct labor, materials and supplies, and overhead. The allocation of indirect costs is a customary procedure in cost-accounting systems (see Chapter 17 for more). It can be misleading for decision making, as the following discussion indicates.

The shipping department would reduce its cost by \$105 ( $= \$793 - \$688$ ) by using the outside printer. In that case, how much would the printing department's costs decline, and which solution is better for the firm?

1. **Direct Labor.** If the printing department had been working overtime, then the overtime could be reduced or eliminated. But, assuming no overtime, how much would the saving be? It seems unlikely that an employee could be fired or even put on less than a 40-hour

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 10 CHAPTER 1: MAKING ECONOMIC DECISIONS

work week. Thus, although there might be a \$228 saving, it is much more likely that there will be no reduction in direct labor.

2. *Materials and Supplies.* There would be a \$294 saving in materials and supplies.
3. *Allocated Overhead Costs.* There will be no reduction in the printing department's monthly overhead, and in fact the firm will incur \$50 of additional expenses in purchasing and accounting for processing the purchase order, invoice, and payment.

The firm will save \$294 in materials and supplies, will spend \$50 in purchasing and accounting, and may or may not save \$228 in direct labor if the printing department no longer does the shipping department work. The maximum saving would be  $294 + 228 - 50 = \$472$ . Either value of \$294 or \$472 is less than the \$688 the firm would pay the outside printer. The shipping department should not be allowed to send its printing to the outside printer.

Gathering cost data presents other difficulties. One way to look at the financial consequences—costs and benefits—of various alternatives is as follows.

- *Market Consequences.* These consequences have an established price in the marketplace. We can quickly determine raw material prices, machinery costs, labor costs, and so forth.
- *Extra-Market Consequences.* There are other items that are not directly priced in the marketplace. But by indirect means, a price may be assigned to these items. (Economists call these prices **shadow prices**.) Examples might be the cost of an employee injury or the value to employees of going from a 5-day to a 4-day, 40-hour week.
- *Intangible Consequences.* Numerical economic analysis probably never fully describes the real differences between alternatives. The tendency to leave out consequences that do not have a significant impact on the analysis itself, or on the conversion of the final decision into actual money, is difficult to resolve or eliminate. How does one evaluate the potential loss of workers' jobs due to automation? What is the value of landscaping around a factory? These and a variety of other consequences may be left out of the numerical calculations, but they must be considered in reaching a decision.

### 4. Identify Feasible Alternatives

One must keep in mind that unless the best alternative is considered, the result will always be suboptimal.<sup>1</sup> Two types of alternatives are sometimes ignored. First, in many situations a do-nothing alternative is feasible. This may be the "Let's keep doing what we are now doing," or the "Let's not spend any money on that problem" alternative. Second, there are often feasible (but unglamorous) alternatives, such as "Patch it up and keep it running for another year before replacing it."

<sup>1</sup>A group of techniques called value analysis or **value engineering** is used to examine past decisions and current trade-offs in designing alternatives.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

There is no way to ensure that the best alternative is among the alternatives being considered. One should try to be certain that all conventional alternatives have been listed and then make a serious effort to suggest innovative solutions. Sometimes a group of people considering alternatives in an innovative atmosphere—**brainstorming**—can be helpful. Even impractical alternatives may lead to a better possibility. The payoff from a new, innovative alternative can far exceed the value of carefully selecting between the existing alternatives.

Any good listing of alternatives will produce both practical and impractical alternatives. It would be of little use, however, to seriously consider an alternative that cannot be adopted. An alternative may be infeasible for a variety of reasons. For example, it might violate fundamental laws of science, require resources or materials that cannot be obtained, violate ethics standards, or conflict with the firm's strategy. Only the feasible alternatives are retained for further analysis.

### **5. Select the Criterion to Determine the Best Alternative**

The central task of decision making is choosing from among alternatives. How is the choice made? Logically, to choose the best alternative, we must define what we mean by *best*. There must be a **criterion**, or set of **criteria**, to judge which alternative is best. Now, we recognize that *best* is on one end of the following relative subjective judgment:

Worst	Bad	Fair	Good	Better	Best
-------	-----	------	------	--------	------

*relative subjective judgment spectrum*

Since we are dealing in *relative terms*, rather than *absolute values*, the choice will be the alternative that is relatively the most desirable. Consider a driver found guilty of speeding and given the alternatives of a \$475 fine or 3 days in jail. In absolute terms, neither alternative is good. But on a relative basis, one simply makes the best of a bad situation.

There may be an unlimited number of ways that one might judge the various alternatives. Several possible criteria are:

- Create the least disturbance to the environment.
- Improve the distribution of wealth among people.
- Minimize the expenditure of money.
- Ensure that the benefits to those who gain from the decision are greater than the losses of those who are harmed by the decision.<sup>2</sup>
- Minimize the time to accomplish the goal or objective.
- Minimize unemployment.
- Maximize profit.

<sup>2</sup>This is the Kaldor criterion.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 12 CHAPTER 1: MAKING ECONOMIC DECISIONS

---

Selecting the criterion for choosing the best alternative will not be easy if different groups support different criteria and desire different alternatives. The criteria may conflict. For example, minimizing unemployment may require increasing the expenditure of money. Or minimizing environmental disturbance may conflict with minimizing time to complete the project. The disagreement between management and labor in collective bargaining (concerning wages and conditions of employment) reflects a disagreement over the objective and the criterion for selecting the best alternative.

The last criterion—maximize profit—is the one normally selected in engineering decision making. When this criterion is used, all problems fall into one of three categories: neither input nor output fixed, fixed input, or fixed output.

**Neither input nor output fixed.** The first category is the general and most common situation, in which the amount of money or other inputs is not fixed, nor is the amount of benefits or other outputs. For example:

- A consulting engineering firm has more work available than it can handle. It is considering paying the staff for working evenings to increase the amount of design work it can perform.
- One might wish to invest in the stock market, but the total cost of the investment is not fixed, and neither are the benefits.
- A car battery is needed. Batteries are available at different prices, and although each will provide the energy to start the vehicle, the useful lives of the various products are different.

What should be the criterion in this category? Obviously, to be as economically efficient as possible, we must maximize the difference between the return from the investment (benefits) and the cost of the investment. Since the difference between the benefits and the costs is simply profit, a businessperson would define this criterion as **maximizing profit**.

**Fixed input.** The amount of money or other input resources (like labor, materials, or equipment) is fixed. The objective is to effectively utilize them. For economic efficiency, the appropriate criterion is to maximize the benefits or other outputs. For example:

- A project engineer has a budget of \$350,000 to overhaul a portion of a petroleum refinery.
- You have \$300 to buy clothes for the start of school.

**Fixed output.** There is a fixed task (or other output objectives or results) to be accomplished. The economically efficient criterion for a situation of fixed output is to minimize the costs or other inputs. For example:

- A civil engineering firm has been given the job of surveying a tract of land and preparing a “record of survey” map.
- You must choose the most cost-effective design for a roof, an engine, a circuit, or other component.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

For the three categories, the proper economic criteria are:

Category	Economic Criterion
Neither input nor output fixed	Maximize profit = value of outputs – cost of inputs.
Fixed input	Maximize the benefits or other outputs.
Fixed output	Minimize the costs or other inputs.

#### **6. Constructing the Model**

At some point in the decision-making process, the various elements must be brought together. The *objective*, *relevant data*, *feasible alternatives*, and *selection criterion* must be merged. For example, if one were considering borrowing money to pay for a car, there is a mathematical relationship between the loan's variables: amount, interest rate, duration, and monthly payment.

Constructing the interrelationships between the decision-making elements is frequently called **model building** or **constructing the model**. To an engineer, modeling may be a scaled *physical representation* of the real thing or system or a *mathematical equation*, or set of equations, describing the desired interrelationships. In economic decision making, the model is usually mathematical.

In modeling, it is helpful to represent only that part of the real system that is important to the problem at hand. Thus, the mathematical model of the student capacity of a classroom might be

$$\text{Capacity} = \frac{lw}{k}$$

where  $l$  = length of classroom, in meters

$w$  = width of classroom, in meters

$k$  = classroom arrangement factor

The equation for student capacity of a classroom is a very simple model; yet it may be adequate for the problem being solved.

#### **7. Predicting the Outcomes for Each Alternative**

A model and the data are used to predict the outcomes for each feasible alternative. As was suggested earlier, each alternative might produce a variety of outcomes. Selecting a motorcycle, rather than a bicycle, for example, may make the fuel supplier happy, the neighbors unhappy, the environment more polluted, and one's savings account smaller. But, to avoid unnecessary complications, we assume that decision making is based on a single criterion for measuring the relative attractiveness of the various alternatives. As will be shown in Example 1–5, one can devise a single composite criterion that is the weighted average of several different choice criteria.

To choose the best alternative, the outcomes for each alternative must be stated in a *comparable* way. Usually the consequences of each alternative are stated in terms of money, that is, in the form of costs and benefits. **Resolving the consequences** is done with

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

#### 14 CHAPTER 1: MAKING ECONOMIC DECISIONS

---

all monetary and nonmonetary consequences. The consequences can also be categorized as follows:

Market consequences—where there are established market prices available

Extra-market consequences—no direct market prices, so priced indirectly

Intangible consequences—valued by judgment, not monetary prices.

In the initial problems we will examine, the costs and benefits occur over a short time period and can be considered as occurring at the same time. In other situations the various costs and benefits take place in a longer time period. The result may be costs at one point in time followed by periodic benefits. We will resolve these in the next chapter into a *cash flow diagram* to show the timing of the various costs and benefits.

For these longer-term problems, the most common error is to assume that the current situation will be unchanged for the do-nothing alternative. In reality if a firm does nothing new then current profits will shrink or vanish as a result of the actions of competitors and the expectations of customers. As another example, traffic congestion normally increases over the years as the number of vehicles increases—doing nothing does not imply that the situation will not change.

#### **8. Choosing the Best Alternative**

Earlier we said that choosing the best alternative may be simply a matter of determining which alternative best meets the selection criterion. But the solutions to most problems in economics have market consequences, extra-market consequences, and intangible consequences. Since the intangible consequences of possible alternatives are left out of the numerical calculations, they should be introduced into the decision-making process at this point. The alternative to be chosen is the one that best meets the choice criterion after considering both the numerical consequences and the consequences not included in the monetary analysis.

During the decision-making process certain feasible alternatives are eliminated because they are dominated by other, better alternatives. For example, shopping for a computer on-line may allow you to buy a custom-configured computer for less money than a stock computer in a local store. Buying at the local store is feasible, but dominated. While eliminating dominated alternatives makes the decision-making process more efficient, there are dangers.

Having examined the structure of the decision-making process, we can ask, When is a decision made, and who makes it? If one person performs *all* the steps in decision making, then she is the decision maker. When she makes the decision is less clear. The selection of the feasible alternatives may be the key item, with the rest of the analysis a methodical process leading to the inevitable decision. We can see that the decision may be drastically affected, or even predetermined, by the way in which the decision-making process is carried out. This is illustrated by the following example.

Liz, a young engineer, was assigned to develop an analysis of additional equipment needed for the machine shop. The single criterion for selection was that the equipment should be the most economical, considering both initial costs and future operating costs. A little investigation by Liz revealed three practical alternatives:

1. A new specialized lathe
2. A new general-purpose lathe
3. A rebuilt lathe available from a used-equipment dealer

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

A preliminary analysis indicated that the rebuilt lathe would be the most economical. Liz did not like the idea of buying a rebuilt lathe, so she decided to discard that alternative. She prepared a two-alternative analysis that showed that the general-purpose lathe was more economical than the specialized lathe. She presented this completed analysis to her manager. The manager assumed that the two alternatives presented were the best of all feasible alternatives, and he approved Liz's recommendation.

At this point we should ask: Who was the decision maker, Liz or her manager? Although the manager signed his name at the bottom of the economic analysis worksheets to authorize purchasing the general-purpose lathe, he was merely authorizing what already had been made inevitable, and thus he was not the decision maker. Rather Liz had made the key decision when she decided to discard the most economical alternative from further consideration. The result was a decision to buy the better of the two *less economically desirable* alternatives.

### 9. Audit the Results

An audit of the results is a comparison of what happened against the predictions. Do the results of a decision analysis reasonably agree with its projections? If a new machine tool was purchased to save labor and improve quality, did it? If so, the economic analysis seems to be accurate. If the savings are not being obtained, what was overlooked? The audit may help ensure that projected operating advantages are ultimately obtained. On the other hand, the economic analysis projections may have been unduly optimistic. We want to know this, too, so that the mistakes that led to the inaccurate projection are not repeated. Finally, an effective way to promote *realistic* economic analysis calculations is for all people involved to know that there *will* be an audit of the results!

## ETHICS

You must be mindful of the ethical dimensions of engineering economic analysis and of your engineering and personal decisions. This text can only introduce the topic, and we hope that you will explore this subject in greater depth.

Ethics can be described variously; however, a common thread is the concept of distinguishing between right and wrong in decision making. Ethics includes establishing systems of beliefs and moral obligations, defining values and fairness, and determining duty and guidelines for conduct. Ethics and ethical behavior are important because when people behave in ethical ways, individuals and society benefit. Usually the ethical choice is reasonably clear, but there are ethical dilemmas with conflicting moral imperatives. Consider an overloaded and sinking lifeboat. If one or more passengers are thrown into the shark-infested waters, the entire lifeboat can be saved. How is the decision made, how is it implemented, and who if anyone goes into the water? Ethical dilemmas also exist in engineering and business contexts. Ethical decision making requires the understanding of problem context, choices, and associated outcomes.

### Ethical Dimensions in Engineering Decision Making

Ethical issues can arise at every stage of the integrated process for engineering decision making described in Figure 1–1. Ethics is such an important part of professional and business decision making that ethical codes or standards of conduct exist for professional

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 16 CHAPTER 1: MAKING ECONOMIC DECISIONS

engineering societies, small and large organizations, and every individual. Written professional codes are common in the engineering profession, serving as a reference basis for new engineers and a basis for legal action against engineers who violate the code.

One such example is the Code of Ethics of the National Society of Professional Engineers (NSPE). Here is NSPE's fundamental canon of ethical behavior for engineering:

Engineers, in the fulfillment of their professional duties, shall:

- Hold paramount the safety, health and welfare of the public.
- Perform services only in areas of their competence.
- Issue public statements only in an objective and truthful manner.
- Act for each employer or client as faithful agents or trustees.
- Avoid deceptive acts.
- Conduct themselves honorably, responsibly, ethically and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

In addition, NSPE has Rules of Practice and Professional Obligations for its members. Most engineering organizations have similar written standards. For all engineers difficulties arise when they act contrary to these written or internal codes, and opportunities for ethical dilemmas are found throughout the engineering decision-making process. Table 1-1 provides examples of ethical lapses that can occur at each step of the decision-making process.

**TABLE 1-1 Example Ethical Lapses by Decision Process Step**

Decision Process Step	Example Ethical Lapses
1. Recognize the problem	<ul style="list-style-type: none"><li>• "Looking the other way," that is, not to recognize the problem—due to bribes or perhaps fear of retribution for being a "whistle-blower"</li></ul>
2. Define the goal or objective	<ul style="list-style-type: none"><li>• Favoring one group of stakeholders by focusing on their objective for a project</li></ul>
3. Assemble relevant data	<ul style="list-style-type: none"><li>• Using faulty or inaccurate data</li></ul>
4. Identify feasible alternatives	<ul style="list-style-type: none"><li>• Leaving legitimate alternatives out of consideration</li></ul>
5. Select the criterion to determine the best alternative	<ul style="list-style-type: none"><li>• Considering only monetary consequences when there are other significant consequences</li></ul>
6. Construct a model	<ul style="list-style-type: none"><li>• Using a short horizon that favors one alternative over another</li></ul>
7. Predict each alternative's outcomes or consequences	<ul style="list-style-type: none"><li>• Using optimistic estimates for one alternative and pessimistic ones for the other alternatives</li></ul>
8. Choose the best alternative	<ul style="list-style-type: none"><li>• Choosing an inferior alternative, one that is unsafe, adds unnecessary cost for the end user, harms the environment, etc.</li></ul>
9. Audit the result	<ul style="list-style-type: none"><li>• Hiding past mistakes</li></ul>

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

Ethical dilemmas for engineers may arise in connection with engineering economic analysis in many situations. Following are examples of a few of these.

#### **Gaining Knowledge and Building Trust Versus Favors for Influence**

Consider these three situations:

- The salesman for a supplier of HVAC (heating, ventilating, and air conditioning) equipment invites a mechanical engineer and spouse to come along on the company jet for a users' conference at a vacation resort.
- Same salesman and same engineer, but the invitation is for a day of golfing at an exclusive club.
- Same salesman invites the same engineer to lunch.

In each case the salesman is trying to "get the order," and there is likely to be some mix of business—discussing specifications—and pleasure. The first case, which brings up the largest ethical questions, also has the largest business justification. This is the opportunity to meet other users of the products and see displays of the product line. Often, firms and government agencies have strict guidelines that dictate behavior in these situations.

#### **Cost, Quality, and Functionality**

One of the most common conflicts in the conceptual and design phase involves the trade-offs between cost, quality, and required functionality. Most modern products entail many thousands of decisions by designers that ultimately affect the cost and quality for the end user.

- A designer in an engineering consulting firm knows that a "gold-plated" solution would be very profitable for his firm (and for his bonus). This solution may also provide excellent reliability and require little maintenance cost.
- Engineers in the consumer durables division of a multinational company know that by using lower-quality connectors, fasteners, and subcomponents they can lower costs and improve the firm's market position. In addition, they know that these design elements have only a limited usable life, and the firm's most profitable business is repairs and extended warranties.

#### **The Environment We Live In**

Projects for transportation and power generation typically must consider environmental impacts in their design and in deciding whether the project should be done in any form. Who incurs the costs for the project, and who receives the benefits? Many other engineering products are designed to promote recycling, reduce energy usage, and reduce pollution. Ethical issues can be particularly difficult because there are often stakeholders with opposing viewpoints, and some of the data may be uncertain and hard to quantify.

**Green engineering** design includes the effects of environmental impacts and gives consideration to life-cycle sustainability issues. In this context, **societal costs** are the

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 18 CHAPTER 1: MAKING ECONOMIC DECISIONS

---

negative impacts of a project or product. Reducing these societal costs is the goal of environmental fees and regulation. For the opening vignette on electric vehicles, examples of the social costs of combustion-engine automobiles include tailpipe emissions and the negative environmental impact of mining, refining, and distributing gasoline/diesel fuels. Other examples of difficult choices include:

- Protecting the habitat of an endangered species versus flood control projects that protect people, animals, and structures.
- Meeting the needs for electrical power when all choices have some negative environmental impacts:
  - Hydroelectric—reservoir covers land and habitat
  - Coal—underground mining can be dangerous, open-pit mining damages habitat, and burning the coal can cause air pollution
  - Nuclear—disposal of radioactive waste
  - Fuel oil—air pollution and economic dependence
  - Wind—visual pollution of wind farms; birds killed by whirling blades
- Determining standards for pollutants: Is 1 part per million OK, or is 1 part per billion needed?

### *Safety and Cost*

Some of the most common and most difficult ethical dilemmas involve trade-offs between safety and cost. If a product is “too safe,” then it will be too expensive, and it will not be used. Also sometimes the cost is incurred by one party and the risk by another.

- Should the oil platform be designed for the 100-year, 500-year, or 1000-year hurricane?
- Should the auto manufacturer add run-flat tires, stability control, side-cushion airbags, and rear-seat airbags to every car?
- Should a given product design go through another month of testing?
- Are stainless steel valves required, or is it economically better to use less corrosion-resistant valves and replace them more frequently?

### *Emerging Issues and “Solutions”*

Breaches of the law by corporate leaders of Enron, Tyco, and other firms have led to attempts to prevent, limit, and expose financial wrongdoing within corporations. One part of the solution has been the Sarbanes-Oxley Act of 2002, which imposed requirements on firm executives and auditing accounting firms, as well as penalties for violations.

Globalization is another area of increasing importance for ethical considerations. One reason is that different ethical expectations prevail in the world’s various countries and regions. A second reason is that jobs may be moved to another country based on differences in cost, productivity, environmental standards, and so on. What may be viewed as a

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

sweatshop from a U.S. perspective may be viewed as a wonderful opportunity to support many families from the perspective of a less developed nation.

### Importance of Ethics in Engineering and Engineering Economy

Many times engineers and firms try to act ethically, but mistakes are made—the data were wrong, the design was changed, or the operating environment was different than expected. In other cases, a choice was made between expediency (profit) and ethics. For example, some engineers and managers within VW chose to manipulate diesel vehicle performance during emission testing. As of 2016, estimates of international costs to VW exceeded \$38B. The firm and management are driven by the need to make a profit, and they expect the engineer to identify when safety will be compromised.

Ethics in engineering economic analysis focuses on how well and how honestly the decision-making process is conducted—the data, method of analysis, recommendations, and follow-up. The first step in avoiding problems is to recognize that ethical issues exist and to make them an explicit part of your decision-making process.

As a student, you've no doubt heard discussions about cheating on exams, plagiarism on written reports, violating university drinking and drug use policies, accepting one job while continuing to interview for others, and selling student sports tickets to nonstudents. You've made your own decisions about your behavior, and you've established patterns of behavior.

You should know that your professors care deeply about the ethical decisions you make at school. Your ethical habits there form a foundation for the character of your work and personal behavior after graduation.

Often recent engineering graduates are asked, "What is the most important thing you want from your supervisor?" The most common response is mentoring and opportunities to learn and progress. When employees with 5, 15, 25, or more years of experience are asked the same question, the most common response at all experience levels is *integrity*. This is what your subordinates, peers, and superiors will expect and value the most from you. Integrity is the foundation for long-term career success.

## ENGINEERING DECISION MAKING FOR CURRENT COSTS

Some of the easiest forms of engineering decision making deal with problems of alternative *designs, methods, or materials*. If results of the decision occur in a very short period of time, one can quickly add up the costs and benefits for each alternative. Then, using the suitable economic criterion, the best alternative can be identified. Three example problems illustrate these situations.

### EXAMPLE 1-2

A concrete aggregate mix must contain at least 31% sand by volume for proper batching. One source of material, which has 25% sand and 75% coarse aggregate, sells for \$3 per cubic meter ( $m^3$ ). Another source, which has 40% sand and 60% coarse aggregate, sells for \$4.40/ $m^3$ . Determine the least cost per cubic meter of blended aggregates.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 20 CHAPTER 1: MAKING ECONOMIC DECISIONS

### SOLUTION

The least cost of blended aggregates results from using just enough higher-cost material to meet the minimum 31% proportion of sand.

Let  $x$  = Portion of blended aggregates from \$3.00/m<sup>3</sup> source

$1 - x$  = Portion of blended aggregates from \$4.40/m<sup>3</sup> source

#### Sand Balance

$$x(0.25) + (1 - x)(0.40) = 0.31$$

$$-.15x = -.09 \Rightarrow x = 0.60$$

The 60%/40% blended aggregate will cost

$$0.60(\$3.00) + 0.40(\$4.40) = 1.80 + 1.76 = \$3.56/\text{m}^3$$

### EXAMPLE 1-3

A machine part is manufactured at a unit cost of 40¢ for material and 15¢ for direct labor. An investment of \$500,000 in tooling is required. The order calls for 3 million pieces. Halfway through the order, managers learn that a new method of manufacture can be put into effect that will reduce the unit costs to 34¢ for material and 10¢ for direct labor—but it will require \$100,000 for additional tooling. This tooling will not be useful for future orders. Other costs are allocated at 2.5 times the direct labor cost. What, if anything, should be done?

### SOLUTION

Since there is only one way to handle the first 1.5 million pieces, our problem concerns only the second half of the order. While the arithmetic can easily be done on a calculator, in the real world problems like these are usually done using a spreadsheet. This allows easy substitution of “better” numbers for the initial estimates and supports **what-if analysis**. The first spreadsheet shows the data entry stage of the problem. These values form the problem’s **data block** (see Appendix A). Note that we want a clear, compact table, so columns of these values are alternated with calculation columns for our two alternatives.

	A	B	C	D	E
1	1,500,000	Number of pieces			
2	2.5	Other cost \$/direct labor \$			
3		A: Present Method	B: New method		
4	Costs	unit	total	unit	total
5	Material	0.4		0.34	
6	Direct labor	0.15		0.1	
7	Other				
8	Added tooling			\$100,000	

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

The second spreadsheet includes column F to show the formulas for the cells in column E. Note that the formulas in cells E5, E6, and C6 are all copied from cell C5. Because the C5 formula was originally written as =B5\*\$A\$1, the **absolute address** of \$A\$1 does not change when copied. Note: Appendix A discusses how to efficiently do this and other examples of addressing alternatives that maximize the flexibility of copying formulas.

The most efficient way to create the formulas is to:

- Write the formula for C5 as = "click on B5" \* "click on A1" "F4 or Apple T to toggle to \$A\$1"
- Copy it to C6
- Write the formula for C7 (including an absolute address)
- Copy C5:C7 to E5:E7

Select E5:E9 and click on the "sum" formula button. This can be copied to C9.

	A	B	C	D	E	F
1	1,500,000	Number of pieces				
2	2.5	Other cost S/direct labor \$				
3		A: Present Method	B: New method			
4	Costs	unit	total	unit	total	
5	Material	0.4	\$600,000	0.34	\$510,000	=D5*\$A\$1
6	Direct labor	0.15	\$225,000	0.1	\$150,000	=D6*\$A\$1
7	Other		\$562,500		\$375,000	=E6*\$A\$2
8	Added tooling			\$100,000	\$100,000	
9	Total		\$1,387,500		\$1,135,000	
10			Possible savings		\$252,500	

Looking at the results, we can see that much of the total \$252,500 in savings comes from the reduced value of other costs. Thus, before making a final decision, one should closely examine the *other costs* to see whether they do, in fact, vary as the *direct labor cost* varies. Assuming they do, the decision would be to change the manufacturing method.

#### EXAMPLE 1-4

In the design of a cold-storage warehouse, the specifications call for a maximum heat transfer through the warehouse walls of 30,000 joules per hour per square meter of wall when there is a 30°C temperature difference between the inside surface and the outside surface of the insulation. The two insulation materials being considered are as follows:

Insulation Material	Cost per Cubic Meter	Conductivity (J·m/m <sup>2</sup> ·°C·hr)
Rock wool	\$12.50	140
Foamed insulation	14.00	110

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 22 CHAPTER 1: MAKING ECONOMIC DECISIONS

The basic equation for heat conduction through a wall is

$$Q = \frac{K(\Delta T)}{L}$$

where  $Q$  = heat transfer, in J/hr/m<sup>2</sup> of wall

$K$  = conductivity, in J-m/m<sup>2</sup>-°C-hr

$\Delta T$  = difference in temperature between the two surfaces, in °C

$L$  = thickness of insulating material, in meters

Which insulation material should be selected?

### SOLUTION

Two steps are needed to solve the problem. First, the required thickness of each of the available materials must be calculated. Then, since the problem is one of providing a fixed output (heat transfer through the wall limited to a fixed maximum amount), the criterion is to minimize the input (cost).

#### Required Insulation Thickness

$$\text{Rock wool} \quad 30,000 = \frac{140(30)}{L}, \quad L = 0.14 \text{ m}$$

$$\text{Foamed insulation} \quad 30,000 = \frac{110(30)}{L}, \quad L = 0.11 \text{ m}$$

#### Cost of Insulation per Square Meter of Wall

Unit cost = Cost/m<sup>3</sup> × Insulation thickness, in meters

$$\text{Rock wool} \quad \text{Unit cost} = \$12.50 \times 0.14 \text{ m} = \$1.75/\text{m}^2$$

$$\text{Foamed insulation} \quad \text{Unit cost} = \$14.00 \times 0.11 \text{ m} = \$1.54/\text{m}^2$$

The foamed insulation is the lesser-cost alternative. However, there is a constraint that must be considered. How thick is the available wall space?

This constraint suggests a better problem definition—how should the available wall thickness be used? A better decision criterion that looks at total costs (not just insulation costs) requires engineering economy and the time value of money to decide what the maximum heat transfer should be. What is the cost of more insulation versus the cost of cooling the warehouse over its life?

From a broader perspective energy use and emissions are both environmental issues. Thus any government regulations on insulation standards should consider costs and benefits from a societal perspective, and not just from the firm's.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

### WHEN MORE THAN ECONOMICS IS INVOLVED

Consider the moderately complex problem of which job offer to accept. Example 1–5 shows a simple way to address this **multiple-objective** problem. These models should:

- Include all important objectives.
- Weight the relative importance of the objectives.
- Select an objective and rate all alternatives. Then repeat for all objectives.
- Disqualify alternatives that do not meet the minimum performance requirements of one or more objectives.

This example uses simple 0 to 10 rating scales. Since the weights are stated as percentages (or their decimal equivalents), the totals show how close to a perfect 10 each alternative is.

Multi-objective models do much more than calculate a measure of each alternative's attractiveness. Constructing the model enforces a level of clarity about the importance of each objective and how each alternative performs. The model also communicates those assumptions and estimates to others, who may suggest changes. Since there may be multiple iterations in arriving at the final model, spreadsheets are particularly effective here.

Examples in later chapters will show how to convert numeric values to a 0 to 10 point scale. For those who want to search the web for additional examples, this is an *additive* model, because the scores are added together. This is also a *compensatory* model, because strength on one objective can compensate for a weakness on another objective.

Example 1–5 is linked to an individual's financial and life decision making. But this situation can also be viewed from the firm's or government agency's perspective. Which applicant(s) should receive offer(s) of employment? In that case, evaluations from multiple individuals might be combined for the overall total.

#### EXAMPLE 1–5

A senior undergraduate has received four job offers, but the salary on one is unacceptably low. The other three offers have been rated on three criteria or objectives, with a scale of 0 = barely acceptable and 10 = outstanding! *Job* considers the salary relative to the local cost of housing and the job itself. The latter was hard to estimate because it considered the initial job, growth prospects, the firm, and the industry. *Family* is important to this senior, but the senior wanted to live the right distance away—neither too close nor too far. *Livability* covers the senior's desires on community size, climate, commuting time, and overall political balance. The senior weighted the importance of the three criteria at 50%, 30%, and 20% respectively. Given the following table of ratings, which job offer should the senior accept?

Offer	Job	Family	Livability
A	4	9	5
B	8	5	4
C	6	3	8

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

**24 CHAPTER 1: MAKING ECONOMIC DECISIONS****SOLUTION**

None of the job offers is ideal in any respect, and each has some aspect that is less attractive than the other offers. Comparing the total values, offer B is the most attractive. This table is the result of many hours of thinking, and more model iterations would not be useful. Thus offer B should be accepted.

There are many ways to write the formula, but the easiest uses the function SUMPRODUCT. As shown, the function uses a fixed address for the weights, so the formula for offer A can be copied for the other offers.

	A	B	C	D	E
1		Job	Family	Livability	
2	Weight	50%	30%	20%	
3	Offer				Total
4	A	4	9	5	5.7
5	B	8	5	4	6.3
6	C	6	3	8	5.5
7					
8					=SUMPRODUCT(\$B\$2:\$D\$2,B4:D4)

**SUMMARY****Classifying Problems**

Many problems are simple and thus easy to solve. Others are of intermediate difficulty and need considerable thought and/or calculation to properly evaluate. These intermediate problems tend to have a substantial economic component and to require economic analysis. Complex problems, on the other hand, often contain people elements, along with political and economic components. Economic analysis is still very important, but the best alternative must be selected by considering all criteria—not just economics.

**The Decision-Making Process**

Rational decision making uses a logical method of analysis to select the best alternative from among the feasible alternatives. The following nine steps can be followed sequentially, but decision makers often repeat some steps, undertake some simultaneously, and skip others altogether.

1. Recognize the problem.
2. Define the goal or objective: What is the task?
3. Assemble relevant data: What are the facts? Is more data needed, and is it worth more than the cost to obtain it?
4. Identify feasible alternatives.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

**Summary 25**

5. Select the criterion for choosing the best alternative: possible criteria include political, economic, environmental, and social. The single criterion may be a composite of several different criteria.
6. *Mathematically model* the various interrelationships.
7. Predict the outcomes for each alternative.
8. Choose the best alternative.
9. Audit the results.

Engineering decision making refers to solving substantial engineering problems in which economic aspects dominate and economic efficiency is the criterion for choosing from among possible alternatives. It is a particular case of the general decision-making process. Some of the unusual aspects of engineering decision making are as follows:

1. Cost-accounting systems, while an important source of cost data, contain allocations of indirect costs that may be inappropriate for use in economic analysis.
2. The various consequences—costs and benefits—of an alternative may be of three types:
  - (a) Market consequences—there are established market prices.
  - (b) Extra-market consequences—there are no direct market prices, but prices can be assigned by indirect means.
  - (c) Intangible consequences—valued by judgment, not by monetary prices.
3. The economic criteria for judging alternatives can be reduced to three cases:
  - (a) When neither input nor output is fixed: maximize profit, which equals the difference between benefits and costs.
  - (b) For fixed input: maximize benefits or other outputs.
  - (c) For fixed output: minimize costs or other inputs.The first case states the general rule from which both the second and third cases may be derived.
4. To choose among the alternatives, the market consequences and extra-market consequences are organized into a cash flow diagram. We will see in Chapter 3 that engineering economic calculations can be used to compare differing cash flows. These outcomes are compared against the selection criterion. From this comparison *plus* the consequences not included in the monetary analysis, the best alternative is selected.
5. An essential part of engineering decision making is the postaudit of results. This step helps to ensure that projected benefits are obtained and to encourage realistic estimates in analyses.

### **Importance of Ethics in Engineering and Engineering Economy**

One of the gravest responsibilities of an engineer is protecting the safety of the public, clients, and/or employees. In addition, the engineer can be responsible for the economic performance of projects and products on which bonuses and jobs depend. Not surprisingly, in this environment one of the most valued personal characteristics is integrity.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

**26 CHAPTER 1: MAKING ECONOMIC DECISIONS****Decision Making with Current Costs**

When all costs and benefits occur within a brief period of time, the time value of money is not a consideration. We still must use the criteria of maximizing profit, minimizing cost, or maximizing benefits.

**PROBLEMS**

Key to icons: **A** = Answer in Appendix E; **G** = Green, which may include environmental ethics; **E** = Ethics other than green.

Many end-of-chapter problems are primarily numerical, but others require more discussion—especially the case studies and questions linked to ethics. Section C in Chapter 2 of *Cases in Engineering Economy 2<sup>nd</sup>* on the student website may be helpful for the more discussion-oriented questions.

**Decision Making**

- 1-1** Think back over your past academic year and decisions that you made. List a few decisions that you would classify as simple, intermediate, and complex. What did you learn about your decision making by the way you approached these decisions?
- 1-2** Some of the following problems would be suitable for solution by engineering economic analysis. Which ones are they?
- (a) Would it be better to buy a hybrid car?
  - (b) Should an automatic machine be purchased to replace three workers now doing a task by hand?
  - (c) Would it be wise to enroll for an early morning class to avoid traveling during the morning traffic rush hours and thus improve fuel efficiency?
  - (d) Would you be better off if you changed your major?
  - (e) Should you work more and borrow less even if it delays your graduation?
  - (f) Should a corporate farm build waste mitigation ponds or continue using a contracted service?
- 1-3** Which one of the following problems is *most* suitable for analysis by engineering economic analysis?
- (a) One of your two favorite sandwich shops offers a 10-punch loyalty card and the other does not. Where should you stop today?
  - (b) A woman has \$150,000 in a bank checking account that pays no interest. She can either invest it immediately at a desirable interest rate

or wait a week and know that she will be able to obtain an interest rate that is 0.15% higher.

**(c)** Joe backed his car into a tree, damaging the fender. He has car insurance that will pay for the fender repair. But if he files a claim for payment, they may charge him more for car insurance in the future.

**1-4** If you have \$1000 and could make the right decisions, how long would it take you to become a millionaire? Explain briefly what you would do.

**1-5** One can find books on "How I Made My Millions" in any bookstore. In some cases the authors seem to plan to make millions by selling that book. Do you think this is ethical? How would you lay out the factors to analyze this question?

**1-6** The owner of a small machine shop has just lost one of his larger customers. The solution to his problem, he says, is to fire three machinists to balance his workforce with his current level of business. The owner says it is a simple problem with a simple solution.

- (a) The three machinists disagree. Why?
- (b) What are the ethical factors from the perspective of the owner and the workers?

**1-7** Designing a chair for use in a classroom seems like a simple task. Make an argument for how this can be considered a complex decision and include environmental and ethical factors in your argument.

**1-8** Toward the end of the twentieth century, the U.S. government wanted to save money by closing a small portion of its domestic military installations. While many people agreed that saving money was a desirable goal, people in areas potentially affected by a closing soon reacted negatively. Congress finally selected a panel whose task was to develop a list of installations to close, with the legislation specifying that Congress could not alter the list. Since the goal was to save money, why was this problem so hard to solve?

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## Problems 27

- 1-9** The college bookstore has put pads of engineering computation paper on sale at half price. What is the minimum and maximum number of pads you might buy during the sale? Explain.
- 1-10** Consider the five situations described. Which one situation seems most suitable for solution by economic analysis?
- John has met two college students that interest him. Beth is a music major who is lots of fun to be with. Alice is a fellow engineering student, but she does not like to party. John wonders what to do.
  - You drive periodically to the post office to send or pick up packages. The parking meters cost \$1 for 15 minutes—about the time required for medium length lines. If parking fines cost \$20, do you put money in the meter or not?
  - The cost of car insurance varies widely from company to company. Should you check with several insurance companies when your policy comes up for renewal?
  - There is a special local sales tax ("sin tax") on a variety of things that the town council would like to remove from local distribution. As a result, a store has opened up just outside the town and offers an abundance of these specific items at prices about 30% less than is charged in town. Should you shop there?
  - One of your professors mentioned that you have a poor attendance record in her class. You wonder whether to drop the course now or wait to see how you do on the first midterm exam. Unfortunately, the course is required for graduation.
- 1-11** A car manufacturer is considering locating an assembly plant in your region.  
**G**
  - List two simple, two intermediate, and two complex problems associated with this proposal.
  - What is NIMBY? Does this come into play for this complex decision?

**1-12** Consider the following situations. Which ones appear to represent rational decision making? Explain.

  - Joe's best friend has decided to become a civil engineer, so Joe has decided that he will also become a civil engineer.
  - Jill needs to get to the university from her home. She bought a car and now drives to the university each day. When Jim asks her why she didn't

buy a bicycle instead, she replies, "Gee, I never thought of that."

**c** Don needed a wrench to replace the spark plugs in his car. He went to the local automobile supply store and bought the cheapest one they had. It broke before he had finished replacing all the spark plugs in his car.

**1-13** Identify possible objectives for NASA. For your favorite of these, how should alternative plans to achieve the objective be evaluated?

**E** **1-14** Suppose you have just 2 hours to determine how many students would be interested in a highway trash pickup event. Give a step-by-step outline of how you would proceed.

**1-15** A college student determines he will have only half of the cost for university housing available for the coming year. List five feasible alternatives.

**E** **1-16** Think about the issue of implementing renewable energies in the U.S. Research/find an instance where a decision was made to implement without adequately looking at other potential alternative solutions.

**1-17** If there are only two alternatives available and both are unpleasant and undesirable, what should you do?

**A** **1-18** The three economic criteria for choosing the best alternative are maximize the difference between output and input, minimize input, and maximize output. For each of the following situations, what is the correct economic criterion?
  - A manufacturer can sell up to two full shifts of production at a fixed price. As production is increased, unit costs increase as a result of overtime pay and so forth. The manufacturer's criterion should be \_\_\_\_\_.
  - An architectural and engineering firm has been awarded the contract to design a wharf with fixed performance specifications for a petroleum company. The engineering firm's criterion for its client should be \_\_\_\_\_.
  - An off-campus bookstore is choosing its target used/new split for next year. Its criterion should be \_\_\_\_\_.
  - At an auction of antiques, a bidder for a particular porcelain statue would be trying to \_\_\_\_\_.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



## 28 CHAPTER 1: MAKING ECONOMIC DECISIONS

**1-19** As in Problem 1-18, state the correct economic criterion for each of the following situations.

- (a) The engineering student club raffled off a donated car; tickets sold for \$5 each or three for \$10. When the students were selling tickets, they noted that many people had trouble deciding whether to buy one or three tickets. This indicates the buyers' criterion was \_\_\_\_\_.
- (b) A student organization bought a soft-drink machine and then had to decide whether to charge 75¢, \$1, or \$1.25 per drink. The organization recognized that the number of soft drinks sold would depend on the price charged. Eventually the decision was made to charge \$1. The criterion was \_\_\_\_\_.
- (c) In many cities, grocery stores find that their sales are much greater on days when they advertise special bargains. However, the advertised special prices do not appear to increase the total physical volume of groceries sold by a store. This leads us to conclude that many shoppers' criterion is \_\_\_\_\_.
- (d) A recently graduated engineer has decided to return to school in the evenings to obtain a master's degree. He feels it should be accomplished in a manner that will allow him the maximum amount of time for his regular day job plus time for recreation. In working for the degree, he will \_\_\_\_\_.

**1-20** Seven criteria are given in the chapter for judging which is the best alternative. After reviewing the list, devise three additional criteria that might be used.

**1-21** Suppose you are assigned the task of determining the route of a new highway through an older section of town. The highway will require that many older homes be either relocated or torn down. Two possible criteria that might be used in deciding exactly where to locate the highway are:

- (a) Ensure that there are benefits to those who gain from the decision and that no one is harmed by the decision.
- (b) Ensure that the benefits to those who gain from the decision are greater than the losses of those who are harmed by the decision.

Which criterion will you select to use in determining the route of the highway? Explain.

**1-22** For the project in Problem 1-21, identify the major costs and benefits. Which are market consequences, which are extra-market consequences, and which are intangible consequences?

**1-23** You must fly to another city for a Friday meeting. If you stay until Sunday morning your ticket will be \$250, rather than \$800. Hotel costs are \$200 per night. Compare the economics with reasonable assumptions for meal expenses. What intangible consequences may dominate the decision?

**1-24** In the fall, Jay Thompson decided to live in a university dormitory. He signed a dorm contract under which he was obligated to pay the room rent for the full college year. One clause stated that if he moved out during the year, he could sell his dorm contract to another student who would move into the dormitory as his replacement. The dorm cost was \$5000 for the two semesters, which Jay had already paid.

A month after he moved into the dorm, he decided he would prefer to live in an apartment. That week, after some searching for a replacement to fulfill his dorm contract, Jay had two offers. One student offered to move in immediately and to pay Jay \$300 per month for the eight remaining months of the school year. A second student offered to move in the second semester and pay \$2500 to Jay.

Jay estimates his food cost per month is \$500 if he lives in the dorm and \$450 if he lives in an apartment with three other students. His share of the apartment rent and utilities will be \$400 per month. Assume each semester is  $4\frac{1}{2}$  months long. Disregard the small differences in the timing of the disbursements or receipts.

- (a) What are the three alternatives available to Jay?
- (b) Evaluate the cost for each of the alternatives.
- (c) What do you recommend that Jay do?

**1-25** An electric motor on a conveyor burned out. The foreman told the plant manager that the motor had to be replaced. The foreman said that there were no alternatives and asked for authorization to order the replacement. In this situation, is any decision making taking place? If so, who is making the decision(s)?

**1-26** A farmer must decide what combination of seed, water, fertilizer, and pest control will be most profitable and environmentally conscious for the coming

G

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## Problems 29

year. The local agricultural college did a study of this farmer's situation and prepared the following table.

Plan	Direct Cost/Acre	Extra-market Cost/Acre	Income/Acre
A	\$750	\$150	\$1200
B	800	450	1400
C	1000	250	1500
D	1300	200	1650

The last page of the college's study was torn off, and hence the farmer is not sure which plan the agricultural college recommends. Which plan should the farmer adopt considering:

- (a) only the direct costs,
- (b) both the direct and extra-market costs?

- 1-27** Identify the alternatives, outcomes, criteria, and process for the selection of your college major. Did you make the best choice for you?
- 1-28** Describe a major problem you must address in the next two years. Use the techniques of this chapter to structure the problem and recommend a decision.
- 1-29** Apply the steps of the decision-making process from this chapter and develop plans to achieve one each of your 5-year, 10-year, and 25-year goals.

- 1-30** One strategy for solving a complex problem is to break it into a group of less complex problems and then find solutions to the smaller problems. The result is the solution of the complex problem. Give an example in which this strategy will work. Then give another example in which this strategy will not work.

#### Ethics

- E** **1-31** When you make professional decisions involving investments in engineering projects, what criteria will you use?  
*Contributed by D. P. Loucks, Cornell University*
- E** **1-32** What are ethics?  
*Contributed by D. P. Loucks, Cornell University*
- E** **1-33** A student accepts a full-time job in November, but a better job comes before graduation in May. What are the ethical dimensions of the student's decision? Would you take the better job? Why or why not?
- E** **1-34** Suppose you are an engineer working in a private engineering firm and you are asked to sign

documents verifying information that you believe is not true. You like your work and your colleagues in the firm, and your family depends on your income. What criteria can you use to guide your decision regarding this issue?

*Contributed by D. P. Loucks, Cornell University*

- E** **1-35** Find the ethics code for the professional society of your major.
- (a) Summarize its key points.
  - (b) What are its similarities and differences in comparison to NSPE's ethics code?
- E** **1-36** Use a personal example or a published source to analyze what went wrong or right with respect to ethics at the assigned stage(s) of the decision-making process.
- (a) Recognize problem.
  - (b) Define the goal or objective.
  - (c) Assemble relevant data.
  - (d) Identify feasible alternatives.
  - (e) Select the criterion for determining the best alternative.
  - (f) Construct a model.
  - (g) Predict each alternative's outcomes or consequences.
  - (h) Choose the best alternative.
  - (i) Audit the result.

*For problems 1-37 to 1-49:*

- (a) What ethical issues can arise—personal, business, and/or environmental?
- (b) Use local, state, national, or international news sources to identify an example situation.
- (c) Summarize and analyze the ethical issues, including relevant laws, regulations, codes, and processes.

- G** **1-37** Municipal assemblies, school boards, transit boards, and municipal utility boards are responsible for public infrastructure, such as roads and schools. Especially for this responsibility, engineers bring skills, knowledge, and perspectives that can improve public decision making. Often the public role is a part-time one; engineers that fulfill it will also have full-time jobs as employees or owners of engineering firms.

- G** **1-38** Increasing population and congestion often are addressed through road improvement projects. These may pit the interests of homeowners and business owners in the project area against the interests of

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



### 30 CHAPTER 1: MAKING ECONOMIC DECISIONS

people traveling through the improvement project and environmental activists.

**1-39 E** Stadiums for professional sports teams often involve some level of municipal support. Some businesses and home owners benefit, while others do not; some pay more in taxes, while others pay less.

**1-40 E** Economic development and redevelopment often require significant acreage that is assembled by acquiring smaller parcels. Sometimes this is done through simple purchase, but the property of an "unwilling seller" can be acquired through the process of eminent domain.

**1-41 E** State governments use a variety of advisory and regulatory bodies. Example responsibilities include oversight of professional engineering licensing and the pricing and operation of regulated utilities. Often the public role is a part-time one, and engineers that fulfill it will also have full-time jobs as employees or owners of engineering firms.

**1-42 E** Many engineers work in state governments, and some are in high-profile roles as legislators, department commissioners, and so on. Many of these individuals move between working in the private and public sectors.

**1-43 E** In the U.S., regulation of payment for overtime hours is done at the state and federal levels. Because most engineering work is accomplished through projects, it is common for engineers to be asked or required to work overtime as projects near deadlines. Sometimes the overtime is paid at time and a half, sometimes as straight time, and sometimes the engineer's salary is treated as a constant even when overtime occurs. In a particular firm, engineering interns, engineers, and partners may be treated the same or differently.

**1-44 E** At the federal government level, the economic consequences of decisions can be very large. Firms hire lobbyists, legislators may focus on their constituents, and advocacy organizations promote their own agendas. In addition, sometimes some of the players are willing to be unethical.

**1-45 E** At both state and federal levels, legislators can be involved in "pork barrel" funding of capital projects. These projects may even bypass the economic evaluation using engineering economy that normal projects are subject to.

**1-46 G** At the international level, a common ethics issue important to engineering and project justification is that of environmental regulation. Often different nations have different environmental standards, and a project or product might be built in either location.

**1-47 E** At the international level, a common ethics issue important to engineering and project justification is that of worker health and safety. Often different nations have different standards, and a project or product could be built in either location.

**1-48 G** At the international level, engineering decisions are critical in matters of "sustainable development," a common ethics issue.

**1-49 E** At the international level, questions arise about whether the U.S. ban on bribery is practical or appropriate. In some countries government workers are very poorly paid, and they can support their families only by accepting money to "grease" a process.

**1-50** In the 1970s the Ford Motor Company sold its sub-compact Pinto model with known design defects. In particular, the gas tank's design and location led to rupture, leaks, and explosion in low-speed, rear-impact collisions. Fifty-nine people burned to death in Pinto accidents. In a cost-benefit analysis weighing the cost of fixing the defects (\$11 per vehicle) versus the firm's potential liability for lawsuits on behalf of accident victims, Ford had placed the value of a human life at \$200,000. Ford eventually recalled 1.4 million Pintos to fix the gas tank problem for a cost of \$30 million to \$40 million. In addition the automaker ultimately paid out millions more in liability settlements and incurred substantial damage to its reputation.

(a) Critique Ford's actions from the perspective of the NSPE Code of Ethics.

(b) One well-known ethical theory, utilitarianism, suggests that an act is ethically justified if it results in the "greatest good for the greatest number" when all relevant stakeholders are considered. Did Ford's cost-benefit analysis validly apply this theory?

(c) What should engineers do when the product they are designing has a known safety defect with an inexpensive remedy?

*Contributed by Joseph R. Herkert, North Carolina State University*

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## Problems 31

- 1-51** The decision-making process used to launch the Challenger shuttle has been extensively analyzed. Briefly summarize the key institutional groups, how the decision was made, and the ethical principles that may have been compromised.

- 1-52** One of the elements in the flooding of New Orleans during Hurricane Katrina was the failure of some of the levees that protected the city. Outline the role that ethical failures by engineers may have played in this situation. How could society structure decision making to minimize such failures?

- G 1-53** Hurricane Sandy's flooding of New York City highlighted the vulnerability of coastal cities to extreme weather events, which are becoming more common. Strengthening and protecting infrastructure and the environment before the fact can be very expensive—and perhaps never needed. The possible availability of after-the-fact disaster aid can distort economic perspectives. Why is minimizing economic, environmental, and human costs related to extreme weather such a difficult problem for public infrastructure?

**Current Costs**

- A 1-54** A manufacturing firm has received a contract to assemble 1000 units of test equipment in the next year. The firm must decide how to organize its assembly operation. Skilled workers, at \$33 per hour each, can individually assemble the test equipment in 2.6 hours per unit. Alternatively, teams of four less skilled workers (at \$19 per hour each) can assemble a unit in one hour. Which approach is more economical?

- G 1-55** Two manufacturing firm, located in cities 90 miles apart, both send their trucks four times a week to the other city full of cargo and return empty. Each driver costs \$275 per day with benefits (the round trip takes all day) and each firm has truck operating costs of \$1.20 a mile.

- How much could each firm save weekly if each sent its truck twice a week and hauled the other firm's cargo on the return trip?
- What would the savings be if there was a \$0.20 per mile emissions tax on all business truck travel?

- A 1-56** An oil company is considering adding a more environmentally friendly grade of fuel at its service stations. To do this, an additional 3000-gallon tank must be buried at each station. Discussions with

tank fabricators indicate that the least expensive tank would be cylindrical with minimum surface area. What size tank should be ordered?

- 1-57** Cathy Gwynn for a class project is analyzing a "Quick Shop" grocery store. The store emphasizes quick service, a limited assortment of grocery items, and higher prices. Cathy wants to see if the store hours (currently 0600 to 0100) can be changed to make the store more profitable.

Time Period	Daily Sales in the Time Period
0600–0700	\$ 40
0700–0800	80
0800–0900	120
0900–1200	400
1200–1500	500
1500–1800	600
1800–2100	800
2100–2200	200
2200–2300	60
2300–2400	120
2400–0100	40

The cost of the groceries sold averages 70% of sales. The incremental cost to keep the store open, including the clerk's wage and other operating costs, is \$22 per hour. To maximize profit, when should the store be opened, and when should it be closed?

- A 1-58** Willie Lohmann travels from city to city for business. Every other year he buys a used car for about \$15,000. The dealer allows about \$8000 as a trade-in allowance, so Willie spends \$7000 every other year for a car. Willie keeps accurate records of his expenses, which total  $32.3\text{¢}$  per mile. Willie's employer has two plans to reimburse car expenses:

- Actual expenses: Willie will receive all his operating expenses, and \$3500 each year for the car's decline in value.
- Standard mileage rate: Willie will receive  $56.5\text{¢}$  per mile but no operating expenses and no depreciation allowance.

If Willie travels 18,000 miles per year, which method gives him the larger reimbursement? At what

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



## 32 CHAPTER 1: MAKING ECONOMIC DECISIONS

annual mileage do the two methods give the same reimbursement?

- 1-59** If you rent a car, you can (1) return it with a full gas tank, (2) return it without filling it and pay \$5.45/gallon, or (3) accept a fixed price of \$50 for gas. The local price is \$3.95/gallon for gasoline, and you expect this car to get 28 miles per gallon. The car has a 16-gallon tank. What choice should you make if you expect to drive:

- (a) 150 miles?
- (b) 300 miles?
- (c) 400 miles?
- (d) How do your answers change if stopping at the filling station takes 15 minutes and your time is worth \$12/hr?

- A 1-60** Your car gets 24 miles per gallon (mpg) at 60 miles per hour (mph) and 20 mpg at 70 mph. At what speed should you make a 500-mile trip:

- (a) If gas costs \$3 per gallon and your time is worth \$18/hr?
- (b) If gas costs \$4 per gallon and your time is worth \$12/hr?
- (c) If gas costs \$5 per gallon and your time is worth \$9/hr?
- (d) Build a spreadsheet (see Appendix A) to calculate the total trip cost for gas costs of \$2, \$3, \$4, and \$5 and values of time of \$6, \$9, \$12, \$15, and \$18 per hour. Do two tables: one at 60 mph and one at 70 mph.

- G 1-61** A city needs to choose area rubbish disposal areas.

*Area A:* A gravel pit has a capacity of 16 million cubic meters. Owing to the possibility of high groundwater the Regional Water Pollution Control Board has restricted the lower 2 million cubic meters of fill to inert material only (earth, concrete, asphalt, paving, brick, etc.). This must be purchased and hauled to this area for the bottom fill.

*Area B:* Capacity is 14 million cubic meters. For 20% of the city, the haul is the same distance as for Area A. The round-trip haul is 5 miles longer for 60% of the city, and 2 miles shorter for 20% of the city.

Assume the following conditions:

- Cost of inert material placed in Area A will be \$9.40/m<sup>3</sup>.
- Average speed of trucks from last pickup to disposal site is 25 miles per hour.
- The rubbish truck and a two-man crew will cost \$210 per hour.
- Truck capacity of 4½ tons per load or 20 m<sup>3</sup>.
- Sufficient cover material is available at all areas.

Which of the sites do you recommend?

- 1-62** A firm is planning to manufacture a new product. As the selling price is increased, the quantity that can be sold decreases. Numerically the sales department estimates:

$$P = \$350 - 0.2Q$$

where  $P$  = selling price per unit

$Q$  = quantity sold per year

On the other hand, management estimates that the average unit cost of manufacturing and selling the product will decrease as the quantity sold increases. They estimate

$$C = \$40Q + \$20,000$$

where  $C$  = cost to produce and sell  $Q$  per year

The firm's management wishes to maximize profit. What quantity should the decision makers plan to produce and sell each year and what profit will be earned?

- 1-63** The vegetable buyer for a group of grocery stores has decided to sell packages of sprouted grain in the vegetable section of the stores. The product is perishable, and any remaining unsold after one week in the store is discarded. The supplier will deliver the packages to the stores, arrange them in the display space, and remove and dispose of any old packages. The price the supplier will charge the stores depends on the size of the total weekly order for all the stores.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## Problems 33

Weekly Order	Price per Package
Less than 1000 packages	70¢
1000–1499	56
1500–1999	50
2000 or more	46

The vegetable buyer estimates the quantity that can be sold per week, at various selling prices, as follows:

Selling Price	Packages Sold per Week
\$1.20	300
.90	600
.80	1200
.66	1800
.52	2300

The sprouted grain will be sold at the same price in all the grocery stores.

- (a) How many packages should be purchased per week, and at which of the five prices listed above should they be sold?
- (b) Build a spreadsheet (see Appendix A) to calculate the profit for every combination of selling price and weekly order size.

- 1-64** Jim Jones, a motel owner, noticed that just down the street the "Motel 46" advertises a \$46-per-night room rental rate on its sign. As a result, this competitor has rented all 80 rooms every day by late afternoon. Jim, on the other hand, does not advertise his rate, which is \$64 per night, and he averages only a 68% occupancy of his 50 rooms.

There are a lot of other motels nearby, but only Motel 46 advertises its rate on its sign. (Rates at the other motels vary from \$48 to \$99 per night.) Jim estimates that his actual incremental cost per night

for each room rented, rather than remaining vacant, is \$12. This \$12 pays for all the cleaning, laundering, maintenance, utilities, and so on. Jim believes his eight alternatives are:

Alternative	Resulting Occupancy Rate	
<b>Advertise and Charge</b>		
1	\$45 per night	100%
2	52 per night	94
3	58 per night	80
4	64 per night	66
<b>Do Not Advertise and Charge</b>		
5	\$58 per night	70%
6	64 per night	68
7	72 per night	66
8	78 per night	56

What should Jim do? Show how you reached your conclusion.

- 1-65** A grower estimates that if he picks his apple crop now, he will obtain 1000 boxes of apples, which he can sell at \$30 per box. However, he thinks his crop will increase by 120 boxes of apples for each week he delays picking, but that the price will drop at a rate of \$1.50 per box per week; in addition, he estimates that approximately 20 boxes per week will spoil for each week he delays picking.

- (a) When should he pick his crop to obtain the largest total cash return? How much will he receive for his crop at that time?
- (b) Build a spreadsheet (see Appendix A) to calculate the profit for 0, 1, 2, ..., 6 weeks.

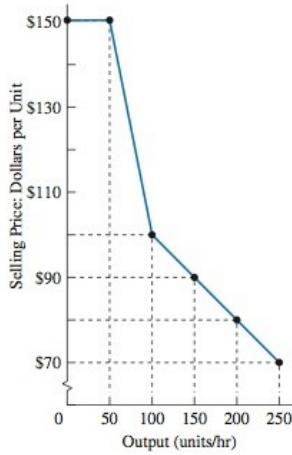
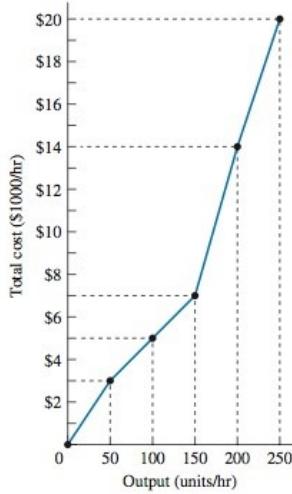
- 1-66** On her first engineering job, Joy Hayes was given the responsibility of determining the production rate for

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



### 34 CHAPTER 1: MAKING ECONOMIC DECISIONS

a new product. She has assembled the data presented in the graphs. Note that costs are in \$1000s.



(a) Select an appropriate economic criterion and estimate the production rate based upon it.

(b) Joy's boss told Joy: "I want you to maximize output with minimum input." Joy wonders if it is possible to meet her boss's criterion. What would you tell her?

#### Multiple Objectives

1-67 Use the data in Example 1-5.

(a) What is the total score for each offer if the three objectives have the same weight?

(b) Holding livability's weight constant, how important does family have to be for offer A to be the best choice? Remember that the weights must sum to 1.

(c) Holding family's weight constant, how important does livability have to be for offer C to be the best choice?

1-68 A graduating senior has been accepted by three universities for an M.S. in engineering. Two criteria have been identified. The first is the program and university's academic ranking. The second is the cost. A third criteria of location was initially considered, but then the student recognized that it is only for about a year, and applications were only made to acceptable schools. The student is currently enrolled in the first university, which is rated as a 5 for academic rank and a 10 for cost. The second is a larger out-of-state public university, which is rated as an 8 for academic rank and a 6 for cost. The third is a prestigious private school, which is rated as a 10 academically and a 3 for its higher cost.

(a) What is the total score for each school if the two objectives have the same weight?

(b) If academic rank has a weight of 75%, what is the total score for each school?

#### Minicases

1-69 Pick a decision involving multiple objectives that you must make. Estimate each objective's weighted importance, rate the alternative choices on each objective, and develop the totals for a model like Example 1-5.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

Problems **35**

- G** **1-70** Green engineering is a design construct that explicitly considers environmental and sustainability factors within the design process. It seeks to promote responsible use of limited resources, and to produce environmentally ethical and safe engineering products, goods, and services. Using the web, find two lists of principles that have been suggested by different groups.

- (a) Write a short paragraph on each list of principles that describes the who, when, and why of their formation.  
(b) Compare and contrast the two lists. Which do you think is best and why? Is there anything that you see is missing from both lists?

**CASES**

The following cases from *Cases in Engineering Economy* ([www.oup.com/us/newnan](http://www.oup.com/us/newnan)) are suggested as matched with this chapter.

**CASE 1** **New Office Equipment**

Student develops requirements for new copier machines with little given data. Organizational thinking required.

**CASE 2** **Budgeting Issues**

Strategies for a group's operating budget request. One focus is ethics.



PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## CHAPTER

## 2

## ESTIMATING ENGINEERING COSTS AND BENEFITS



### LightTUBE

The Tullahoma Utilities Board (TUB) installed a \$3.1 million Automated Metering Information System in its full service area in Tennessee. The process uses special meters, each equipped with a radio transmitter. They collect information on water and electric usage at residences and businesses, and then forward the information to collectors mounted on nearby poles. The usage information is then relayed using LightTUBE, the utility's fiber optics network, eliminating the need for employees to physically read utility meters. It provides not only real-time monitoring capability for residential and commercial users but also the ability to monitor the entire system's health and loads.

The change to the automated system allows TUB customers to better understand and actively manage their consumption patterns. Customers are able to access a portal to examine their use habits and reduce their bills by doing household tasks that require more electricity during off-peak hours. The new system also reduces personnel costs, provides better information on leak detection, outage management, and any theft of service.

After the system was economically justified and built for automated metering, TUB found that there was significant unused bandwidth on the fiber optic network. It now operates the LightTUBE network throughout the City of Tullahoma to provide Fiber to the Premise (FTTP), producing high quality video, high speed Internet, and telephone services. LightTUBE provides voice, video, and data services over 250 miles of Fiber Optic cable. TUB serves nearly 10,000 residential, commercial, and industrial customers.

This "hybrid" business model crosses traditional boundaries associated with public utilities, phone companies, and Internet/cable TV providers. Traditionally, public utilities

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



operate with a set profit margin, which allows them to minimize the cost to the customer while maintaining operational and future growth requirements. Most cable TV, Internet, and phone companies operate on a private sector business model in which profits are maximized. ■■■

*Contributed by James Simonton, University of Tennessee Space Institute*

### QUESTIONS TO CONSIDER

1. How do you estimate the cost—and ultimately the benefit—of such a “hybrid” operation with the traditional utility segment of the business (water, electricity, and sewage) working to minimize cost, while the LightTUBE segment works to maximize profit?
2. Discuss the ethical issues related to using public funds for an operation that could be seen as a for profit venture that is in competition with private sector companies.
3. In general, private sector project cost estimating may seem the same as public sector estimating. The real difference in this case would be the ability of TUB to consider both what it collects and consumer surplus value. How would a project that blurs the line between the two be handled?
4. When performing an economic analysis of “hybrid” projects, what tools would be appropriate to establish the benefit for justification purposes?

### After Completing This Chapter...

*The student should be able to:*

- Define and use costs and benefits of many types including: average, external, fixed, incremental, internal, marginal, opportunity, sunk, and variable costs and benefits.
- Provide specific examples of how and why these concepts are important.
- Define engineering estimating for costs and benefits.
- Explain the three types of engineering estimate, as well as common difficulties encountered in making engineering estimates.
- Use several common mathematical estimating models in estimating costs and benefits.
- Discuss the impact of the *learning curve* on estimates.
- State the relationship between cost estimating and estimating project benefits.
- Draw *cash flow diagrams* to show project costs and benefits.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

### 38 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS

#### Key Words

average cost	incremental cost	recurring cost
book cost	internal cost	rough estimate
breakeven	learning curve	segmenting model
cash cost	life-cycle cost	semidetailed estimate
cash flow diagram	marginal cost	sunk cost
cost and price index	nonrecurring cost	triangulation
detailed estimate	opportunity cost	variable cost
estimation by analogy	per-unit model	work breakdown structure
external cost	power-sizing model	
fixed cost	profit-loss breakeven chart	

Estimating the engineering costs and benefits of proposed decision choices is “where the numbers come from.” In this chapter we describe cost and benefit concepts and methods. These include fixed and variable costs, marginal and average costs, sunk and opportunity costs, recurring and nonrecurring benefits and costs, incremental cash costs, book costs, and life-cycle costs. We then describe the various types of estimates and difficulties sometimes encountered. The models that are described include unit factor, segmenting, cost indexes, power sizing, triangulation, and learning curves. The chapter discusses estimating benefits, developing cash flow diagrams, and drawing these diagrams with spreadsheets.

#### FIXED, VARIABLE, MARGINAL, AND AVERAGE COSTS

**Fixed** costs are constant or unchanging regardless of the level of output or activity. In contrast, **variable** costs depend on the level of output or activity. A **marginal** cost is the variable cost for one more unit, while the **average** cost is the total cost divided by the number of units.

In a production environment, for example, fixed costs, such as those for factory floor space and equipment, remain the same even though production quantity, number of employees, and level of work-in-process may vary. Labor costs are classified as a *variable* cost because they depend on the number of employees and the number of hours they work. Thus *fixed* costs are level or constant regardless of output or activity, and *variable* costs are changing and related to the level of output or activity.

As another example, many universities charge full-time students a fixed cost for 12 to 18 hours and a cost per credit hour for each credit hour over 18. Thus for full-time students who are taking an overload ( $>18$  hours), there is a variable cost that depends on the level of activity, but for most full-time students tuition is a fixed cost.

This example can also be used to distinguish between *marginal* and *average* costs. A marginal cost is the cost of one more unit. This will depend on how many credit hours the student is taking. If currently enrolled for 12 to 17 hours, adding one more is free. The marginal cost of an additional credit hour is \$0. However, for a student taking 18 or more hours, the marginal cost equals the variable cost of one more hour.

To illustrate average costs, suppose the cost of 12 to 18 hours is \$3600 per term and overload credits are \$240/hour. If a student takes 12 hours, the *average* cost is  $\$3600/12 = \$300$  per credit hour. If the student were to take 18 hours, the *average* cost would decrease to  $\$3600/18 = \$200$  per credit hour. If the student takes 21 hours, the

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

**average** cost is \$205.71 per credit hour  $[\$3600 + (3 \times \$240)]/21$ . Average cost is thus calculated by dividing the total cost for all units by the total number of units. Decision makers use **average** cost to attain an overall cost picture of the investment on a per unit basis.

**Marginal** cost is used to decide whether an additional unit should be made, purchased, or enrolled in. For our example full-time student, the marginal cost of another credit is \$0 or \$240 depending on how many credits the student has already signed up for.

### EXAMPLE 2-1

The Federation of Student Societies of Engineering (FeSSE) wants to offer a one-day training course to help students in job hunting and to raise funds. The organizing committee is sure that they can find alumni, local business people, and faculty to provide the training at no charge. Thus the main costs will be for space, meals, handouts, and advertising.

The organizers have classified the costs for room rental, room setup, and advertising as fixed costs. They also have included the meals for the speakers as a fixed cost. Their total of \$225 is pegged to a room that will hold 40 people. So if demand is higher, the fixed costs will also increase.

The variable costs for food and bound handouts will be \$20 per student. The organizing committee believes that \$35 is about the right price to match value to students with their budgets. Since FeSSE has not offered training courses before, they are unsure how many students will reserve seats.

Develop equations for FeSSE's total cost and total revenue, and determine the number of registrations that would be needed for revenue to equal cost.

### SOLUTION

Let  $x$  equal the number of students who sign up. Then,

$$\text{Total cost} = \$225 + \$20x$$

$$\text{Total revenue} = \$35x$$

To find the number of student registrants for revenue to equal cost, we set the equations equal to each other and solve.

$$\text{Total cost} = \text{Total revenue}$$

$$\$225 + \$20x = \$35x$$

$$\$225 = (\$35 - \$20)x$$

$$x = 225/15 = 15 \text{ students}$$

While this example has been defined for a student engineering society, we could just as easily have described this as a training course to be sponsored by a local chapter of a professional technical society. The fixed cost and the revenue would increase by a factor of about 10, while the variable cost would probably double or triple.

If a firm were considering an in-house short course, the cost of the in-house course would be compared with the cost per employee (a variable cost) for enrolling employees in external training.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

#### 40 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS

From Example 2–1 we see how it is possible to calculate total fixed and total variable costs. Furthermore, these values can be combined into a single **total cost** equation as follows:

$$\text{Total cost} = \text{Total fixed cost} + \text{Total variable cost} \quad (2-1)$$

Example 2–1 developed *total cost* and *total revenue* equations to describe a training course proposal. These equations can be used to create what is called a **profit-loss break-even chart** (see Figure 2–1). A plot of revenues against costs for various levels of output (activity) allows one to illustrate a *break-even point* (in terms of costs and revenue) and regions of *profit* and *loss*. These terms can be defined as follows.

**Breakeven point:** The activity level at which total costs are *equal to* the revenue (or savings) generated. This is the level at which one “just breaks even.”

**Profit region:** The variable  $x$  is greater than the breakeven point and total revenue is *greater* than total costs.

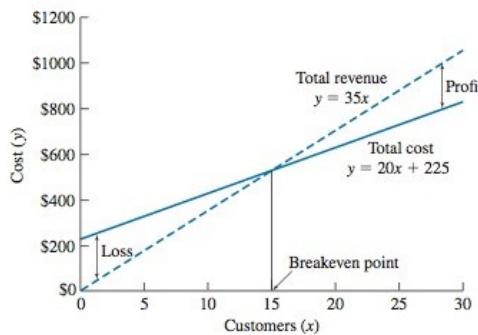
**Loss region:** The variable  $x$  is less than the breakeven point and total revenue is *less* than total costs.

Notice in Figure 2–1 that the *breakeven point* for the number of persons in the training course is 15 people. For more than 15 people, FeSSE will make a profit. If fewer than 15 sign up, there will be a net loss.

The fixed costs of our simple model are in reality *fixed* over a range of values for  $x$ . In Example 2–1, that range was 1 to 40 students. If *zero* students signed up, then the course could be canceled and many of the fixed costs would not be incurred. Some costs such as advertising might already have been spent, and there might be cancellation fees. If more than 40 students signed up, then greater costs for larger rooms or multiple sessions would be incurred. The model is valid only within the range named.

When modeling a specific situation, we often use *linear* variable costs and revenues. However, sometimes the relationship may be nonlinear. For example, employees are often paid at 150% of their hourly rate for overtime hours, so that production levels requiring overtime have higher variable costs. Total cost in Figure 2–2 is a fixed cost of \$3000 plus

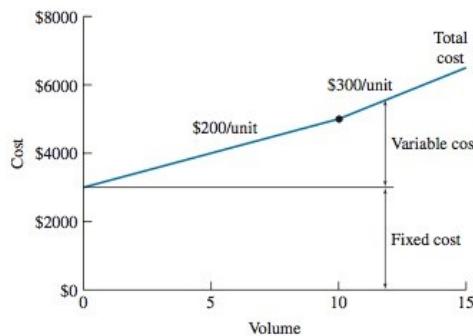
**FIGURE 2–1** Profit-loss break-even chart for Example 2–1.



PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

Fixed, Variable, Marginal, and Average Costs **41**

**FIGURE 2-2** Nonlinear variable costs.



a variable cost of \$200 per unit for straight-time production of up to 10 units and \$300 per unit for overtime production of up to 5 more units.

Figure 2–2 can also be used to illustrate marginal and average costs. At a volume of 5 units the marginal cost is \$200 per unit, while at a volume of 12 units the marginal cost is \$300 per unit. At 5 units the average cost is \$800 per unit, or  $(3000 + 200 \times 5)/5$ . At 12 units the average cost is \$467 per unit, or  $(3000 + 200 \times 10 + 300 \times 2)/12$ .

### Sunk Costs

A **sunk cost** is money already spent as a result of a *past* decision. If only 5 students signed up for the training course in Example 2–1, the advertising costs would be a *sunk cost*.

Sunk costs must be ignored in engineering economic analysis because current decisions cannot change the past. For example, dollars spent last year to purchase new production machinery is money that is *sunk*: the money has already been spent—there is nothing that can be done now to change that action. As engineering economists we deal with present and future opportunities.

Many times it is difficult not to be influenced by sunk costs. Consider 100 shares of stock in XYZ, Inc., purchased for \$15 per share last year. The share price has steadily declined over the past 12 months to a price of \$10 per share today. Current decisions must focus on the \$10 per share that could be attained today (as well as future price potential), not the \$15 per share that was paid last year. The \$15 per share paid last year is a *sunk cost* and has no influence on present opportunities.

As another example, when Regina was a sophomore, she purchased a newest-generation laptop from the college bookstore for \$2000. By the time she graduated, the most anyone would pay her for the computer was \$400 because the newest models were faster and cheaper and had more capabilities. For Regina, the original purchase price was a *sunk cost* that has no influence on her present opportunity to sell the laptop at its current market value of \$400.

When we get to Chapters 11 and 12 on depreciation and income taxes, we will find an exception to the rule of *ignore sunk costs*. When an asset is sold or disposed of, then the

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 42 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS

sunk cost of what was paid for it is important in figuring out how much is owed in taxes. This exception applies only to the after-tax analysis of capital assets.

### Opportunity Costs

An **opportunity cost** is associated with using a resource in one activity instead of another. Every day firms use resources to accomplish various tasks—forklifts transport materials, engineers design products and processes, assembly lines make a product, and parking lots provide parking for employees' vehicles. There are costs for these intended purposes. These are also forgone opportunity costs. For instance, the assembly line could produce a different product, and the parking lot could be rented out, used as a building site, or converted into a small airstrip. Each alternative use would provide some benefit to the firm. These opportunity costs can be included, or they can be addressed by considering that alternative use as another decision-making choice.

As an example, suppose a college student may travel through Europe over the summer break. The student should estimate all the *out-of-pocket* cash costs for air travel, lodging, meals, entertainment, and train passes. Suppose this amounts to \$3000 for a 10-week period—which the student can afford. However, the *true* cost includes not only *out-of-pocket* cash costs but also the *opportunity cost*. By taking the trip, the student is giving up the *opportunity* to earn \$5000 as a summer intern. The student's total cost is thus \$8000.

Remember that opportunity costs are really foregone benefits. When those benefits are not chosen they become costs. The key is to make a choice whereby the *actual* benefits realized outweigh the foregone benefits not chosen. Example 2–2 shows how opportunity costs are part of decisions about idle or under-used assets. What benefit is foregone by keeping the pumps?

### EXAMPLE 2-2

A distributor of electric pumps must decide what to do with a "lot" of old electric pumps purchased 3 years ago. Soon after the distributor purchased the lot, technology advances made the old pumps less desirable to customers. The pumps are becoming obsolescent as they sit in inventory. The pricing manager has the following information.

Distributor's purchase price 3 years ago	\$ 7,000
Distributor's storage costs to date	1,000
Distributor's list price 3 years ago	9,500
Current list price of the same number of new pumps	12,000
Amount offered for the old pumps from a buyer 2 years ago	5,000
Current price the lot of old pumps would bring	3,000

Looking at the data, the pricing manager has concluded that the price should be set at \$8000. This is the money that the firm has "tied up" in the lot of old pumps (\$7000 purchase and \$1000 storage), and it was reasoned that the company should at least recover this cost. Furthermore, the pricing manager has argued that an \$8000 price would be \$1500 less than the list price from 3 years ago, and it would be \$4000 less than what a lot of new pumps would cost (\$12,000 – \$8000). What would be your advice on price?

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

**SOLUTION**

Let's look more closely at each of the data items.

*Distributor's purchase price 3 years ago:* This is a sunk cost that should not be considered in setting the price today.

*Distributor's storage costs to date:* The storage costs for keeping the pumps in inventory are sunk costs; that is, they have been paid. Hence they should not influence the pricing decision.

*Distributor's list price 3 years ago:* If there have been no willing buyers in the past 3 years at this price, it is unlikely that a buyer will emerge in the future. This past list price should have no influence on the current pricing decision.

*Current list price of newer pumps:* Newer pumps now include technology and features that have made the older pumps less valuable. Directly comparing the older pumps to those with new technology is misleading. However, the price of the new pumps and the value of the new features help determine the market value of the old pumps.

*Amount offered by a buyer 2 years ago:* This once was an opportunity. At the time of the offer, the company chose to keep the lot and thus the \$5000 offered became an opportunity cost for keeping the pumps. This amount should not influence the current pricing.

*Current price the lot could bring:* The price a willing buyer in the marketplace offers is called the asset's *market value*. This \$3000 is the relevant opportunity cost for decision making.

From this analysis, it is easy to see the flaw in the pricing manager's reasoning. In an engineering economist analysis we deal only with *today's* and prospective *future* opportunities. It is impossible to go back in time and change decisions that have been made. Thus, the pricing manager should recommend to the distributor that the price be set at the current value that a buyer assigns to the item: \$3000.

**Recurring and Nonrecurring Costs**

**Recurring costs** refer to any expense that is known and anticipated and that occurs at regular intervals. **Nonrecurring costs** are one-of-a-kind expenses that occur at irregular intervals and thus are sometimes difficult to plan for or anticipate from a budgeting perspective.

Examples of recurring costs include those for resurfacing a highway and reshingling a roof. Annual expenses for maintenance and operation are also recurring expenses. Examples of nonrecurring costs include the cost of installing a new machine (including any facility modifications required), the cost of augmenting equipment based on older technology to restore its usefulness, emergency maintenance expenses, and the disposal or close-down costs associated with ending operations.

In engineering economic analyses *recurring costs* are modeled as cash flows that occur at regular intervals (such as every year or every 5 years). Their magnitude can be estimated, and they can be included in the overall analysis. *Nonrecurring costs* can be handled easily

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

#### 44 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS

in our analysis if we are able to anticipate their timing and size. However, this is not always so easy to do.

There are also recurring and nonrecurring benefits. A nonrecurring benefit is a single cash inflow that is anticipated today or in the future, such as the proceeds from selling a house, business, vehicle, or any other asset. Personal examples include a graduation gift, retirement plan lump sum distribution, lottery winnings, or inheritance. Engineering projects are often intended to produce recurring benefits that continue for months, years, or decades. Examples include sales of a new product, faster travel on a safer bridge or highway, attending events at a sports arena or theater, and the services of schools, hospitals, and libraries.

#### Incremental Costs

One of the fundamental principles in engineering economic analysis is that in choosing between competing alternatives, the focus is on the *differences* between those alternatives. This is the concept of **incremental costs**. For instance, one may be interested in comparing two options to lease a vehicle for personal use. The two lease options may have several specifics for which costs are the same. However, there may be incremental costs associated with one option but not with the other. In comparing the two leases, the focus should be on the differences between the alternatives, not on the costs that are the same.

The principle described above for costs also holds true for the incremental benefits of competing alternatives. Consider the case of lease options for the vehicle. The benefits associated with each option were assumed to be the same, and thus we were only interested in the incremental cost differences. However, what if the benefits of the two options were different? In this case your focus would be on the differences of the costs *and the benefits* associated with each option.

#### EXAMPLE 2-3

Philip is choosing between model A (a budget model) and model B (with more features and a higher purchase price). What *incremental costs* would Philip incur if he chose model B instead of the less expensive model A?

Cost Items	Model A	Model B
Purchase price	\$10,000	\$17,500
Installation costs	3,500	5,000
Annual maintenance costs	2,500	750
Annual utility expenses	1,200	2,000
Disposal costs after useful life	700	500

#### SOLUTION

We are interested in the incremental or *extra* costs that are associated with choosing model B instead of model A. To obtain these we subtract model A costs from model B costs for each category (cost item) with the following results.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

Cost Items	(Model B Cost – A Cost)	Incremental Cost of B
Purchase price	17,500 – 10,000	\$7500
Installation costs	5,000 – 3,500	1500
Annual maintenance costs	750 – 2,500	–1750/yr
Annual utility expenses	2,000 – 1,200	800/yr
Disposal costs after useful life	500 – 700	–200

Notice that for the cost categories given, the incremental costs of model *B* are both positive and negative. Positive incremental costs mean that model *B* costs more than model *A*, and negative incremental costs mean that there would be a *savings* (reduction in cost) if model *B* were chosen instead.

As described in the problem statement, because model *B* has more features, the decision must also include incremental benefits offered by those features rather than focussing only on costs.

### Cash Costs Versus Book Costs

A *cash cost* requires the cash transaction of dollars “out of one person’s pocket” into “the pocket of someone else.” When you buy dinner for your friends or make your monthly car payment you are incurring a *cash cost* or *cash flow*. Cash costs and cash flows are the basis for engineering economic analysis.

*Book costs* do not require the transaction of dollars “from one pocket to another.” Rather, *book costs* are cost effects from past decisions that are recorded “in the books” (accounting books) of a firm. In one common book cost, asset depreciation (which we discuss in Chapter 11), the expense paid for a particular business asset is “written off” on a company’s accounting system over a number of periods. Book costs do not ordinarily represent cash flows and thus are not included in engineering economic analysis. One exception to this is the impact of asset depreciation on tax payments—which are cash flows and are included in after-tax analyses.

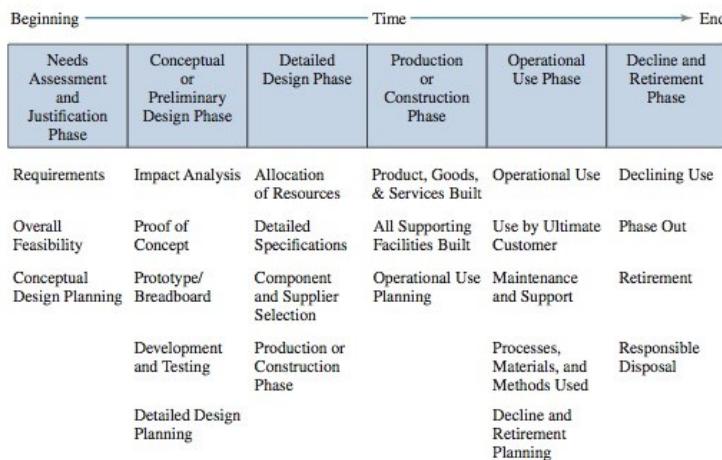
## CONSIDERING ALL COSTS

### Life-Cycle Costs

The products, goods, and services designed by engineers all progress through a *life cycle* very much like the human life cycle. People are conceived, go through a growth phase, reach their peak during maturity, and then gradually decline and expire. The same general pattern holds for products, goods, and services. As with humans, the duration of the different phases, the height of the peak at maturity, and the time of the onset of decline and termination all vary depending on the individual product, good, or service. Figure 2–3 illustrates the typical phases that a product, good, or service progresses through over its life cycle.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

#### 46 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS



**FIGURE 2-3** Typical life cycle for products, goods, and services.

**Life-cycle costing** refers to the concept of designing products, goods, and services with a full and explicit recognition of the associated costs over the various phases of their life cycles. Since *all* costs over the life cycle are considered, this is the correct approach to economic decision making. This contrasts with decisions by firms, agencies, or individuals that only consider acquisition costs.

#### Design Changes and Cost Impacts

Two key concepts in life-cycle costing are that the later design changes are made, the higher the costs, and that decisions made early in the life cycle tend to “lock in” costs and benefits that will be incurred later. Figure 2-4 illustrates how costs are committed early in the product life cycle—nearly 70–90% of all costs are set during the design phases. At the same time, as the figure shows, only 10–30% of cumulative life-cycle costs have been spent. In addition, notice that as life-cycle costs are committed, ultimate life-cycle benefits are set. This highlights the fact that early decisions not only commit resources, but also bound the benefits that will be realized by the product, good, or service.

Figure 2-5 reinforces these concepts by illustrating that later product changes are more costly and that earlier changes are easier (and less costly) to make. When planners try to save money at an early design stage, the result is often poor design that results in change orders during construction and prototype development. These changes, in turn, are more costly than working out a better design would have been.

From Figures 2-4 and 2-5 we see that the time to consider all life-cycle effects and make design changes is during the needs and conceptual/preliminary design phases—before a lot of dollars are committed. Some of the life-cycle effects that engineers should consider at design time include product costs for liability, production, material, testing and quality assurance, and maintenance and warranty.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

**SOLUTION**

*Internal costs* include the site, land, legal, design, administrative, labor, materials, equipment, overhead, and construction categories.

*External (societal) costs* include items such as:

- Water quality costs: impacts on downstream water sources and aquifers
- Community costs: prospective loss of culture, quaintness, community values
- Habitat costs: effect on natural habitat for native/migratory animals
- Viewshed costs: negative impact on the visual sight lines
- Recreational costs: impact on hikers, fishermen, hunters, birdwatchers, and others
- Roadway costs: cost to community to build roads and bridges (developers sometimes share these costs with local, state and federal entities)

**ESTIMATING BENEFITS**

Along with estimating the costs of proposed projects, engineering economists must often also quantify the anticipated benefits. Example benefits include sales from products, revenues from bridge tolls and electric power sales, cost reductions from reduced material or labor costs, less time spent in traffic jams, and reduced risk of flooding. Many engineering projects are undertaken precisely to secure the benefits.

Uncertainty associated with benefit estimates is asymmetric, with broader limits for negative outcomes. Compared to costs, benefits are more likely to be overestimated, thus an example set of limits might be  $(-50\%, +20\%)$ . Another important difference between cost and benefit estimation is that many costs of engineering projects occur in the near future (design and construction), but benefits are further into the future—thus more uncertainty is typical.

The estimation of economic benefits is an important step that should not be overlooked. Most of the models, concepts, and issues that apply in estimating costs also apply to estimating economic benefits.

**THE ESTIMATING PROCESS**

Engineering economic analysis focuses on the future consequences of current decisions. Because these consequences are in the future, usually they must be estimated and cannot be known with certainty. Estimates that may be needed in engineering economic analysis include purchase costs, annual revenue, yearly maintenance, interest rates for investments, annual labor and insurance costs, equipment salvage values, and tax rates.

Estimating is the foundation of economic analysis. As in any analysis procedure, the outcome is only as good as the numbers used to reach the decision. For example, a person who wants to estimate her federal income taxes for a given year could do a very detailed analysis, including social security deductions, retirement savings deductions,

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

---

The Estimating Process **51**

one also moves from less to more accuracy. As a result "significant digits" become more important with detailed estimates as opposed to rough estimates. For example, at the feasibility phase of a large construction project one might estimate costs to the nearest million dollars when looking at several design decisions. However, when contracts are signed after detailed design they will be to the dollar.

When both costs and benefits are estimated for a decision situation one should balance the order of accuracy of each. One should not estimate costs to the nearest \$100 while estimating benefits to the nearest \$1000. Such an imbalance may skew a comparison of the true difference in costs and benefits for a proposed action.

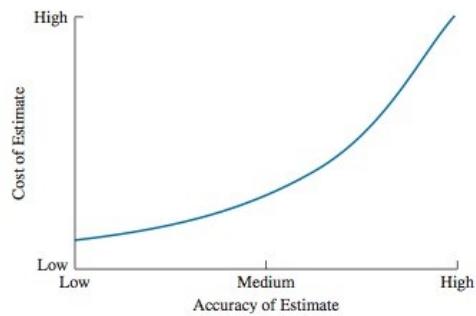
Continuity in perspective in estimating costs and benefits is another important accuracy issue. We had previously mentioned that most people tend to underestimate costs and overestimate benefits in isolation. Care must be taken to balance one's perspective to ensure a consistent approach to quantifying both costs and benefits.

Differences in degree of accuracy and cost-benefit perspective may result in an inaccurate analysis and thus favor one decision choice over another. Care must be taken from the outset to mitigate or eliminate these effects.

#### **Cost Versus Accuracy Trade-off**

Increasing the accuracy of an estimate is not a free thing—it requires added time and resources. Figure 2-7 illustrates the trade-off between accuracy and cost. In general, in engineering economic analysis, the resources spent must be justified by the need for detail in the estimate. From the figure we see that low accuracy estimates should have low costs, and high accuracy estimates will have higher costs. This relationship applies for cost estimates as well as estimating the benefits associated with a prospective choice. As a rule, we should not spend resources developing accuracy that is not warranted by the use and purpose of that estimate. For example, during the project feasibility phase we would not want to use our people, time, and money to develop detailed estimates for infeasible alternatives that will be quickly eliminated from further consideration.

**FIGURE 2-7** Accuracy versus cost trade-off in estimating costs and benefits.



PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 52 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS

---

### Difficulties in Estimation

Estimating is difficult because the future is unknown. With few exceptions (such as with legal contracts) it is difficult to foresee future economic consequences exactly. In this section we discuss several aspects of estimating that make it a difficult task.

#### One-of-a-Kind Estimates

Estimated parameters can be for one-of-a-kind or first-run projects. The first time something is done, it is difficult to estimate both the costs required to design, produce, and maintain a product over its life cycle as well as the anticipated benefits. Consider the projected cost estimates that were developed for the first NASA missions. The U.S. space program initially had no experience with human flight in outer space; thus the development of the cost estimates for design, production, launch, and recovery of the astronauts, flight hardware, and payloads was a “first-time experience.” In addition, estimating the benefits of space exploration, such as advances in aircraft design, database management, surveying, water preservation, telemetry, and forest management (to name a few) were initially difficult to envision. The same is true for any endeavor lacking local or global historical cost data. New products or processes that are unique and fundamentally different make estimating costs difficult.

The good news is that there are very few one-of-a-kind estimates to be made in engineering design and analysis. Nearly all new technologies, products, and processes have “close cousins” that have led to their development. The concept of **estimation by analogy** allows one to use knowledge about well-understood activities to anticipate costs and benefits for new activities. In the 1950s, at the start of the military missile program, aircraft companies drew on their in-depth knowledge of designing and producing aircraft when they bid on missile contracts. As another example, consider the problem of estimating the production labor requirements for a brand new product, *X*. A company may use its labor knowledge about Product *Y*, a similar type of product, to build up the estimate for *X*. Thus, although “first-run” estimates are difficult to make, estimation by analogy can be an effective tool.

#### Time and Effort Available

Our ability to develop engineering estimates is constrained by time and person-power availability. In an ideal world, it would *cost nothing* to use *unlimited resources* over an *extended period of time*. However, reality requires the use of limited resources in fixed intervals of time. Thus for a rough estimate only limited effort is used.

Constraints on time and person-power can make the overall estimating task more difficult. If the estimate does not require as much detail (such as when a rough estimate is the goal), then time and personnel constraints may not be a factor. When detail is necessary and critical (such as in legal contracts), however, requirements must be anticipated and resource use planned.

#### Estimator Expertise

Consider two common expressions: *The past is our greatest teacher*, and *Knowledge is power*. These simple axioms hold true for much of what we encounter during life, and they

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

are true in engineering estimating as well. The more experienced and knowledgeable the engineering estimator is, the less difficult the estimating process will be, the more accurate the estimate will be, the less likely it is that a major error will occur, and the more likely it is that the estimate will be of high quality.

How is experience acquired in industry? One approach is to assign inexperienced engineers relatively small jobs, to create expertise and build familiarity with products and processes. Another strategy used is to pair inexperienced engineers with mentors who have vast technical experience. Technical boards and review meetings conducted to "justify the numbers" also are used to build knowledge and experience. Finally, many firms maintain databases of their past estimates and the costs that were actually incurred.

## ESTIMATING MODELS

This section develops several estimating models that can be used at the rough, semidetailed, or detailed design levels. For rough estimates the models are used with rough data, likewise for detailed design estimates they are used with detailed data.

### Per-Unit Model

The **per-unit model** uses a "per unit" factor, such as cost per square foot, to develop the estimate desired. This is a very simplistic yet useful technique, especially for developing estimates of the rough or order-of-magnitude type. The per-unit model is commonly used in the construction industry. As an example, you may be interested in a new home that is constructed with a certain type of material and has a specific construction style. Based on this information a contractor may quote a cost of \$65 per square foot for your home. If you are interested in a 2000-square-foot floor plan, your cost would thus be:  $2000 \times 65 = \$130,000$ . Other examples where per unit factors are used for both costs and benefits include

- Service cost per customer
- Safety cost per employee
- Gasoline cost per mile
- Cost of defects per batch
- Maintenance cost per window
- Mileage cost per vehicle
- Utility cost per square foot of floor space
- Housing cost per student
- Sales per customer region
- Revenue per acre
- Fee per transaction
- Royalty per book
- Revenue per mile
- Quality improvement per training hour
- Rent per square footage
- Sales increase per representative

It is important to note that the per-unit model does not make allowances for economies of scale (the fact that higher quantities usually cost less on a per-unit basis). In most cases, however, the model can be effective at getting the decision maker "in the ballpark" of likely costs and benefits, and it can be very accurate if accurate data are used.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

**54 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS****EXAMPLE 2-5**

Gaber Land Corp. is evaluating a 4-acre waterfront property for development into rental condominiums. The front 2-acre lot is more expensive to purchase than the rear 2-acre lot, and condo leases closer to the waterfront can be more expensive than those units in the rear. Gaber is considering a design that includes a 32-unit building on each lot. Data includes the following:

**Initial Costs**

- Lot purchase prices: \$400,000/acre front lot, \$100,000/acre back lot
- Legal fees, applications, permits, etc.: \$80,000
- Site clearing and preparation: \$3000/acre
- Paving roadways, parking, curbs, and sidewalks: 25% of total lot at \$40,000/acre
- Construction costs: \$3,000,000 per building

**Recurring Costs**

- Taxes and insurance: \$5000/month per building
- Landscaping: 25% of lot at \$1000/acre/month
- Security: \$1000/building + \$1500/month
- Other costs: \$2000/month

**Revenue (assume 90% annual occupancy)**

- Front lot units: \$2500/unit/month
- Rear lot units: \$1750/unit/month
- Other revenue: \$5000/month

Answer the following: (1) Use the concept of the per-unit model to estimate the total initial cost, annual cost, and annual revenue of this prospective project, and (2) If you made the simplifying assumption of no changes to costs and revenues for 10 years, estimate the profitability of this prospective investment ignoring the effects of money's value over time.

**SOLUTION**

(1) Using the per unit model:

Total Initial Cost	=	
Purchase price: $(400,000 \times 2) + (100,000 \times 2)$	=	\$1,000,000
Legal costs	=	80,000
Site clearing & preparation: $3000 \times 4$	=	12,000
Roadways, etc.: $(.25 \times 4) \times 40,000$	=	40,000
Construction: $3,000,000 \times 2$	=	6,000,000
		\$7,132,000

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

Annual Cost		
Taxes and insurance: $20,000 \times 12$	=	\$240,000
Landscaping: $(.25 \times 4) \times 1000 \times 12$	=	12,000
Security: $(1000 \times 2) + (1500 \times 12)$	=	20,000
Other costs: $2000 \times 12$	=	24,000
		\$296,000

Annual Revenue		
Front lot leases: $(32 \times 2500 \times 12) \times .90$	=	\$864,000
Rear lot leases: $(32 \times 1750 \times 12) \times .90$	=	604,800
Other revenue: $5000 \times 12$	=	60,000
		\$1,528,800

(2) Using the fundamental relationship that Net Profit = Revenue – Costs:

$$\begin{aligned} \text{Net Profit} &= [1,528,800 \times 10] - [7,132,000 + (296,000 \times 10)] \\ &= \$5,196,000 \end{aligned}$$

### Segmenting Model

The **segmenting model** can be described as “divide and conquer.” An estimate is decomposed into its individual components, estimates are made at those lower levels, and then the estimates are aggregated (added) back together. It is much easier to estimate at the lower levels because they are more readily understood. This approach is common in engineering estimating in many applications and for any level of accuracy needed. In estimating costs for the condominiums in Example 2–5, the estimate was segmented into the initial and monthly costs, and monthly revenues. The example illustrated the segmenting model (division of the overall estimate into various categories and activities, such as costs and benefits) together with the unit factor model to make the subestimates for each category. Example 2–6 provides another example of the segmenting approach.

### EXAMPLE 2–6

Clean Lawn Corp., a manufacturer of yard equipment, is planning to introduce a new high-end industrial-use lawn mower called the Grass Grabber. The Grass Grabber is designed as a walk-behind, self-propelled mower. Clean Lawn engineers have been asked by the accounting department to estimate the material costs for the new mower. The material cost estimate will be used, along with estimates for labor and overhead to evaluate the potential of this new model.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

industrial facilities and equipment. The exponent given applies only to equipment within the size range specified.

In Equation 2–3 equipment costs for both  $A$  and  $B$  occur at the same point in time. This equation is useful for scaling equipment costs but *not* for updating those costs. When the time of the desired cost estimate is different from the time in which the scaling occurs (per Equation 2–3) cost indexes accomplish the time updating. Thus, in cases like Example 2–8 involving both scaling and updating, we use the power-sizing model together with cost indexes.

### EXAMPLE 2–8

Based on her work in Example 2–7, Miriam has been asked to estimate the cost today of a 2500- $\text{ft}^2$  heat exchange system for the new plant being analyzed. She has the following data.

- Her company paid \$50,000 for a 1000- $\text{ft}^2$  heat exchanger 5 years ago.
- Heat exchangers within this range of capacity have a power-sizing exponent ( $x$ ) of 0.55.
- Five years ago the Heat Exchanger Cost Index (HECI) was 1306; it is 1487 today.

#### SOLUTION

Miriam will first use Equation 2–3 to scale up the cost of the 1000- $\text{ft}^2$  exchanger to one that is 2500  $\text{ft}^2$  using the 0.55 power-sizing exponent.

$$\frac{\text{Cost of } 2500\text{-ft}^2 \text{ equipment}}{\text{Cost of } 1000\text{-ft}^2 \text{ equipment}} = \left( \frac{2500\text{-ft}^2 \text{ equipment}}{1000\text{-ft}^2 \text{ equipment}} \right)^{0.55}$$
$$\text{Cost of } 2500\text{-ft}^2 \text{ equipment} = \left( \frac{2500}{1000} \right)^{0.55} \times 50,000 = \$82,800$$

Miriam knows that the \$82,800 reflects only the scaling up of the cost of the 1000- $\text{ft}^2$  model to a 2500- $\text{ft}^2$  model. Now she will use Equation 2–2 and the HECHI data to estimate the cost of a 2500- $\text{ft}^2$  exchanger today. Miriam's cost estimate would be

$$\frac{\text{Equipment cost today}}{\text{Equipment cost 5 years ago}} = \frac{\text{Index value today}}{\text{Index value 5 years ago}}$$
$$\text{Equipment cost today} = \frac{1487}{1306} \times \$82,800 = \$94,300$$

### Triangulation

Triangulation is used in engineering surveying. A geographical area is divided into triangles from which the surveyor is able to map points within that region by using three fixed points and horizontal angular distances to locate fixed points of interest (e.g., property line reference points). Since any point can be located with two lines, the third line represents an extra perspective and check. We will not use trigonometry to arrive at our cost and benefit estimates, but we can use the concept of triangulation. We should approach our economic estimate from different perspectives because such varied perspectives add richness, confidence, and quality to the estimate. **Triangulation** in estimating costs and

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

## 62 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS

	A	B	C	D	E
1	-0.2345	learning curve rate	Unit	Time to Produce N <sup>th</sup>	Cum. Time
2	191.6	time for first unit	(N)		1 to N
3			1	191.6	191.6
4	100	steady state time	2	162.8	354.4
5	16	steady state unit	3	148.1	502.5
6			4	138.4	640.9
7	20	# units	5	131.4	772.3
8	15	workers per unit	6	125.9	898.1
9	25	labor rate (\$/hr)	7	121.4	1019.5
10			8	117.6	1137.2
11		=\\$A\$2*C11^\$A\$1	9	114.4	1251.6
12			10	111.7	1363.3
13			11	109.2	1472.5
14		Cost if steady state assumed	12	107.0	1579.4
15	\$ 750,000	=A4*A7*A8*A9	13	105.0	1684.4
16			14	103.2	1787.6
17			15	101.5	1889.1
18			16	100.0	1989.1
19			17	100	2089.1
20			18	100	2189.1
21		Cost of 20 units	19	100	2289.1
22	\$ 895,927	=A9*A8*E22	20	100	2389.1
23					
24	19.5%	increase due to learning curve			

From the spreadsheet the total labor cost estimate would have been underestimated by 19.5% had Green Energy not included learning-curve effects in the estimate. The underestimate would have lowered their bid and increased the chance that they would win the project. Had they won the bid this would have affected the project's profitability and with a 20% error, they would probably have lost money on the project.

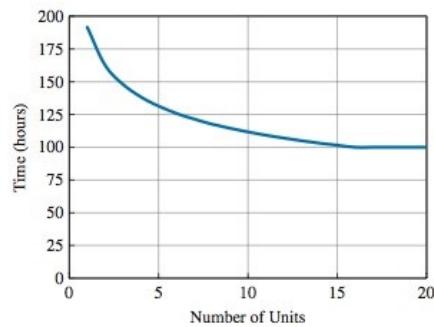
Figures 2–8 and 2–9 illustrate learning curves using the Green Energy data in columns C and D of the spreadsheet. When plotted on a linear scale the time per unit decreases as a declining rate. When plotted on a *log-log* scale, the relationship is a straight line through the 16<sup>th</sup> unit, when a steady state is reached. The straight line is because the 2<sup>nd</sup>, 4<sup>th</sup>, 8<sup>th</sup>, and 16<sup>th</sup> units have a production time that is 85% of the 1<sup>st</sup>, 2<sup>nd</sup>, 4<sup>th</sup>, and 8<sup>th</sup> units respectively.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

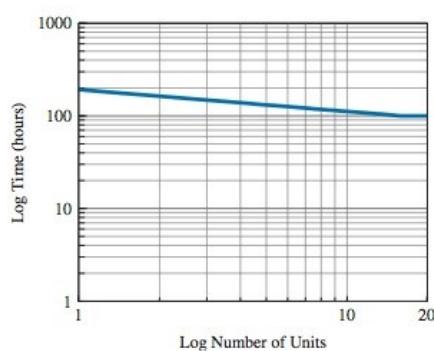
---

**Cash Flow Diagrams 63**

**FIGURE 2-8** Learning curve of time vs. number of units.



**FIGURE 2-9** Learning curve on log-log scale.



---

## CASH FLOW DIAGRAMS

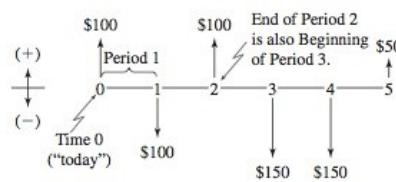
The costs and benefits of engineering projects occur over time and are summarized on a cash flow diagram (CFD). Specifically, a CFD illustrates the size, sign, and timing of individual cash flows. In this way the CFD is the basis for engineering economic analysis.

A **cash flow diagram** is created by first drawing a segmented time-based horizontal line, divided into time units. The time units on the CFD can be years, months, quarters, or any other consistent time unit. Then at each time at which a cash flow will occur, a vertical arrow is added—pointing down for costs and up for revenues or benefits. These cash flows are drawn to scale.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

#### 64 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS

**FIGURE 2-10** An example cash flow diagram (CFD).



Unless otherwise stated, cash flows are **assumed** to occur at time 0 or at the **end** of each period. Consider Figure 2–10, the CFD for a specific investment opportunity whose cash flows are described as follows:

Timing of Cash Flow	Size of Cash Flow
At time zero (now or today)	A positive cash flow of \$100
1 time period from today	A negative cash flow of \$100
2 time periods from today	A positive cash flow of \$100
3 time periods from today	A negative cash flow of \$150
4 time periods from today	A negative cash flow of \$150
5 time periods from today	A positive cash flow of \$50

#### Categories of Cash Flows

The expenses and receipts due to engineering projects usually fall into one of the following categories:

First cost  $\equiv$  expense to build or to buy and install

Operating and maintenance (O&M)  $\equiv$  annual expense, such as electricity, labor, and minor repairs

Salvage value  $\equiv$  receipt at project termination for sale or transfer of the equipment  
(can be a salvage cost)

Revenues  $\equiv$  annual receipts due to sale of products or services

Overhaul  $\equiv$  major capital expenditure that occurs during the asset's life

Individual projects will often have specific costs, revenues, or user benefits. For example, annual operating and maintenance (O&M) expenses on an assembly line might be divided into direct labor, power, and other. Similarly, a public-sector dam project might have its annual benefits divided into flood control, agricultural irrigation, and recreation.

#### Drawing a Cash Flow Diagram

The cash flow diagram shows when all cash flows occur. Look at Figure 2–10 and the \$100 positive cash flow at the end of period 2. From the time line one can see that this cash flow can also be described as occurring at the *beginning* of period 3. Thus, in a CFD the end of *period t* is the same time as the beginning of *period t + 1*. Beginning-of-period cash

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

#### Cash Flow Diagrams **65**

flows (such as rent, lease, and insurance payments) are thus easy to handle: just draw your CFD and put them in where they occur. Thus O&M, salvages, revenues, and overhauls are assumed to be end-of-period cash flows.

The choice of time 0 is arbitrary. For example, it can be when a project is analyzed, when funding is approved, or when construction begins. When construction periods are assumed to be short, first costs are assumed to occur at time 0, and the first annual revenues and costs start at the end of the first period. When construction periods are long, time 0 is usually the date of commissioning—when the facility comes on stream.

Perspective is also important when one is drawing a CFD. Consider the simple transaction of paying \$5000 for some equipment. To the firm buying the equipment, the cash flow is a cost and hence negative in sign. To the firm selling the equipment, the cash flow is a revenue and positive in sign. This simple example shows that a consistent perspective is required when one is using a CFD to model the cash flows of a problem. One person's cash outflow is another person's inflow.

Often two or more cash flows occur in the same year, such as an overhaul and an O&M expense or the salvage value and the last year's O&M expense. Combining these into one total cash flow per year would simplify the cash flow diagram. However, it is

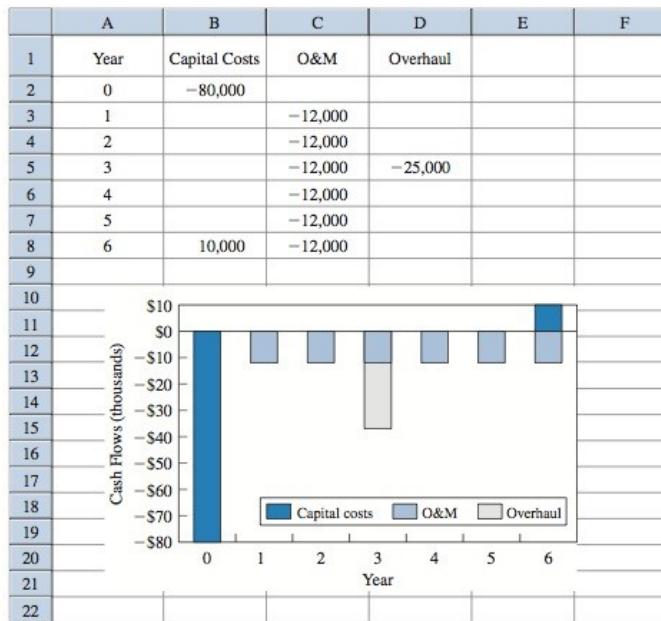


FIGURE 2-11 Example of cash flow diagram in spreadsheets.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.



## 68 CHAPTER 2: ESTIMATING ENGINEERING COSTS AND BENEFITS

be produced and sold at \$197 each for the automated process to be preferred to the labor-intensive process?

*Contributed by Paul R. McCright, University of South Florida*

- 2-6** CleanTech manufactures equipment to mitigate the environmental effects of waste.

- A** (a) If Product A has fixed expenses of \$15,000 per year and each unit of product has a \$0.20 variable cost, and Product B has fixed expenses of \$5000 per year and a \$0.50 variable cost, at what number of units of annual production will A have the same overall cost as B?  
(b) As a manager at CleanTech what other data would you need to evaluate these two products?

- 2-7** Heinrich is a manufacturing engineer with the Miller Company. He has determined the costs of producing a new product to be as follows:

Equipment cost: \$288,000/year  
Equipment salvage value at EOY5 = \$41,000  
Variable cost per unit of production: \$14.55  
Overhead cost per year: \$48,300

If the Miller Company uses a 5-year planning horizon and the product can be sold for a unit price of \$39.75, how many units must be produced and sold each year to break even? *Contributed by Paul R. McCright, University of South Florida*

- 2-8** An assembly line can produce 90 units per hour. The line's hourly cost is \$4500 on straight time (the first 8 hours). Workers are guaranteed a minimum of 6 hours. There is a 50% premium for overtime, however, productivity for overtime drops by 5%. What are the average and marginal costs per unit for the following daily quantities?

- (a) 450  
(b) 600  
(c) 720  
(d) 900

- 2-9** Christine Lynn travels from her home to a remote island. Her trip involves: car travel of 250 miles, air travel of 400 miles, and a boat ride of 75 miles. She is interested in calculating the average fuel cost per mile (per person) of her trip. Assume the fuel efficiency of car, air, and boat travel is 20, 0.20, and 2 miles per gallon, respectively, and that fuel cost per gallon is equal for all and is \$3.00/gallon. She was alone in the car and among 180 people on the plane

and 15 on the boat. What is the average fuel cost per mile, per person?

- 2-10** This month your vendor invoiced \$50,000 in testing charges for your production run. The unit cost for testing is twice as much for each of the first 500 units per month as compared to each unit over 500. If we shipped 750 units to the vendor this month, find:

- (a) Average cost per unit;  
(b) Cost per unit below the price break point;  
(c) Marginal cost for the 600<sup>th</sup> unit.

- 2-11** The Country Fields Retirement Community charges \$6000/month for a single senior citizen to reside in an efficiency apartment with assisted living care. The facility has operating expenses of \$600,000 per month. Staffing levels are dependent on the number of residents. Each senior who enters the community requires additional food, personal care, and support staff time. The estimated cost for each person is \$4000 per person per month.

- (a) How many senior citizen residents does the facility need to have in order to reach the break-even point?  
(b) What is the company's annual profit or loss if they maintain an average residency level of 350 senior citizens?

*Contributed by Gillian Nicholls, Southeast Missouri State University*

- 2-12** The Ozzie Chocolate Company is preparing to offer a new product in its candy offerings, the Minty Dark Chocolate Bite bar. Material costs per new candy bar are \$0.20 for chocolate, \$0.01 for sugar, and \$0.02 for mint flavoring. Labor costs of the new product are approximately \$0.12 per bar. Adding a production line devoted to the new candy will cost \$250,000 per year.

- (a) If the sales price is \$1.25 per candy bar, how many must the company make per year in order to break even? Assume that each bar made is sold at full price.  
(b) What is the company's profit or loss if they make and sell 300,000 candy bars at the \$1.25 price in the first year?  
(c) About 20% of the food consumed in the U.S. is imported. Production in many industries has been offshored. What ethical issues do companies face when presented with the decision to move operations?

*Contributed by Gillian Nicholls, Southeast Missouri State University*

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

- 2-13** A small machine shop, with 30 hp of connected load, purchases electricity at the following monthly rates (assume any demand charge is included in this schedule) per hp of connected load:

First 50 kWh at 12.6¢ per kWh

Next 50 kWh at 10.6¢ per kWh

Next 150 kWh at 9.0¢ per kWh

Over 250 kWh at 7.7¢ per kWh

The shop uses 2800 kWh per month.

- (a) Calculate the monthly bill for this shop. What are the marginal and average costs per kilowatt-hour?

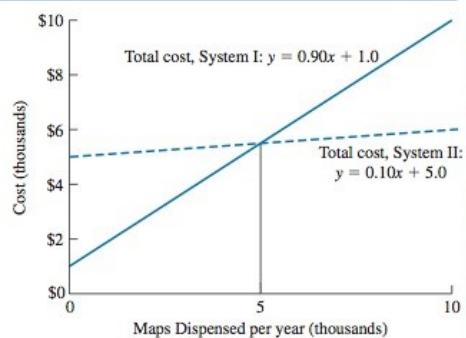
- (b) A contract for additional business would require more operating hours per day. This will use an extra 1200 kWh per month. What is the "cost" of this additional energy? What is this per kilowatt-hour?

- (c) New machines would reduce the labor time required on certain operations. These will increase the connected load by 10 hp, but since they will operate only on certain special jobs, will add only 100 kWh per month. In a study to determine the economy of installing these new machines, what should be considered as the "cost" of this energy? What is this per kilowatt-hour?

- 2-14** Two automatic systems for dispensing maps are being compared by the state highway department. The accompanying breakeven chart of the comparison of these systems (System I vs. System II) shows total yearly costs for the number of maps dispensed per year for both alternatives. Answer the following questions.

- (a) What is the fixed cost for System I?  
 (b) What is the fixed cost for System II?  
 (c) What is the variable cost per map dispensed for System I?  
 (d) What is the variable cost per map dispensed for System II?  
 (e) What is the breakeven point in terms of maps dispensed at which the two systems have equal annual costs?  
 (f) For what range of annual number of maps dispensed is System I recommended?  
 (g) For what range of annual number of maps dispensed is System II recommended?  
 (h) At 3000 maps per year, what are the marginal and average map costs for each system?

### Problems 69



- 2-15** A privately owned summer camp for youngsters has the following data for a 12-week session:

Charge per camper	\$480 per week
Fixed costs	\$192,000 per session
Variable cost per camper	\$320 per week
Capacity	200 campers

- (a) Develop the mathematical relationships for total cost and total revenue.  
 (b) What is the total number of campers that will allow the camp to *just break even*?  
 (c) What is the profit or loss for the 12-week session if the camp operates at 80% capacity?  
 (d) What are marginal and average costs per camper at 80% capacity?  
 (e) Would it be ethical to charge campers different rates depending on their family's socioeconomic status? Identify and describe two points pro and two points con for such a policy.

- 2-16** Two new rides are being compared by a local amusement park in terms of their annual operating costs. The two rides would generate the same level of revenue (thus the focus on costs). The Tummy Tugger has fixed costs of \$10,000 per year and variable costs of \$2.50 per visitor. The Head Buzzer has fixed costs of \$4000 per year and variable costs of \$4 per visitor.  
 (a) Mathematically find the number of visitors per year for the two rides to have equal annual costs.  
 (b) Develop a breakeven graph to show:

- Accurate total cost lines for the two alternatives (show line, slopes, and equations).
- The breakeven point for the two rides in terms of number of visitors.
- The ranges of visitors per year where each alternative is preferred.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

PRINTED BY: taylorgalileasmith@tamu.edu. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.