

# Contents

Preface xv

## Part I Principles of Engineering Economy 1

- 1 Engineering Economy and the Decision-Making Process 3
  - 1.1 The Engineer 6
  - 1.2 Engineering Economy 8
  - 1.3 Engineering Economic Decisions 9
  - 1.4 The Decision-Making Process 16
  - 1.5 The Engineering Design Process 19
  - 1.6 Examining the Real Decision Problems 21
  - 1.7 Key Points 22
  - 1.8 Further Reading 23
  - 1.9 Questions and Problems 23
    - 1.9.1 Concept Questions 23
    - 1.9.2 Application Questions 24
    - 1.9.3 Fundamentals of Engineering Exam Prep 27
- 2 Cash Flows and the Time Value of Money 29
  - 2.1 Cash Flows and Cash Flow Diagrams 31
  - 2.2 Using Spreadsheets to Represent Cash Flows 34
    - 2.2.1 Spreadsheet Fundamentals 34
    - 2.2.2 Spreadsheet Usage 35
  - 2.3 The Time Value of Money 39
  - 2.4 Interest and Interest Rates 40
    - 2.4.1 Simple Interest 40
    - 2.4.2 Compound Interest 42
  - 2.5 Nominal and Effective Interest Rates 45
    - 2.5.1 Nominal Interest Rates 45
    - 2.5.2 Effective Interest Rates 47
    - 2.5.3 Comparing Interest Rates 51

2.6	Cash Flow Timing and the Interest Rate	53
2.6.1	Compounding Is More Frequent than Cash Flows	53
2.6.2	Compounding Is Less Frequent than Cash Flows	54
2.7	Inflation and Purchasing Power	56
2.7.1	Measuring Inflation	56
2.7.2	Cash Flows as Real or Current Dollars	59
2.7.3	Market and Inflation-Free Interest Rates	62
2.7.4	Real- and Current-Dollar Cash Flow Analysis	64
2.8	Exchange Rates and Cash Flow Analysis	64
2.9	Examining the Real Decision Problems	67
2.10	Key Points	69
2.11	Further Reading	71
2.12	Questions and Problems	71
2.12.1	Concept Questions	71
2.12.2	Drill Problems	72
2.12.3	Application Problems	76
2.12.4	Fundamentals of Engineering Exam Prep	78
<b>3</b>	<b>Interest Formulas</b>	<b>84</b>
3.1	Compound Amount Factors	87
3.1.1	Single-Payment Analysis	87
3.1.2	Equal-Payment Series Analysis	91
3.1.3	Arithmetic Gradient Series Analysis	94
3.1.4	Geometric Gradient Series Analysis	101
3.2	Present-Worth Factors	105
3.2.1	Single-Payment Analysis	106
3.2.2	Equal-Payment Series Analysis	108
3.2.3	Arithmetic Gradient Series Analysis	111
3.2.4	Geometric Gradient Series Analysis	115
3.3	Equal-Payment Factors	118
3.3.1	Single-Payment Analysis: Sinking-Fund Factor	118
3.3.2	Single-Payment Analysis: Capital-Recovery Factor	120
3.3.3	Arithmetic Gradient Series Analysis	122
3.3.4	Geometric Gradient Series Factor	125
3.4	Summary of Interest Factors	130
3.5	Using Multiple Factors in Analysis	130
3.6	Discrete Payments and Continuous Compounding	134
3.7	Examining the Real Decision Problems	137
3.8	Key Points	139
3.9	Further Reading	139
3.10	Questions and Problems	140
3.10.1	Concept Questions	140
3.10.2	Drill Problems	140

3.10.3	Application Problems	143
3.10.4	Fundamentals of Engineering Exam Prep	146

#### 4 Economic Equivalence 149

4.1	Economic Equivalence Properties	151
4.2	Equivalence Involving the Interest Rate	160
4.3	Equivalence Involving the Horizon	164
4.4	Interest Factor Behavior	166
4.5	Examples of Equivalence: Raising Capital	168
4.5.1	Loans	169
4.5.2	Bonds	177
4.5.3	Stocks	186
4.6	Examining the Real Decision Problems	191
4.7	Key Points	192
4.8	Further Reading	193
4.9	Questions and Problems	194
4.9.1	Concept Questions	194
4.9.2	Drill Problems	195
4.9.3	Application Problems	198
4.9.4	Fundamentals of Engineering Exam Prep	204

### Part II Decision-Making Preliminaries 211

#### 5 Problem or Opportunity Definition 213

5.1	Defining Problems	215
5.2	Recognizing Opportunities	219
5.3	Opportunities and Problems	223
5.4	The Definition	226
5.5	Examining the Real Decision Problems	226
5.6	Key Points	227
5.7	Further Reading	228
5.8	Questions and Problems	228
5.8.1	Concept Questions	228
5.8.2	Application Questions	228
5.8.3	Fundamentals of Engineering Exam Prep	231

#### 6 Generating and Designing Feasible Solution Alternatives 232

6.1	Generating Alternatives	234
6.2	Working Alone	234
6.3	Working in a Group	235
6.3.1	The Delphi Method	237
6.3.2	The Nominal Group Process	238
6.4	The Do-Nothing Alternative	239

6.5	Reduction to a Feasible Set of Alternatives	240
6.6	Examining the Real Decision Problems	244
6.7	Key Points	247
6.8	Further Reading	247
6.9	Questions and Problems	248
6.9.1	Concept Questions	248
6.9.2	Application Questions	249
6.9.3	Fundamentals of Engineering Exam Prep	249
7	Developing Cash Flows and Gathering Information	250
7.1	Life-Cycle Costs and Revenues	253
7.2	Priorities in Estimation	256
7.3	Estimation Techniques	268
7.3.1	Unit Method	269
7.3.2	Index Method	270
7.3.3	Power Law and Sizing Model	271
7.3.4	The Learning Curve	273
7.3.5	Curve Fitting	275
7.4	Ranges of Estimates	276
7.5	Generating the Cash Flow Diagram	279
7.6	Choosing an Interest Rate	280
7.6.1	Weighted-Average Cost of Capital	281
7.6.2	Growth Rate and Opportunity Cost	283
7.7	Choosing a Study Period	284
7.8	Additional Information Gathering	286
7.9	Sources of Data	286
7.10	Examining the Real Decision Problems	287
7.11	Key Points	289
7.12	Further Reading	290
7.13	Questions and Problems	291
7.13.1	Concept Questions	291
7.13.2	Drill Problems	291
7.13.3	Application Questions	294
7.13.4	Fundamentals of Engineering Exam Prep	297
8	Developing After-Tax Cash Flows	301
8.1	Taxation	304
8.2	Taxes on Ordinary Income	305
8.2.1	Federal Tax Rates	306
8.2.2	Effective Tax Rates	308
8.3	Depreciation and Book Value	310
8.3.1	Straight-Line Depreciation	311
8.3.2	Declining-Balance Depreciation	313

8.3.3	Declining Balance Switching to Straight-Line Depreciation	316
8.3.4	MACRS Depreciation	318
8.3.5	Choosing a Depreciation Method	326
8.4	Historical Methods of Depreciation	330
8.5	Taxes on Nonordinary Income	333
8.5.1	Retiring an Asset	333
8.5.2	Replacing an Asset	334
8.5.3	Capital Gains	336
8.6	Notable Exceptions and Adjustments to Taxable Income	337
8.6.1	Units-of-Depletion Method of Depreciation	337
8.6.2	Losses from Operations or from Sales of Assets	340
8.6.3	Investment Credits	341
8.6.4	Amortization	342
8.7	After-Tax Cash Flows	343
8.8	Examining the Real Decision Problems	348
8.9	After-Tax MARR	350
8.10	Key Points	351
8.11	Further Reading	352
8.12	Questions and Problems	353
8.12.1	Concept Questions	353
8.12.2	Drill Problems	354
8.12.3	Application Problems	356
8.12.4	Fundamentals of Engineering Exam Prep	360

### Part III Making the Decision for a Single Project 365

9	Deterministic Evaluation	367
9.1	Absolute Measures of Worth	369
9.1.1	Present Worth	370
9.1.2	Future Worth	374
9.1.3	Annual Equivalent Worth	377
9.1.4	Market Value Added	380
9.2	Relative Measures of Worth	386
9.2.1	Internal Rate of Return	386
9.2.2	External Rate of Return (Modified Internal Rate of Return)	397
9.2.3	Benefit–Cost Ratio	401
9.3	Examining the Real Decision Problems	405
9.4	Key Points	408
9.5	Further Reading	408
9.6	Questions and Problems	409
9.6.1	Concept Questions	409
9.6.2	Drill Problems	410

- 9.6.3 Application Problems 412
- 9.6.4 Fundamentals of Engineering Exam Prep 414

## 10 Considering Risk 417

- 10.1 Payback Period 421
- 10.2 Payback Period with Interest 424
- 10.3 Project Balance 425
- 10.4 Break-Even Analysis 429
- 10.5 Sensitivity Analysis 433
  - 10.5.1 Single-Parameter Analysis 435
  - 10.5.2 Multiple-Parameter Analysis 439
- 10.6 Scenario Analysis 441
- 10.7 Probabilistic Analysis 444
  - 10.7.1 Probabilistic Scenario Analysis 446
  - 10.7.2 Simulation Analysis 448
- 10.8 Examining the Real Decision Problems 457
- 10.9 Key Points 459
- 10.10 Further Reading 460
- 10.11 Questions and Problems 461
  - 10.11.1 Concept Questions 461
  - 10.11.2 Drill Problems 461
  - 10.11.3 Application Problems 464
  - 10.11.4 Fundamentals of Engineering Exam Prep 468

## 11 Considering Noneconomic Factors and Multiatributes 471

- 11.1 Noneconomic Factors 473
- 11.2 Including Noneconomic Factors in Analysis 475
- 11.3 Multiattribute Analysis 478
- 11.4 Judgment in Decision Making 482
- 11.5 Writing the Business Case 483
- 11.6 Examining the Real Decision Problems 485
- 11.7 Key Points 486
- 11.8 Further Reading 487
- 11.9 Questions and Problems 487
  - 11.9.1 Concept Questions 487
  - 11.9.2 Drill Problems 487
  - 11.9.3 Application Problems 488
  - 11.9.4 Fundamentals of Engineering Exam Prep 490

## Part IV Making the Decision for Multiple Projects 493

## 12 Deterministic Evaluation 495

- 12.1 Classifying Engineering Projects 498

12.2	Forming Mutually Exclusive Alternatives	499
12.3	Evaluation of Revenue Projects with Equal Lives	501
12.3.1	Total Investment Analysis	501
12.3.2	Incremental Investment Analysis	504
12.4	Evaluation of Revenue Projects with Unequal Lives	510
12.5	Evaluation of Service Projects with Equal Lives	514
12.6	Evaluation of Service Projects with Unequal Lives	515
12.7	Mixing Revenue and Service Projects	519
12.8	Solutions to Large-Scale Applications	519
12.8.1	Integer Programming Approach	520
12.8.2	Heuristic Methods: Project-Ranking Approaches	522
12.9	Examining the Real Decision Problems	523
12.10	Key Points	527
12.11	Further Reading	528
12.12	Questions and Problems	529
12.12.1	Concept Questions	529
12.12.2	Drill Problems	530
12.12.3	Application Problems	532
12.12.4	Fundamentals of Engineering Exam Prep	536
<b>13</b>	<b>Considering Options in Time</b>	<b>540</b>
13.1	Decision Networks	543
13.2	Decision Trees	547
13.2.1	Single-Stage Decision Tree	547
13.2.2	Two-Stage Decision Tree	551
13.2.3	Calculating Conditional Probabilities	553
13.2.4	Rollback Solution Procedure	556
13.2.5	Multistage Decision Trees	559
13.3	Real Options	561
13.4	Examining the Real Decision Problems	564
13.5	Key Points	565
13.6	Further Reading	565
13.7	Questions and Problems	566
13.7.1	Concept Questions	566
13.7.2	Drill Problems	566
13.7.3	Application Problems	568
13.7.4	Fundamentals of Engineering Exam Prep	573
<b>14</b>	<b>Multicriteria Evaluation</b>	<b>575</b>
14.1	Sensitivity and Break-Even Analysis	577
14.2	Simulation Analysis	581
14.3	Project Elimination Methods	582
14.3.1	Dominance and Efficient Frontier Analysis	582
14.3.2	Minimum-Threshold Analysis	586

- 14.4 Project-Ranking Methods 589
- 14.5 Considering Noneconomic Factors 589
- 14.6 Examining the Real Decision Problems 590
- 14.7 Key Points 591
- 14.8 Further Reading 592
- 14.9 Questions and Problems 593
  - 14.9.1 Concept Questions 593
  - 14.9.2 Drill Problems 593
  - 14.9.3 Application Problems 595
  - 14.9.4 Fundamentals of Engineering Exam Prep 598

## Part V Postimplementation Analysis 601

- 15 Postimplementation and Evaluation 603
  - 15.1 Sunk Costs Revisited 605
  - 15.2 Tracking an Investment 606
    - 15.2.1 Error Analysis 606
    - 15.2.2 Cash Flow Charting 610
    - 15.2.3 Considering Dynamic Options 614
    - 15.2.4 Updating the Forecast 617
  - 15.3 Maintaining a Database 618
  - 15.4 Cost Accounting 619
    - 15.4.1 Balance Sheet 619
    - 15.4.2 Income Statement 621
    - 15.4.3 Cash Flow Statement 621
  - 15.5 Activity-Based Costing 621
  - 15.6 Examining the Real Decision Problems 622
  - 15.7 Key Points 626
  - 15.8 Further Reading 626
  - 15.9 Questions and Problems 627
    - 15.9.1 Concept Questions 627
    - 15.9.2 Drill Problems 627
    - 15.9.3 Application Problems 629
    - 15.9.4 Fundamentals of Engineering Exam Prep 632
- 16 Abandonment and Replacement Analysis 633
  - 16.1 Abandonment Analysis 635
    - 16.1.1 Dynamic Deterministic Evaluation 637
    - 16.1.2 Probabilistic Evaluation 639
  - 16.2 Replacement Analysis 643
    - 16.2.1 Considering Deterioration 644
    - 16.2.2 Considering Technological Change 659
    - 16.2.3 After-Tax Issues in Replacement Analysis 668
  - 16.3 Examining the Real Decision Problems 672

- 16.4 Key Points 673
- 16.5 Further Reading 674
- 16.6 Questions and Problems 675
  - 16.6.1 Concept Questions 675
  - 16.6.2 Drill Problems 675
  - 16.6.3 Application Problems 676
  - 16.6.4 Fundamentals of Engineering Exam Prep 680

## Part VI Appendix 683

Solutions to Fundamentals of Engineering Exam Prep Questions 685

Interest Rate Factors for Discrete Compounding 688

Index 725