

FOURTH EDITION



Engineering Design

GEORGE E. DIETER

LINDA C. SCHMIDT

McGRAW-HILL INTERNATIONAL EDITION



BRIEF CONTENTS

Chapter 2	Product Development Process	37
2.1	Introduction	37
2.2	Product Development Process	39
2.2.1	Factors for Success	41
2.2.2	Static Versus Dynamic Products	46
2.2.3	Variations on the Generic Product Development Process	46
2.3	Product and Process Cycles	47
2.3.1	Stages of Development of a Product	47
2.3.2	Technology Development and Insertion Cycle	48
2.3.3	Process Development Cycle	50
Chapter 1	Engineering Design	1
Chapter 2	Product Development Process	39
Chapter 3	Problem Definition and Need Identification	75
Chapter 4	Team Behavior and Tools	116
Chapter 5	Gathering Information	158
Chapter 6	Concept Generation	196
Chapter 7	Decision Making and Concept Selection	262
Chapter 8	Embodiment Design	298
Chapter 9	Detail Design	386
Chapter 10	Modeling and Simulation	411
Chapter 11	Materials Selection	457
Chapter 12	Design with Materials	515
Chapter 13	Design for Manufacturing	558
Chapter 14	Risk, Reliability, and Safety	669
Chapter 15	Quality, Robust Design, and Optimization	723
Chapter 16	Cost Evaluation	779
Chapter 17	Legal and Ethical Issues in Engineering Design	www.mhhe.com/dieter
Chapter 18	Economic Decision Making	www.mhhe.com/dieter
	Appendices	A-1
	Author & Subject Indexes	I-1

DETAILED CONTENTS

	Preface	xxiii
Chapter 1	Engineering Design	1
1.1	Introduction	1
1.2	Engineering Design Process	3
1.2.1	Importance of the Engineering Design Process	4
1.2.2	Types of Designs	5
1.3	Ways to Think About the Engineering Design Process	6
1.3.1	A Simplified Iteration Model	6
1.3.2	Design Method Versus Scientific Method	8
1.3.3	A Problem-Solving Methodology	10
1.4	Considerations of a Good Design	14
1.4.1	Achievement of Performance Requirements	14
1.4.2	Total Life Cycle	17
1.4.3	Regulatory and Social Issues	18
1.5	Description of Design Process	19
1.5.1	Phase I. Conceptual Design	19
1.5.2	Phase II. Embodiment Design	20
1.5.3	Phase III. Detail Design	21
1.5.4	Phase IV. Planning for Manufacture	22
1.5.5	Phase V. Planning for Distribution	23
1.5.6	Phase VI. Planning for Use	23
1.5.7	Phase VII. Planning for Retirement of the Product	23
1.6	Computer-Aided Engineering	24
1.7	Designing to Codes and Standards	26
1.8	Design Review	29
1.8.1	Redesign	30
1.9	Societal Considerations in Engineering Design	31

	1.10 Summary	35
	New Terms and Concepts	36
	Bibliography	37
	Problems and Exercises	37
Chapter 2	Product Development Process	39
	2.1 Introduction	39
	2.2 Product Development Process	39
	2.2.1 Factors for Success	43
	2.2.2 Static Versus Dynamic Products	46
	2.2.3 Variations on the Generic Product Development Process	46
	2.3 Product and Process Cycles	47
	2.3.1 Stages of Development of a Product	47
	2.3.2 Technology Development and Insertion Cycle	48
	2.3.3 Process Development Cycle	50
	2.4 Organization for Design and Product Development	51
	2.4.1 A Typical Organization by Functions	53
	2.4.2 Organization by Projects	54
	2.4.3 Hybrid Organizations	55
	2.4.4 Concurrent Engineering Teams	57
	2.5 Markets and Marketing	58
	2.5.1 Markets	59
	2.5.2 Market Segmentation	60
	2.5.3 Functions of a Marketing Department	63
	2.5.4 Elements of a Marketing Plan	63
	2.6 Technological Innovation	64
	2.6.1 Invention, Innovation, and Diffusion	64
	2.6.2 Business Strategies Related to Innovation and Product Development	67
	2.6.3 Characteristics of Innovative People	68
	2.6.4 Types of Technology Innovation	69
	2.7 Summary	71
	New Terms and Concepts	72
	Bibliography	72
	Problems and Exercises	73
Chapter 3	Problem Definition and Need Identification	75
	3.1 Introduction	75
	3.2 Identifying Customer Needs	77
	3.2.1 Preliminary Research on Customers Needs	79
	3.2.2 Gathering Information from Customers	80
	3.3 Customer Requirements	86
	3.3.1 Differing Views of Customer Requirements	87
	3.3.2 Classifying Customer Requirements	89

3.4	Establishing the Engineering Characteristics	91
3.4.1	Benchmarking in General	93
3.4.2	Competitive Performance Benchmarking	95
3.4.3	Reverse Engineering or Product Dissection	96
3.4.4	Determining Engineering Characteristics	97
3.5	Quality Function Deployment	98
3.5.1	The House of Quality Configurations	100
3.5.2	Steps for Building a House of Quality	102
3.5.3	Interpreting Results of HOQ	107
3.6	Product Design Specification	109
3.7	Summary	111
	Bibliography	113
	New Terms and Concepts	114
	Problems and Exercises	114
Chapter 4	Team Behavior and Tools	116
4.1	Introduction	116
4.2	What It Means to be an Effective Team Member	117
4.3	Team Roles	118
4.4	Team Dynamics	119
4.5	Effective Team Meetings	122
4.5.1	Helpful Rules for Meeting Success	123
4.6	Problems with Teams	124
4.7	Problem-Solving Tools	126
4.7.1	Applying the Problem-Solving Tools in Design	140
4.8	Time Management	145
4.9	Planning and Scheduling	146
4.9.1	Work Breakdown Structure	147
4.9.2	Gantt Chart	147
4.9.3	Critical Path Method	149
4.10	Summary	154
	New Terms and Concepts	155
	Bibliography	155
	Problems and Exercises	156
Chapter 5	Gathering Information	158
5.1	The Information Challenge	158
5.1.1	Your Information Plan	159
5.1.2	Data, Information, and Knowledge	160
5.2	Types of Design Information	162
5.3	Sources of Design Information	162
5.4	Library Sources of Information	166
5.4.1	Dictionaries and Encyclopedias	167
5.4.2	Handbooks	169
5.4.3	Textbooks and Monographs	169

	5.4.4	Finding Periodicals	169
	5.4.5	Catalogs, Brochures, and Business Information	171
	5.5	Government Sources of Information	171
	5.6	Information From the Internet	172
	5.6.1	Searching with Google	174
	5.6.2	Some Helpful URLs for Design	176
	5.6.3	Business-Related URLs for Design and Product Development	178
	5.7	Professional Societies and Trade Associations	180
	5.8	Codes and Standards	181
	5.9	Patents and Other Intellectual Property	183
	5.9.1	Intellectual Property	184
	5.9.2	The Patent System	185
	5.9.3	Technology Licensing	187
	5.9.4	The Patent Literature	187
	5.9.5	Reading a Patent	189
	5.9.6	Copyrights	191
	5.10	Company-Centered Information	192
	5.11	Summary	193
		New Terms and Concepts	194
		Bibliography	194
		Problems and Exercises	194
Chapter 6	Concept Generation	196	
	6.1	Introduction to Creative Thinking	197
	6.1.1	Models of the Brain and Creativity	197
	6.1.2	Thinking Processes that Lead to Creative Ideas	201
	6.2	Creativity and Problem Solving	202
	6.2.1	Aids to Creative Thinking	202
	6.2.2	Barriers to Creative Thinking	205
	6.3	Creative Thinking Methods	208
	6.3.1	Brainstorming	208
	6.3.2	Idea Generating Techniques Beyond Brainstorming	210
	6.3.3	Random Input Technique	212
	6.3.4	Synectics: An Inventive Method Based on Analogy	213
	6.3.5	Concept Map	215
	6.4	Creative Methods for Design	217
	6.4.1	Refinement and Evaluation of Ideas	217
	6.4.2	Generating Design Concepts	219
	6.4.3	Systematic Methods for Designing	221
	6.5	Functional Decomposition and Synthesis	222
	6.5.1	Physical Decomposition	223
	6.5.2	Functional Representation	225
	6.5.3	Performing Functional Decomposition	229
	6.5.4	Strengths and Weaknesses of Functional Synthesis	232

6.6	Morphological Methods	233
6.6.1	Morphological Method for Design	234
6.6.2	Generating Concepts from Morphological Chart	236
6.7	TRIZ: The Theory of Inventive Problem Solving	237
6.7.1	Invention: Evolution to Increased Ideality	238
6.7.2	Innovation by Overcoming Contradictions	239
6.7.3	TRIZ Inventive Principles	240
6.7.4	The TRIZ Contradiction Matrix	243
6.7.5	Strengths and Weaknesses of TRIZ	247
6.8	Axiomatic Design	249
6.8.1	Axiomatic Design Introduction	249
6.8.2	The Axioms	250
6.8.3	Using Axiomatic Design to Generate a Concept	251
6.8.4	Using Axiomatic Design to Improve an Existing Concept	253
6.8.5	Strengths and Weaknesses of Axiomatic Design	257
6.9	Summary	258
	New Terms and Concepts	259
	Bibliography	260
	Problems and Exercises	260
Chapter 7	Decision Making and Concept Selection	262
7.1	Introduction	262
7.2	Decision Making	263
7.2.1	Behavioral Aspects of Decision Making	263
7.2.2	Decision Theory	266
7.2.3	Utility Theory	269
7.2.4	Decision Trees	273
7.3	Evaluation Methods	274
7.3.1	Comparison Based on Absolute Criteria	275
7.3.2	Pugh Concept Selection Method	277
7.3.3	Measurement Scales	280
7.3.4	Weighted Decision Matrix	282
7.3.5	Analytic Hierarchy Process (AHP)	285
7.4	Summary	292
	New Terms and Concepts	294
	Bibliography	294
	Problems and Exercises	294
Chapter 8	Embodiment Design	298
8.1	Introduction	298
8.1.1	Comments on Nomenclature Concerning the Phases of the Design Process	299
8.1.2	Oversimplification of the Design Process Model	300

8.2	Product Architecture	301
	8.2.1 Types of Modular Architectures	303
	8.2.2 Modularity and Mass Customization	303
	8.2.3 Create the Schematic Diagram of the Product	305
	8.2.4 Cluster the Elements of the Schematic	306
	8.2.5 Create a Rough Geometric Layout	307
	8.2.6 Define Interactions and Determine Performance Characteristics	308
8.3	Configuration Design	309
	8.3.1 Generating Alternative Configurations	312
	8.3.2 Analyzing Configuration Designs	315
	8.3.3 Evaluating Configuration Designs	315
8.4	Best Practices for Configuration Design	316
	8.4.1 Design Guidelines	317
	8.4.2 Interfaces and Connections	321
	8.4.3 Checklist for Configuration Design	324
	8.4.4 Design Catalogs	325
8.5	Parametric Design	325
	8.5.1 Systematic Steps in Parametric Design	326
	8.5.2 A Parametric Design Example: Helical Coil Compression Spring	328
	8.5.3 Design for Manufacture (DFM) and Design for Assembly (DFA)	336
	8.5.4 Failure Modes and Effects Analysis (FMEA)	337
	8.5.5 Design for Reliability and Safety	337
	8.5.6 Design for Quality and Robustness	338
8.6	Dimensions and Tolerances	338
	8.6.1 Dimensions	339
	8.6.2 Tolerances	340
	8.6.3 Geometric Dimensioning and Tolerancing	350
	8.6.4 Guidelines for Tolerance Design	355
8.7	Industrial Design	356
	8.7.1 Visual Aesthetics	357
8.8	Human Factors Design	358
	8.8.1 Human Physical Effort	359
	8.8.2 Sensory Input	361
	8.8.3 Anthropometric Data	364
	8.8.4 Design for Serviceability	364
8.9	Design for the Environment	365
	8.9.1 Life Cycle Design	366
	8.9.2 Design for the Environment (DFE)	368
	8.9.3 DFE Scoring Methods	370
8.10	Prototyping and Testing	370
	8.10.1 Prototype and Model Testing Throughout the Design Process	371
	8.10.2 Building Prototypes	372

	8.10.3	Rapid Prototyping	373
	8.10.4	RP Processes	374
	8.10.5	Testing	377
	8.10.6	Statistical Design of Testing	378
	8.11	Design for X (DFX)	380
	8.12	Summary	382
		New Terms and Concepts	382
		Bibliography	383
		Problems and Exercises	383
Chapter 9	Detail Design		386
	9.1	Introduction	386
	9.2	Activities and Decisions in Detail Design	387
	9.3	Communicating Design and Manufacturing Information	391
	9.3.1	Engineering Drawings	391
	9.3.2	Bill of Materials	394
	9.3.3	Written Documents	395
	9.3.4	Common Challenges in Technical Writing	398
	9.3.5	Meetings	399
	9.3.6	Oral Presentations	400
	9.4	Final Design Review	402
	9.4.1	Input Documents	402
	9.4.2	Review Meeting Process	403
	9.4.3	Output from Review	403
	9.5	Design and Business Activities Beyond Detail Design	403
	9.6	Facilitating Design and Manufacturing with Computer-Based Methods	406
	9.6.1	Product Lifecycle Management (PLM)	407
	9.7	Summary	408
		New Terms and Concepts	408
		Bibliography	409
		Problems and Exercises	409
Chapter 10	Modeling and Simulation		411
	10.1	The Role of Models in Engineering Design	411
	10.1.1	Types of Models	412
	10.1.2	Iconic, Analog, and Symbolic Models	413
	10.2	Mathematical Modeling	414
	10.2.1	The Model-Building Process	414
	10.3	Dimensional Analysis	423
	10.3.1	Similitude and Scale Models	425
	10.4	Finite-Difference Method	429
	10.5	Geometric Modeling on the Computer	432
	10.6	Finite Element Analysis	434
	10.6.1	The Concept Behind FEA	435
	10.6.2	Types of Elements	439

	10.6.3	Steps in the FEA Process	442
	10.6.4	Current Practice	444
	10.7	Simulation	446
	10.7.1	Introduction to Simulation Modeling	446
	10.7.2	Simulation Programming Software	447
	10.7.3	Monte Carlo Simulation	449
	10.8	Summary	452
		New Terms and Concepts	453
		Bibliography	454
		Problems and Exercises	454
Chapter 11	Materials Selection		457
	11.1	Introduction	457
	11.1.1	Relation of Materials Selection to Design	458
	11.1.2	General Criteria for Selection	460
	11.1.3	Overview of the Materials Selection Process	460
	11.2	Performance Characteristics of Materials	461
	11.2.1	Classification of Materials	462
	11.2.2	Properties of Materials	463
	11.2.3	Specification of Materials	470
	11.2.4	Ashby Charts	471
	11.3	The Materials Selection Process	472
	11.3.1	Design Process and Materials Selection	474
	11.3.2	Materials Selection in Conceptual Design	476
	11.3.3	Materials Selection in Embodiment Design	476
	11.4	Sources of Information on Materials Properties	478
	11.4.1	Conceptual Design	479
	11.4.2	Embodiment Design	479
	11.4.3	Detail Design	482
	11.5	Economics of Materials	482
	11.5.1	Cost of Materials	482
	11.5.2	Cost Structure of Materials	485
	11.6	Overview of Methods of Materials Selection	486
	11.7	Selection with Computer-Aided Databases	487
	11.8	Material Performance Indices	488
	11.8.1	Material Performance Index	489
	11.9	Materials Selection with Decision Matrices	494
	11.9.1	Pugh Selection Method	495
	11.9.2	Weighted Property Index	496
	11.10	Design Examples	499
	11.11	Recycling and Materials Selection	503
	11.11.1	Benefits from Recycling	504
	11.11.2	Steps in Recycling	504
	11.11.3	Design for Recycling	506
	11.11.4	Material Selection for Eco-attributes	508

	11.12	Summary	510
		New Terms and Concepts	511
		Bibliography	512
		Problems and Exercises	512
Chapter 12		Design with Materials	515
	12.1	Introduction	515
	12.2	Design for Brittle Fracture	516
		12.2.1 Plane Strain Fracture Toughness	518
		12.2.2 Limitations on Fracture Mechanics	522
	12.3	Design for Fatigue Failure	523
		12.3.1 Fatigue Design Criteria	524
		12.3.2 Fatigue Parameters	525
		12.3.3 Information Sources on Design for Fatigue	528
		12.3.4 Infinite Life Design	529
		12.3.5 Safe-Life Design Strategy	531
		12.3.6 Damage-Tolerant Design Strategy	536
		12.3.7 Further Issues in Fatigue Life Prediction	538
	12.4	Design for Corrosion Resistance	539
		12.4.1 Basic Forms of Corrosion	539
		12.4.2 Corrosion Prevention	541
	12.5	Design Against Wear	544
		12.5.1 Types of Wear	544
		12.5.2 Wear Models	546
		12.5.3 Wear Prevention	547
	12.6	Design with Plastics	549
		12.6.1 Classification of Plastics and Their Properties	549
		12.6.2 Design for Stiffness	552
		12.6.3 Time-Dependent Part Performance	553
	12.7	Summary	555
		New Terms and Concepts	556
		Bibliography	556
		Problems and Exercises	556
Chapter 13		Design for Manufacturing	558
	13.1	Role of Manufacturing in Design	558
	13.2	Manufacturing Functions	560
	13.3	Classification of Manufacturing Processes	562
		13.3.1 Types of Manufacturing Processes	563
		13.3.2 Brief Description of the Classes of Manufacturing Processes	564
		13.3.3 Sources of Information on Manufacturing Processes	565
		13.3.4 Types of Manufacturing Systems	565
	13.4	Manufacturing Process Selection	568
		13.4.1 Quantity of Parts Required	569
		13.4.2 Shape and Feature Complexity	573

13.4.3	Size	576
13.4.4	Influence of Material on Process Selection	577
13.4.5	Required Quality of the Part	579
13.4.6	Cost to Manufacture	583
13.4.7	Availability, Lead Time, and Delivery	586
13.4.8	Further Information for Process Selection	586
13.5	Design for Manufacture (DFM)	593
13.5.1	DFM Guidelines	594
13.5.2	Specific Design Rules	597
13.6	Design for Assembly (DFA)	597
13.6.1	DFA Guidelines	598
13.7	Role of Standardization in DFMA	601
13.7.1	Benefits of Standardization	601
13.7.2	Achieving Part Standardization	603
13.7.3	Group Technology	603
13.8	Mistake-Proofing	606
13.8.1	Using Inspection to Find Mistakes	606
13.8.2	Frequent Mistakes	607
13.8.3	Mistake-Proofing Process	608
13.8.4	Mistake-Proofing Solutions	609
13.9	Early Estimation of Manufacturing Cost	610
13.10	Computer Methods for DFMA	617
13.10.1	DFA Analysis	617
13.10.2	Concurrent Costing with DFM	620
13.10.3	Process Modeling and Simulation	624
13.11	Design of Castings	624
13.11.1	Guidelines for the Design of Castings	626
13.11.2	Producing Quality Castings	627
13.12	Design of Forgings	629
13.12.1	DFM Guidelines for Closed-Die Forging	631
13.12.2	Computer-Aided Forging Design	632
13.13	Design for Sheet-Metal Forming	633
13.13.1	Sheet Metal Stamping	633
13.13.2	Sheet Bending	634
13.13.3	Stretching and Deep Drawing	635
13.13.4	Computer-Aided Sheet Metal Design	637
13.14	Design of Machining	637
13.14.1	Machinability	640
13.14.2	DFM Guidelines for Machining	640
13.15	Design of Welding	643
13.15.1	Joining Processes	643
13.15.2	Welding Processes	643
13.15.3	Welding Design	646
13.15.4	Cost of Joining	649
13.16	Residual Stresses in Design	650
13.16.1	Origin of Residual Stresses	650
13.16.2	Residual Stress Created by Quenching	652

	11.12	13.16.3	Other Issues Regarding Residual Stresses	654
		13.16.4	Relief of Residual Stresses	656
	13.17		Design for Heat Treatment	656
		13.17.1	Issues with Heat Treatment	657
		13.17.2	DFM for Heat Treatment	658
	13.18		Design for Plastics Processing	659
		13.18.1	Injection Molding	659
		13.18.2	Extrusion	660
		13.18.3	Blow Molding	661
		13.18.4	Rotational Molding	661
		13.18.5	Thermoforming	661
		13.18.6	Compression Molding	661
		13.18.7	Casting	662
		13.18.8	Composite Processing	662
		13.18.9	DFM Guidelines for Plastics Processing	663
	13.19		Summary	664
			New Terms and Concepts	666
			Bibliography	666
			Problems and Exercises	666
Chapter 14			Risk, Reliability, and Safety	669
	14.1		Introduction	669
		14.1.1	Regulation as a Result of Risk	671
		14.1.2	Standards	672
		14.1.3	Risk Assessment	673
	14.2		Probabilistic Approach to Design	674
		14.2.1	Basic Probability Using the Normal Distribution	675
		14.2.2	Sources of Statistical Tables	677
		14.2.3	Frequency Distributions Combining Applied Stress and Material Strength	677
		14.2.4	Variability in Material Properties	679
		14.2.5	Probabilistic Design	682
		14.2.6	Safety Factor	684
		14.2.7	Worst-Case Design	685
	14.3		Reliability Theory	685
		14.3.1	Definitions	688
		14.3.2	Constant Failure Rate	688
		14.3.3	Weibull Frequency Distribution	690
		14.3.4	Reliability with a Variable Failure Rate	692
		14.3.5	System Reliability	696
		14.3.6	Maintenance and Repair	699
		14.3.7	Further Topics	700
	14.4		Design for Reliability	701
		14.4.1	Causes of Unreliability	703
		14.4.2	Minimizing Failure	703
		14.4.3	Sources of Reliability Data	706
		14.4.4	Cost of Reliability	706

	14.5	Failure Mode and Effects Analysis (FMEA)	707
	14.5.1	Making a FMEA Analysis	710
	14.6	Defects and Failure Modes	712
	14.7.1	Causes of Hardware Failure	713
	14.7.2	Failure Modes	713
	14.7.3	Importance of Failure	715
	14.7	Design for Safety	715
	14.9.1	Potential Dangers	716
	14.9.2	Guidelines for Design for Safety	717
	14.9.3	Warning Labels	718
	14.8	Summary	718
		New Terms and Concepts	719
		Bibliography	719
		Problems and Exercises	720
Chapter 15		Quality, Robust Design, and Optimization	723
	15.1	The Concept of Total Quality	723
	15.1.1	Definition of Quality	724
	15.1.2	Deming's 14 Points	725
	15.2	Quality Control and Assurance	726
	15.2.1	Fitness for Use	726
	15.2.2	Quality-Control Concepts	727
	15.2.3	Newer Approaches to Quality Control	729
	15.2.4	Quality Assurance	729
	15.2.5	ISO 9000	730
	15.3	Quality Improvement	730
	15.3.1	Pareto chart	731
	15.3.2	Cause-and-Effect Diagram	732
	15.4	Process Capability	734
	15.4.1	Six Sigma Quality Program	738
	15.5	Statistical Process Control	739
	15.5.1	Control Charts	739
	15.5.2	Other Types of Control Charts	742
	15.5.3	Determining Process Statistics from Control Charts	743
	15.6	Taguchi Method	743
	15.6.1	Loss Function	744
	15.6.2	Noise Factors	747
	15.6.3	Signal-to-Noise Ratio	748
	15.7	Robust Design	749
	15.7.1	Parameter Design	749
	15.7.2	Tolerance Design	755
	15.8	Optimization Methods	755
	15.8.1	Optimization by Differential Calculus	758
	15.8.2	Search Methods	762
	15.8.3	Nonlinear Optimization Methods	767
	15.8.4	Other Optimization Methods	770

	15.9	Design Optimization	772
	15.10	Summary	774
		New Terms and Concepts	775
		Bibliography	775
		Problems and Exercises	775
Chapter 16		Cost Evaluation	779
	16.1	Introduction	779
	16.2	Categories of Costs	780
	16.3	Overhead Cost	784
	16.4	Activity-Based Costing	787
	16.5	Methods of Developing Cost Estimates	789
	16.5.1	Analogy	790
	16.5.2	Parametric and Factor Methods	790
	16.5.3	Detailed Methods Costing	791
	16.6	Make-Buy Decision	795
	16.7	Manufacturing Cost	796
	16.8	Product Profit Model	797
	16.8.1	Profit Improvement	801
	16.9	Refinements to Cost Analysis Methods	802
	16.9.1	Cost Indexes	802
	16.9.2	Cost-Size Relationships	803
	16.9.3	Learning Curve	805
	16.10	Design to Cost	808
	16.10.1	Order of Magnitude Estimates	809
	16.10.2	Costing in Conceptual Design	809
	16.11	Value Analysis in Costing	811
	16.12	Manufacturing Cost Models	814
	16.12.1	Machining Cost Model	814
	16.13	Life Cycle Costing	818
	16.14	Summary	822
		New Terms and Concepts	823
		Bibliography	823
		Problems and Exercises	823
Chapter 17		Legal and Ethical Issues in Engineering Design	828
		(see www.mhhe.com/dieter)	
	17.1	Introduction	828
	17.2	The Origin of Laws	829
	17.3	Contracts	830
	17.3.1	Types of Contracts	830
	17.3.2	General Form of a Contract	831
	17.3.3	Discharge and Breach of Contract	832
	17.4	Liability	833
	17.5	Tort Law	834

17.6	Product Liability	835
17.6.1	Evolution of Product Liability Law	836
17.6.2	Goals of Product Liability Law	836
17.6.3	Negligence	837
17.6.4	Strict Liability	837
17.6.5	Design Aspect of Product Liability	838
17.6.6	Business Procedures to Minimize Risk of Product Liability	839
17.6.7	Problems with Product Liability Law	839
17.7	Protecting Intellectual Property	840
17.8	The Legal and Ethical Domains	841
17.9	Codes of Ethics	843
17.9.1	Profession of Engineering	844
17.9.2	Codes of Ethics	844
17.9.3	Extremes of Ethical Behavior	848
17.10	Solving Ethical Conflicts	848
17.10.1	Whistleblowing	850
17.10.2	Case Studies	851
17.11	Summary	852
	New Terms and Concepts	854
	Bibliography	854
	Problems and Exercises	855
Chapter 18	Economic Decision Making (see www.mhhe.com/dieter)	858
18.1	Introduction	858
18.2	Mathematics of Time Value of Money	859
18.2.1	Compound Interest	859
18.2.2	Cash Flow Diagram	861
18.2.3	Uniform Annual Series	862
18.2.4	Irregular Cash Flows	865
18.3	Cost Comparison	867
18.3.1	Present Worth Analysis	867
18.3.2	Annual Cost Analysis	869
18.3.3	Capitalized Cost Analysis	870
18.3.4	Using Excel Functions for Engineering Economy Calculation	872
18.4	Depreciation	872
18.4.1	Straight-Line Depreciation	873
18.4.2	Declining-Balance Depreciation	874
18.4.3	Sum-of-Years-Digits Depreciation	874
18.4.4	Modified Accelerated Cost Recovery System (MACRS)	874
18.5	Taxes	876
18.6	Profitability Of Investments	880
18.6.1	Rate of Return	880
18.6.2	Payback Period	882

778	18.3	18.6.3 Net Present Worth	778	882
787	18.10	18.6.4 Internal Rate of Return	787	883
828		18.7 Other Aspects of Profitability	828	887
878		18.8 Inflation	878	888
878		18.9 Sensitivity and Break-Even Analysis	878	891
878		18.10 Uncertainty in Economic Analysis	878	892
		18.11 Benefit-Cost Analysis		894
Chapter 10		18.12 Summary		896
		New Terms and Concepts		898
		Bibliography		898
		Problems and Exercises		898
		Appendices		A-1
		Author & Subject Indexes		I-1
Chapter 18		Economic Decision Making		
18.1		Introduction	18.1	898
18.2		Mathematics of Time Value of Money	18.2	899
18.2.1		Compound Interest	18.2.1	899
18.2.2		Cash Flow Diagrams	18.2.2	918
18.2.3		Uniform Annual Series	18.2.3	918
18.2.4		Geometric Gradient Series	18.2.4	919
18.3		Cost Comparison	18.3	918
18.3.1		Present Worth Analysis	18.3.1	928
18.3.2		Annual Cost Analysis	18.3.2	928
18.3.3		Equivalent Cost Analysis	18.3.3	929
18.3.4		Using Formulas for Engineering Economic Calculations	18.3.4	929
Chapter 17		Legal and Ethical Considerations		
17.1		Introduction	17.1	928
17.1.1		Standards of Professional Practice	17.1.1	928
17.1.2		Design Release (Specification)	17.1.2	929
17.1.3		Standards of Care (Negligence)	17.1.3	929
17.1.4		Professional Liability Insurance	17.1.4	929
17.2		Systematic Design	17.2	930
17.3		Teamwork	17.3	930
17.4		Professional Responsibilities	17.4	930
17.5		Code of Ethics	17.5	930
17.6		Professionalism	17.6	930
17.7		Professionalism	17.7	930
17.8		Professionalism	17.8	930
17.9		Professionalism	17.9	930
17.10		Professionalism	17.10	930
17.11		Professionalism	17.11	930
17.12		Professionalism	17.12	930
17.13		Professionalism	17.13	930
17.14		Professionalism	17.14	930
17.15		Professionalism	17.15	930
17.16		Professionalism	17.16	930
17.17		Professionalism	17.17	930
17.18		Professionalism	17.18	930
17.19		Professionalism	17.19	930
17.20		Professionalism	17.20	930
17.21		Professionalism	17.21	930
17.22		Professionalism	17.22	930
17.23		Professionalism	17.23	930
17.24		Professionalism	17.24	930
17.25		Professionalism	17.25	930
17.26		Professionalism	17.26	930
17.27		Professionalism	17.27	930
17.28		Professionalism	17.28	930
17.29		Professionalism	17.29	930
17.30		Professionalism	17.30	930
17.31		Professionalism	17.31	930
17.32		Professionalism	17.32	930
17.33		Professionalism	17.33	930
17.34		Professionalism	17.34	930
17.35		Professionalism	17.35	930
17.36		Professionalism	17.36	930
17.37		Professionalism	17.37	930
17.38		Professionalism	17.38	930
17.39		Professionalism	17.39	930
17.40		Professionalism	17.40	930
17.41		Professionalism	17.41	930
17.42		Professionalism	17.42	930
17.43		Professionalism	17.43	930
17.44		Professionalism	17.44	930
17.45		Professionalism	17.45	930
17.46		Professionalism	17.46	930
17.47		Professionalism	17.47	930
17.48		Professionalism	17.48	930
17.49		Professionalism	17.49	930
17.50		Professionalism	17.50	930
17.51		Professionalism	17.51	930
17.52		Professionalism	17.52	930
17.53		Professionalism	17.53	930
17.54		Professionalism	17.54	930
17.55		Professionalism	17.55	930
17.56		Professionalism	17.56	930
17.57		Professionalism	17.57	930
17.58		Professionalism	17.58	930
17.59		Professionalism	17.59	930
17.60		Professionalism	17.60	930
17.61		Professionalism	17.61	930
17.62		Professionalism	17.62	930
17.63		Professionalism	17.63	930
17.64		Professionalism	17.64	930
17.65		Professionalism	17.65	930
17.66		Professionalism	17.66	930
17.67		Professionalism	17.67	930
17.68		Professionalism	17.68	930
17.69		Professionalism	17.69	930
17.70		Professionalism	17.70	930
17.71		Professionalism	17.71	930
17.72		Professionalism	17.72	930
17.73		Professionalism	17.73	930
17.74		Professionalism	17.74	930
17.75		Professionalism	17.75	930
17.76		Professionalism	17.76	930
17.77		Professionalism	17.77	930
17.78		Professionalism	17.78	930
17.79		Professionalism	17.79	930
17.80		Professionalism	17.80	930
17.81		Professionalism	17.81	930
17.82		Professionalism	17.82	930
17.83		Professionalism	17.83	930
17.84		Professionalism	17.84	930
17.85		Professionalism	17.85	930
17.86		Professionalism	17.86	930
17.87		Professionalism	17.87	930
17.88		Professionalism	17.88	930
17.89		Professionalism	17.89	930
17.90		Professionalism	17.90	930
17.91		Professionalism	17.91	930
17.92		Professionalism	17.92	930
17.93		Professionalism	17.93	930
17.94		Professionalism	17.94	930
17.95		Professionalism	17.95	930
17.96		Professionalism	17.96	930
17.97		Professionalism	17.97	930
17.98		Professionalism	17.98	930
17.99		Professionalism	17.99	930
17.100		Professionalism	17.100	930