

CONTENTS

Preface xi

CHAPTER 1 **Why Study the Design Process? 1**

- 1.1 Introduction 1
- 1.2 Measuring the Design Process with Product Cost, Quality, and Time to Market 3
- 1.3 The History of the Design Process 8
- 1.4 The Life of a Product 10
- 1.5 The Many Solutions for Design Problems 15
- 1.6 The Basic Actions of Problem Solving 17
- 1.7 Knowledge and Learning During Design 19
- 1.8 Design for Sustainability 20
- 1.9 Summary 21
- 1.10 Sources 22
- 1.11 Exercises 22

CHAPTER 2 **Understanding Mechanical Design 25**

- 2.1 Introduction 25
- 2.2 Importance of Product Function, Behavior, and Performance 28
- 2.3 Mechanical Design Languages and Abstraction 30
- 2.4 Different Types of Mechanical Design Problems 33
- 2.5 Constraints, Goals, and Design Decisions 40
- 2.6 Product Decomposition 41
- 2.7 Summary 44

- 2.8 Sources 44
- 2.9 Exercises 45
- 2.10 On the Web 45

CHAPTER 3 **Designers and Design Teams 47**

- 3.1 Introduction 47
- 3.2 The Individual Designer: A Model of Human Information Processing 48
- 3.3 Mental Processes That Occur During Design 56
- 3.4 Characteristics of Creators 64
- 3.5 The Structure of Design Teams 66
- 3.6 Building Design Team Performance 72
- 3.7 Summary 78
- 3.8 Sources 78
- 3.9 Exercises 79
- 3.10 On the Web 80

CHAPTER 4 **The Design Process and Product Discovery 81**

- 4.1 Introduction 81
- 4.2 Overview of the Design Process 81
- 4.3 Designing Quality into Products 92
- 4.4 Product Discovery 95
- 4.5 Choosing a Project 101
- 4.6 Summary 109
- 4.7 Sources 110
- 4.8 Exercises 110
- 4.9 On the Web 110

CHAPTER 5**Planning for Design** 111

- 5.1 Introduction 111
- 5.2 Types of Project Plans 113
- 5.3 Planning for Deliverables—
The Development of Information 117
- 5.4 Building a Plan 126
- 5.5 Design Plan Examples 134
- 5.6 Communication During the
Design Process 137
- 5.7 Summary 141
- 5.8 Sources 141
- 5.9 Exercises 142
- 5.10 On the Web 142

CHAPTER 6**Understanding the Problem and
the Development of Engineering
Specifications** 143

- 6.1 Introduction 143
- 6.2 Step 1: Identify the Customers:
Who Are They? 151
- 6.3 Step 2: Determine the Customers'
Requirements: *What* Do the Customers
Want? 151
- 6.4 Step 3: Determine Relative Importance of the
Requirements: *Who Versus What* 155
- 6.5 Step 4: Identify and Evaluate the Competition:
How Satisfied Are the Customers *Now*? 157
- 6.6 Step 5: Generate Engineering
Specifications: *How* Will the Customers'
Requirement Be Met? 158
- 6.7 Step 6: Relate Customers' Requirements to
Engineering Specifications: *How* to Measure
What? 163
- 6.8 Step 7: Set Engineering Specification Targets
and Importance: *How* Much Is Good
Enough? 164

- 6.9 Step 8: Identify Relationships Between
Engineering Specifications: How Are the
Hows Dependent on Each Other? 166
- 6.10 Further Comments on QFD 168
- 6.11 Summary 169
- 6.12 Sources 169
- 6.13 Exercises 169
- 6.14 On the Web 170

CHAPTER 7**Concept Generation** 171

- 7.1 Introduction 171
- 7.2 Understanding the Function of Existing
Devices 176
- 7.3 A Technique for Designing with Function 181
- 7.4 Basic Methods of Generating Concepts 189
- 7.5 Patents as a Source of Ideas 194
- 7.6 Using Contradictions to Generate Ideas 197
- 7.7 The Theory of Inventive Machines, TRIZ 201
- 7.8 Building a Morphology 204
- 7.9 Other Important Concerns During Concept
Generation 208
- 7.10 Summary 209
- 7.11 Sources 209
- 7.12 Exercises 211
- 7.13 On the Web 211

CHAPTER 8**Concept Evaluation and
Selection** 213

- 8.1 Introduction 213
- 8.2 Concept Evaluation Information 215
- 8.3 Feasibility Evaluations 218
- 8.4 Technology Readiness 219
- 8.5 The Decision Matrix—Pugh's Method 221
- 8.6 Product, Project, and Decision Risk 226

- 8.7 Robust Decision Making 233
- 8.8 Summary 239
- 8.9 Sources 239
- 8.10 Exercises 240
- 8.11 On the Web 240

CHAPTER 9

Product Generation 241

- 9.1 Introduction 241
- 9.2 BOMs 245
- 9.3 Form Generation 246
- 9.4 Materials and Process Selection 264
- 9.5 Vendor Development 266
- 9.6 Generating a Suspension Design for the Marin 2008 Mount Vision Pro Bicycle 269
- 9.7 Summary 276
- 9.8 Sources 276
- 9.9 Exercises 277
- 9.10 On the Web 278

CHAPTER 10

Product Evaluation for Performance and the Effects of Variation 279

- 10.1 Introduction 279
- 10.2 Monitoring Functional Change 280
- 10.3 The Goals of Performance Evaluation 281
- 10.4 Trade-Off Management 284
- 10.5 Accuracy, Variation, and Noise 286
- 10.6 Modeling for Performance Evaluation 292
- 10.7 Tolerance Analysis 296
- 10.8 Sensitivity Analysis 302
- 10.9 Robust Design by Analysis 305
- 10.10 Robust Design Through Testing 308
- 10.11 Summary 313

- 10.12 Sources 313
- 10.13 Exercises 314

CHAPTER 11

Product Evaluation: Design For Cost, Manufacture, Assembly, and Other Measures 315

- 11.1 Introduction 315
- 11.2 DFC—Design For Cost 315
- 11.3 DFV—Design For Value 325
- 11.4 DFM—Design For Manufacture 328
- 11.5 DFA—Design-For-Assembly Evaluation 329
- 11.6 DFR—Design For Reliability 350
- 11.7 DFT and DFM—Design For Test and Maintenance 357
- 11.8 DFE—Design For the Environment 358
- 11.9 Summary 360
- 11.10 Sources 361
- 11.11 Exercises 361
- 11.12 On the Web 362

CHAPTER 12

Wrapping Up the Design Process and Supporting the Product 363

- 12.1 Introduction 363
- 12.2 Design Documentation and Communication 366
- 12.3 Support 368
- 12.4 Engineering Changes 370
- 12.5 Patent Applications 371
- 12.6 Design for End of Life 375
- 12.7 Sources 378
- 12.8 On the Web 378

APPENDIX A**Properties of 25 Materials Most Commonly Used in Mechanical Design** 379

- A.1 Introduction 379
- A.2 Properties of the Most Commonly Used Materials 380
- A.3 Materials Used in Common Items 393
- A.4 Sources 394

APPENDIX B**Normal Probability** 397

- B.1 Introduction 397
- B.2 Other Measures 401

APPENDIX C**The Factor of Safety as a Design Variable** 403

- C.1 Introduction 403

- C.2 The Classical Rule-of-Thumb Factor of Safety 405

- C.3 The Statistical, Reliability-Based, Factor of Safety 406

- C.4 Sources 414

APPENDIX D**Human Factors in Design** 415

- D.1 Introduction 415

- D.2 The Human in the Workspace 416

- D.3 The Human as Source of Power 419

- D.4 The Human as Sensor and Controller 419

- D.5 Sources 426

Index 427