

CONTENTS

Preface ix

About the Author xiv

CHAPTER 1

Introduction 1

- 1.1 Introduction to System Dynamics 2
 - 1.2 Units 7
 - 1.3 Developing Linear Models 9
 - 1.4 Function Identification and Parameter Estimation 15
 - 1.5 Fitting Models to Scattered Data 23
 - 1.6 MATLAB and the Least-Squares Method 29
 - 1.7 Chapter Review 37
- Problems 37

CHAPTER 2

Modeling of Rigid-Body Mechanical Systems 42

- 2.1 Translational Motion 43
 - 2.2 Rotation About a Fixed Axis 48
 - 2.3 Equivalent Mass and Inertia 55
 - 2.4 General Planar Motion 61
 - 2.5 Chapter Review 70
- Problems 70

CHAPTER 3

Solution Methods for Dynamic Models 80

- 3.1 Differential Equations 81
- 3.2 Response Types and Stability 92
- 3.3 The Laplace Transform Method 101
- 3.4 Transfer Functions 115
- 3.5 Partial-Fraction Expansion 118
- 3.6 The Impulse and Numerator Dynamics 128
- 3.7 Additional Examples 134
- 3.8 Computing Expansion Coefficients with MATLAB 139

- 3.9 Transfer-Function Analysis in MATLAB 142
 - 3.10 Chapter Review 148
- Problems 150

CHAPTER 4

Spring and Damper Elements in Mechanical Systems 157

- 4.1 Spring Elements 158
 - 4.2 Modeling Mass-Spring Systems 167
 - 4.3 Energy Methods 176
 - 4.4 Damping Elements 184
 - 4.5 Additional Modeling Examples 193
 - 4.6 Collisions and Impulse Response 205
 - 4.7 MATLAB Applications 208
 - 4.8 Chapter Review 212
- Problems 213

CHAPTER 5

State-Variable Models and Simulation Methods 224

- 5.1 State-Variable Models 225
 - 5.2 State-Variable Methods with MATLAB 236
 - 5.3 The MATLAB ode Functions 242
 - 5.4 Simulink and Linear Models 249
 - 5.5 Simulink and Nonlinear Models 255
 - 5.6 Chapter Review 263
- Problems 264

CHAPTER 6

Electrical and Electromechanical Systems 272

- 6.1 Electrical Elements 273
- 6.2 Circuit Examples 279
- 6.3 Impedance and Amplifiers 289
- 6.4 Electric Motors 297
- 6.5 Analysis of Motor Performance 304

- 6.6 Sensors and Electroacoustic Devices 314
- 6.7 MATLAB Applications 317
- 6.8 Simulink Applications 325
- 6.9 Chapter Review 328
- Problems 329

CHAPTER 7

Fluid and Thermal Systems 339

- Part I. Fluid Systems 340
- 7.1 Conservation of Mass 340
- 7.2 Fluid Capacitance 345
- 7.3 Fluid Resistance 350
- 7.4 Dynamic Models of Hydraulic Systems 355
- 7.5 Pneumatic Systems 369
- Part II. Thermal Systems 372
- 7.6 Thermal Capacitance 372
- 7.7 Thermal Resistance 374
- 7.8 Dynamic Models of Thermal Systems 383
- Part III. MATLAB and Simulink Applications 391
- 7.9 MATLAB Applications 391
- 7.10 Simulink Applications 395
- 7.11 Chapter Review 400
- Problems 400

CHAPTER 8

System Analysis in the Frequency Domain 415

- 8.1 Frequency Response of First-Order Systems 416
- 8.2 Frequency Response of Higher-Order Systems 432
- 8.3 Frequency Response Examples 442
- 8.4 Filtering Properties of Dynamic Systems 453
- 8.5 System Identification from Frequency Response 461
- 8.6 Frequency Response Analysis Using MATLAB 466
- 8.7 Chapter Review 469
- Problems 470

CHAPTER 9

Transient Response and Block Diagram Models 480

- 9.1 Response of First-Order Systems 482
- 9.2 Response of Second-Order Systems 490
- 9.3 Description and Specification of Step Response 498
- 9.4 Parameter Estimation in the Time Domain 507
- 9.5 Introduction to Block Diagrams 516
- 9.6 Modeling Systems with Block Diagrams 523
- 9.7 MATLAB Applications 532
- 9.8 Simulink Applications 533
- 9.9 Chapter Review 536
- Problems 537

CHAPTER 10

Introduction to Feedback Control Systems 546

- 10.1 Closed-Loop Control 547
- 10.2 Control System Terminology 550
- 10.3 Modeling Control Systems 551
- 10.4 The PID Control Algorithm 565
- 10.5 Control System Analysis 572
- 10.6 Controlling First-Order Plants 577
- 10.7 Controlling Second-Order Plants 587
- 10.8 Additional Examples 595
- 10.9 MATLAB Applications 609
- 10.10 Simulink Applications 615
- 10.11 Chapter Review 619
- Problems 619

CHAPTER 11

Control System Design and the Root Locus Plot 632

- 11.1 Root Locus Plots 633
- 11.2 Design Using the Root Locus Plot 638
- 11.3 State-Variable Feedback 665
- 11.4 Tuning Controllers 674
- 11.5 Saturation and Reset Windup 680
- 11.6 MATLAB Applications 687

11.7 Simulink Applications 693

11.8 Chapter Review 695

Problems 696

CHAPTER 12

Compensator Design and the Bode Plot 713

12.1 Series Compensation 714

12.2 Design Using the Bode Plot 733

12.3 MATLAB Applications 748

12.4 Simulink Applications 752

12.5 Chapter Review 753

Problems 753

CHAPTER 13

Vibration Applications 763

13.1 Base Excitation 764

13.2 Rotating Unbalance 769

13.3 Vibration Absorbers 775

13.4 Modes of Vibrating Systems 783

13.5 Active Vibration Control 792

13.6 Nonlinear Vibration 796

13.7 MATLAB Applications 805

13.8 Chapter Review 807

Problems 808

A P P E N D I C E S

A. Guide to Selected MATLAB Commands and Functions 815

B. Fourier Series 822

C. Introduction to MATLAB (on the text website)

D. Numerical Methods (on the text website)

Glossary 824

Index 827