CONTENTS

1	THE MANUFACTURING SYSTEM	1
	1.1 Evolution of the Enterprise1.2 Classification of Basic Manufacturing	1
	1.3 Design, Materials, and Production	
	1.4 English Metric Practice	10 11
	Questions	11
	Problems More Difficult Problems	12
	Practical Application	12
	Case Study: Professor Smith	12
2	NATURE AND PROPERTIES OF MATERIALS	14
	2.1 Classification of Materials	14
	2.2 Structure of Materials	16
	2.3 Solidification of Metals and Alloys	18
	2.4 Physical Characteristics of Materials	20
	2.5 Engineering Properties of Materials	22
	2.6 Other Methods for Material Evaluation	27
	2.7 Impact and Endurance Testing	27 31
	2.8 Composites and New Materials	33
	Questions Problems	3.
	More Difficult Problems	3
	Practical Application	3.
	Case Study: The Unknown Material	3
3	PRODUCTION OF FERROUS METALS	36
	3.1 Production of Pig Iron	30
	3.2 Furnaces for Steelmaking and Ironmaking	39
	3.3 Steel Ingots and Strand Casting	4
	3.4 Refining Furnaces and Vessels	4
	3.5 Energy Required for Melting	50
	3.6 Ferrous Metals	5 5:
	3.7 Effects of Chemical Elements on Cast Iron	5. 5.
	Questions Problems	5
	More Difficult Problems	6
	Practical Application	6
	Case Study: Melting Cost Estimate for a Foundry	6
4	PRODUCTION OF NONFERROUS METALS	62
	4.1 Properties	6
	4.2 Nonferrous Metals	6

CONTENTS

	 4.3 Production of Aluminum 4.4 Production of Magnesium 4.5 Production of Copper 4.6 Production of Lead 4.7 Casting Nonferrous Materials 4.8 Wrought Alloys 4.9 Die-Casting Alloys 4.10 Continuous Casting of Aluminum Questions Problems Practical Application Case Study: Profit Analysis 	64 65 66 67 69 71 73 74 75 75
5	FOUNDRY PROCESSES	77
	 5.1 Sand Castings and Molding Procedures 5.2 Gating System and Solidification Characteristics 5.3 Patterns 5.4 Removable Patterns 5.5 Sand Technology 5.6 Cores 5.7 Molding Equipment 5.8 Pouring and Cleaning Castings Questions Problems More Difficult Problems Practical Application Case Study: Foundry Business 	77 82 83 86 87 92 94 96 98 99 100 100
6	CONTEMPORARY CASTING PROCESSES	101
	 6.1 Metal Molds 6.2 Precision or Investment Casting 6.3 Continuous Casting Questions Problems Practical Application Case Study: Water Pipe 	101 111 119 121 122 122 123
7	BASIC MACHINE TOOL ELEMENTS	124

хi

8	METAL CUTTING	148
	 8.1 Metal-Cutting Theory 8.2 Metal-Cutting Tools 8.3 Chip Shape and Formation 8.4 Coolants 	148 156 162 165
	8.5 Machinability8.6 Tool Life8.7 Surface Finish	166 168 171
	8.8 Cutting Speeds and Feeds Questions Problems	173 175 176
	More Difficult Problems Practical Application Case Study: Advanced Job Shop	178 179 179
9	TURNING, DRILLING, BORING, AND MILLING MACHINE TOOLS	181
	9.1 Lathe Group9.2 Drill Press Group	182 191
	9.3 Boring Machine Tool Group	194
	9.4 Milling Machine Group9.5 Transfer-Type Production Machine Group	197 201
	9.5 Transfer-Type Production Machine Group Questions	202
	Practical Application	203
	Case Study: Airframe Part, Part Number 50532	203
10	SAWING, BROACHING, SHAPING, AND PLANING	205
	10.1 Metal Sawing Machines	205
	10.2 Broaching10.3 Shapers	210 216
	10.4 Planers	218
	Questions	220
	Problems Practical Application	221 221
	Case Study: ACME Broach Company	222
11	MACHINING CUTTERS, OPERATIONS, AND PERFORMANCE	223
	11.1 Cutting Tools	223
	11.2 Operations	240
	11.3 Performance Questions	250 257
	Problems	258
	More Difficult Problems	259 260
	Practical Application Case Study: Numerical Control Lathe Machined Forging	260
12	GRINDING AND ABRASIVE PROCESSES	263
	12.1 Grinding and Abrasive Practices	263
	12.2 Processes	265

xii	CONTENTS	
	12.3 Abrasives, Grinding Wheels, and Stones Questions Problems Practical Application Case Study: Karlton Grinding Company	278 284 285 286 286
13	WELDING AND JOINING PROCESSES	287
	 13.1 Fundamentals of a Welding System 13.2 Arc Welding Processes 13.3 Resistance Welding Processes 13.4 Oxyfuel Gas Welding Processes 13.5 Solid-State Welding Processes 13.6 Special Welding Processes 13.7 Welding Quality and Safety 13.8 Other Joining Processes 13.9 Allied Processes Questions Problems More Difficult Problems Practical Application Case Study: Welding Spacecraft Heat Shields 	287 289 295 302 305 310 314 315 318 321 322 322 322 323
14	HOT WORKING OF METAL	324
17	14.1 Plastic Deformation 14.2 Rolling 14.3 Forging 14.4 Extrusion 14.5 Pipe and Tube Manufacture 14.6 Drawing 14.7 Special Methods Questions Problems Practical Application Case Study: The Yungk Company	324 326 328 335 336 340 340 343 343 344 344
15	COLD WORKING OF METAL	345
15	 15.1 Cold Working 15.2 Processes 15.3 High-Energy Rate Forming 15.4 Other Methods Questions Problems Practical Application Case Study: Centrifugal Fan Fatigue Problem 	345 347 360 364 366 367 368 368
16	PRESSWORKING AND OPERATIONS	370
	 16.1 Presses 16.2 Drive Mechanisms for Presses 16.3 Feed Mechanisms 	370 380 381

		CONTENTS	XIII
	16.4 Operations 16.5 Efficient Use of Materials Questions Problems More Difficult Problems Practical Application Case Study: Twelve-Ounce Beverage Container Company		382 392 394 394 396 397
17	HEAT TREATING		399
	17.1 Iron-Iron Carbide Diagram 17.2 Grain Size 17.3 Isothermal Transformation Diagrams 17.4 Hardening 17.5 Tempering 17.6 Annealing 17.7 Normalizing and Spheroidizing 17.8 Surface Hardening 17.9 Hardening Nonferrous Materials 17.10 Furnaces for Heat Treating Questions Problems Practical Application Case Study: Heat Treating		399 404 405 406 409 412 413 414 418 419 421 422 422
18	PLASTIC MATERIALS AND PROCESSES		423
	18.1 Raw Materials and Properties 18.2 Thermosetting Compounds 18.3 Thermoplastic Compounds 18.4 Processing Plastics 18.5 Processing Thermosets 18.6 Processing Thermoplastics 18.7 Other Processes 18.8 Design Fundamentals Questions Problems More Difficult Problems Practical Application Case Study: The General Plastics Company		423 426 428 431 432 437 445 447 449 450 451
19	ELECTRONIC FABRICATION		453
	 19.1 Components and Definitions 19.2 From Components to Products 19.3 The Soldering System 19.4 Solder Joint Design 19.5 Thermal Characteristics 19.6 Electromagnetic Interference and Electrostatic Discharges 19.7 Cleaning Process 19.8 Emerging Packaging Technologies Questions Problems 		453 457 458 464 467 469 470 472 474

	More Difficult Problems Practical Application Case Study: The Hot Chip Problem	476 476 477
20	NONTRADITIONAL PROCESSES AND POWDER METALLURGY	478
	20.1 Special Machining Processes 20.2 Temperature Machining 20.3 Chemical Energy 20.4 Electroforming 20.5 Metal Spraying 20.6 Powder Metallurgy Questions Problems More Difficult Problems Practical Application Case Study: Electrochemical Machining	478 486 488 492 494 496 507 508 508 509
21	THREAD AND GEAR WORKING	510
	 21.1 Screw Threads 21.2 Processes for Making Threads 21.3 Gears 21.4 Processes for Making Gears 21.5 Finishing Operations for Gears Questions Problems Practical Application Case Study: Lotus Gear Works 	510 513 520 524 532 532 533 534
22	FINISH PROCESSES	535
	 22.1 Mechanical Surface Preparation 22.2 Chemical Surface Preparation 22.3 Plating Procedures 22.4 Metal Deposition Design Considerations 22.5 Thickness Testing 22.6 Other Metallic Coatings Questions Problems More Difficult Problems Practical Application Case Study: Strike One 	535 539 543 547 549 551 554 554 555 555
23	OPERATIONS PLANNING	556
	 23.1 Business Objectives 23.2 Systems Analysis 23.3 Operations Sheet Preparation 23.4 Information 23.5 Sequence of Operations 23.6 Pinion Operations Sheet 	556 557 558 560 560 561

		CONTENTS X	٧
	23.7 Welded Steel Assembly Operations Sheet 23.8 Trends Questions Problems More Difficult Problems Practical Application Case Study: Super Snap Ring	564 566 567 570 570 577	6 7 0 0
24	GEOMETRIC DIMENSIONING AND TOLERANCING	572	2
	 24.1 Dimension and Tolerance 24.2 Symbols 24.3 Applications 24.4 CAD and CAM 24.5 Appropriate Tolerances Questions Problems More Difficult Problems Practical Application Case Study: Minimum Cost Tolerances for Gear Train 	577 577 587 587 588 588 588 588 588	3 7 2 2 5 5 7 8
25	TOOL DESIGN	590	0
	 25.1 Practices 25.2 Workholding 25.3 Fixtures and Jigs 25.4 Pressworking Tools 25.5 Welding Tools 25.6 Molding Tools 25.7 Inspection Gages 25.8 Stereolithography Questions Problems More Difficult Problems Practical Application Case Study: Oil Filter Wrench 	599 599 599 600 600 600 600 601 611 611	34612488824
26	METROLOGY AND TESTING 26.1 Fundamentals of Metrology 26.2 Linear Measurements 26.3 Angular Measurements 26.4 Surface Measurements 26.5 Electrical Measurements 26.6 Gages and Other Measurements 26.7 Nondestructive Inspection 26.8 Statistics and Uncertainty Questions Problems More Difficult Problems Practical Application Case Study: The Swing Frequency	615 617 627 627 627 627 63 63 64 64 64 64	582378580011
	, , ,		

27	QUALITY SYSTEMS	643
	27.1 Quality Systems and Process Improvement	643
	27.2 Process Variation	646
	27.3 Control Charts for Variable Data	648
	27.4 Control Charts for Attribute Data	653
	27.5 Process Capability Analysis27.6 Statistical Design of Experiments	655 657
	27.6 Statistical Design of Experiments27.7 Reliability Theory	660
	Questions	662
	Problems	662
	More Difficult Problems	663
	Practical Application	665
	Case Study: U Chart for Control	665
28	COMPUTER NUMERICAL CONTROL SYSTEMS	666
	28.1 Types of CNC Systems	666
	28.2 Evolution of CNC Machine Tools	667
	28.3 Types of Controllers	668
	28.4 CNC Operational Sequence	671
	28.5 Rectangular Coordinates	673
	28.6 Program Formatting and Coding	675
	28.7 Types of Programming and Interpolation28.8 High-Level Languages	679 681
	28.8 High-Level Languages28.9 Emergent Control Methods	682
	Questions	683
	Problems	684
	More Difficult Problems	684
	Practical Application	685
	Case Study: Drilled Plate	685
29	PROCESS AUTOMATION	687
	29.1 Simulation	687
	29.2 Automation	688
	29.3 Robots	697
	29.4 Group Technology	707
	29.5 Flexible Manufacturing Systems	709
	29.6 Other Production Systems	711
	29.7 Economic Considerations	716
	Questions Problems	717 718
	More Difficult Problems	718
	Practical Application	719
	Case Study: The Round Plate Company	719
30	OPERATOR-MACHINE SYSTEMS	720
	30.1 Operator-Machine Systems Structure	720
	30.2 Ergonomics	721
	30.3 Designing Ergonomic Tools	723
	30.4 Redesigning Workstations	734

		CONTENTS	xvii
	30.5 Job Analysis 30.6 Systems to Measure Injury Frequency		737 740 742
	30.7 Impact of Intelligent Systems Questions		744
	Problems		744
	More Difficult Problems		74 5
	Practical Application		746
	Case Study: CTD Costs and Frequency in Electronic Parts Manufacturing		746
31	COST ESTIMATING		747
	31.1 Classical Metal Cutting Cost Analysis		747
	31.2 Industrial Cost Estimating Practices		753
	31.3 Estimating Setup and Cycle Time		754
	31.4 Material Estimating		756
	Questions		759
	Problems		759 761
	More Difficult Problems		761 761
	Practical Application Case Study: Pinion		761
Bib	liography		762
Pho	oto Credits		763
Ind	lex		766