

CONTENTS

Preface.....	xv
Acknowledgments.....	xviii
From the Authors.....	xx
About the Authors.....	xxi

SECTION 1

Introduction to Machining..... 3

Unit 1 Introduction to Machining..... 4

Learning Objectives.....	4
Key Terms	4
Introduction.....	5
Machining Defined.....	5
History of Machining.....	5
<i>Simple Machine Tools</i>	5
<i>Industrial Revolution</i>	6
<i>20th-Century Machining</i>	7
The Role of Machining in Society.....	8
<i>People, Manufacturing, and Machining</i>	8
Major Machine Tools.....	11
<i>Sawing Machines</i>	11
<i>The Drill Press</i>	13
<i>The Lathe</i>	13
<i>The Milling Machine</i>	13
<i>Abrasive Machining</i>	15
<i>Electrical Discharge Machining</i>	16
<i>Laser Machining</i>	16
<i>Water Jet Machining</i>	17
Summary	19
Review Questions.....	19

Unit 2 Careers in Machining..... 20

Learning Objectives.....	20
Key Terms	20
Introduction.....	21
Modern Machining Careers	21
<i>Operator</i>	21
<i>Set-up Technician</i>	21

Conventional Machinist.....	22
CNC Machinist	22
Programmer.....	24
Die Maker, Mold Maker, Toolmaker.....	24
Supervisory Positions.....	25
Related Careers	25
<i>Mechanical Designer</i>	25
<i>Engineering Positions</i>	25
<i>Machine Tool Service Technician</i>	26
<i>Quality Control Technician/Inspector</i>	26
<i>Industrial Salesperson</i>	27
Summary	27
Review Questions	27

Unit 3 Workplace Skills 28 |

Learning Objectives.....	28
Key Terms	28
Introduction.....	29
Personal Skills.....	29
<i>Mechanical Aptitude</i>	29
<i>Manual Dexterity and Eye-Hand Coordination</i>	29
<i>Problem-Solving, Troubleshooting, and Decision-Making Skills</i>	29
<i>Focus and Concentration with Attention to Detail</i>	29
<i>Persistence and Patience</i>	30
<i>Personal Responsibility and Reliability</i>	30
<i>Ability to Perform Multi-Step Processes</i>	30
<i>Ability to Use Technical Reference Materials</i>	30
<i>Interpersonal Skills</i>	30
<i>Significant Memory Use</i>	30
Technical Skills	30
<i>Ability to Interpret Engineering Drawings</i>	30
<i>Knowledge of English and Metric Systems of Measurement</i>	31
<i>Proficient Math Skills</i>	31
<i>Use of Hand Tools, Measuring Tools, and Machine and Cutting Tools</i>	31
<i>Understanding of Metals and Other Materials and Their Properties</i>	31

<i>Knowledge and Skill in the Use of Computer Technology</i>	31	SDS.....	56
Training Opportunities/Methods	31	Fire Safety	60
<i>Secondary School (High School) Programs</i>	31	<i>The Fire Triangle</i>	60
<i>Post-Secondary Training</i>	32	<i>Fire Extinguishers</i>	60
<i>Employer-Provided Training</i>	32	Safety Documentation	61
<i>Apprenticeships</i>	32	Summary	62
NIMS	33	Review Questions	63
Job Seeking	33		
<i>Career Plan</i>	33		
<i>Resume</i>	33		
<i>References</i>	36		
<i>Cover Letter</i>	36		
<i>Career Portfolio</i>	38		
<i>Finding Opportunities</i>	38		
<i>Interviewing</i>	38		
Summary	40		
Review Questions	40		
 SECTION 2			
Measurement, Materials, and Safety	42		
Unit 1 Introduction to Safety	44		
Learning Objectives	44	Learning Objectives	64
Key Terms	44	Key Terms	65
Introduction	45	Introduction	65
General Safety Guidelines	45	Measurement Systems of the Machining World	65
<i>OSHA and NIOSH</i>	45	<i>The English System (Inches)</i>	65
General Clothing for a Machining Environment	46	<i>The Metric System or SI</i>	65
Personal Protective Equipment (PPE)	46		
<i>Eye Protection</i>	47	Machining Mathematic Concepts and Operations	65
<i>Hearing Protection</i>	47	<i>Fractional Operations</i>	65
<i>Respirators</i>	48	<i>Fractional/Decimal Conversion</i>	68
<i>Gloves</i>	48	<i>Basic Algebra</i>	68
<i>Hard Hats</i>	49	<i>Ratios and Proportions</i>	70
Housekeeping	49	<i>English/Metric and Metric/English Conversions</i>	70
Guards and Barriers	50	<i>Basic Geometry</i>	71
Handling and Lifting	51	<i>Angles</i>	72
Compressed Air Safety	51	<i>Cartesian Coordinates</i>	76
Lockout/Tagout	52	<i>Basic Trigonometry</i>	77
<i>Tagout</i>	52	Summary	81
<i>Lockout</i>	52	Review Questions	82
Hazardous Materials	53		
<i>Hazardous Material Labeling</i>	53		
 Unit 2 Measurement Systems and Machine Tool Math Overview			
		Learning Objectives	64
		Key Terms	65
		Introduction	65
		Measurement Systems of the Machining World	65
		<i>The English System (Inches)</i>	65
		<i>The Metric System or SI</i>	65
		Machining Mathematic Concepts and Operations	65
		<i>Fractional Operations</i>	65
		<i>Fractional/Decimal Conversion</i>	68
		<i>Basic Algebra</i>	68
		<i>Ratios and Proportions</i>	70
		<i>English/Metric and Metric/English Conversions</i>	70
		<i>Basic Geometry</i>	71
		<i>Angles</i>	72
		<i>Cartesian Coordinates</i>	76
		<i>Basic Trigonometry</i>	77
		Summary	81
		Review Questions	82
 Unit 3 Semi-Precision Measurement			
		Learning Objectives	83
		Key Terms	83
		Introduction	84
		What Is Semi-Precision Measurement?	84
		Rules	84
		<i>Reading English Rules</i>	85
		<i>Reading Metric Rules</i>	86
		Calipers	88
		Adjustable Squares	91
		<i>The Combination Set</i>	91

Angular Measurement	92	Precision Transfer or Helper-Type Measuring Tools.....	133
<i>Protractors</i>	92	<i>Small Hole Gages</i>	133
<i>Bevels</i>	92	<i>Telescoping Gages</i>	134
<i>Die Maker's Square</i>	95	<i>Adjustable Parallels</i>	134
Fixed Gages	95	Dial and Digital Indicators.....	135
<i>Radius and Fillet Gages</i>	95	<i>Applications of Plunge-Type Indicators</i>	136
<i>Angle Gages</i>	96	<i>Applications of Test Indicators</i>	136
<i>Screw Pitch Gage</i>	96	Sine Tools.....	140
Summary	97	<i>Sine Bars and Sine Blocks</i>	140
Review Questions	97	<i>Sine Plates</i>	140
Unit 4 Precision Measurement	99	<i>Sine Vises</i>	141
Learning Objectives.....	99	Surface Finish Measurement	141
Key Terms	100	<i>Surface Roughness Comparator</i>	143
Introduction	100	<i>Profilometer</i>	143
What is Precision Measurement?.....	100	Optical Comparators	143
Care of Precision Tools.....	100	Toolmaker's Microscope.....	144
Straight Edges.....	101	Coordinate Measuring Machine	145
Precision Fixed Gages.....	101	Summary	145
<i>Thickness Gages</i>	101	Review Questions	146
<i>Pin or Plug Gages</i>	101		
<i>Ring Gages</i>	103		
<i>Snap Gages</i>	105		
Surface Plates	106	Unit 5 Quality Assurance, Process Planning, and Quality Control	147
Solid Squares.....	107	Learning Objectives.....	147
Gage Blocks.....	108	Key Terms	147
<i>Selecting Gage Blocks for Builds</i>	109	Introduction	148
Vernier Measuring Tools	111	Quality Assurance	148
<i>Vernier Calipers</i>	111	The Process Plan	148
<i>Vernier Height Gage</i>	111	<i>Material Selection</i>	148
<i>Vernier Depth Gage</i>	112	<i>Machine Selection and Workholding</i>	148
<i>Vernier Gear Tooth Caliper</i>	112	<i>Tooling Selection</i>	148
<i>Vernier Protractor</i>	112	<i>Speed and Feed Calculation</i>	150
<i>Reading Vernier Scales</i>	113	<i>Other Information</i>	150
Micrometers	117	Quality Control	150
<i>Outside Micrometer Caliper</i>	117	<i>Sampling Plan</i>	150
<i>Reading Outside Micrometer Calipers</i>	121	<i>Inspection Plan</i>	150
<i>Calibration of the Outside Micrometer Caliper</i>	122	<i>Statistical Process Control (SPC)</i>	150
<i>Inside Micrometers</i>	125	Summary	156
<i>Depth Micrometers</i>	127	Review Questions	156
Dial and Digital Measuring Tools	128		
<i>Dial and Digital Calipers</i>	128		
<i>Dial and Digital Height Gages</i>	130		
<i>Dial and Digital Depth Gages</i>	130		
<i>Dial and Digital Bore Gages</i>	132		
Unit 6 Metal Composition and Classification	157		
Learning Objectives.....	157		
Key Terms	157		

Contents

Introduction	158
Ferrous Metals.....	158
<i>Wrought Iron</i>	158
<i>Plain Carbon Steels.....</i>	158
<i>Alloy Steels</i>	159
<i>Tool Steels.....</i>	160
<i>Cast Iron.....</i>	164
<i>Stainless Steels.....</i>	164
Nonferrous Metals.....	167
<i>Aluminum Alloys.....</i>	167
<i>Magnesium Alloys.....</i>	168
<i>Copper Alloys.....</i>	169
<i>Titanium Alloys.....</i>	170
<i>Superalloys.....</i>	170
Summary	174
Review Questions	174
 Unit 7 Heat Treatment of Metals.....	175
Learning Objectives.....	175
Key Terms	175
Introduction	176
Hardening	176
<i>Direct Hardening.....</i>	176
<i>Surface Hardening.....</i>	176
<i>Case Hardening.....</i>	176
Tempering	179
Annealing	179
Normalizing	179
Heat Treatment of Nonferrous Metals.....	179
<i>Aluminum Alloys.....</i>	179
Heat-Treating Furnaces	180
<i>Box Furnaces.....</i>	180
<i>Production and Specialty Furnaces.....</i>	180
<i>Atmospheric Furnaces</i>	181
<i>Furnace Controls.....</i>	182
Heat-Treatment Safety.....	182
Hardness Scales and Testing	182
<i>Rockwell Hardness Scales.....</i>	182
<i>Brinell Hardness Scale.....</i>	186
<i>Cross-Reference of Brinell and Rockwell Hardness Values.....</i>	188
Summary	188
Review Questions	189
 Unit 8 Maintenance, Lubrication, and Cutting Fluid Overview	190
Learning Objectives.....	190
Key Terms	190
Maintenance	191
<i>Lubrication</i>	191
<i>Moving Parts and Wear Surfaces</i>	193
Cutting Fluids.....	193
<i>Oil-Based Cutting Fluids.....</i>	194
<i>Chemical-Based Cutting Fluids</i>	195
<i>Measuring Cutting Fluid Mixtures.....</i>	196
<i>Refractometer</i>	196
<i>Cold Air Guns</i>	196
<i>Solid and Semi-Solid Cutting Compounds</i>	196
<i>Methods of Application</i>	197
Summary	198
Review Questions	199
 SECTION 3	
Job Planning, Benchwork, and Layout	200
 Unit 1 Understanding Drawings	202
Learning Objectives.....	202
Key Terms	202
Importance of Engineering Drawings.....	203
Components of Engineering Drawings	203
<i>Title Block</i>	203
<i>Orthographic Projection</i>	203
<i>Line Types</i>	207
Basic Symbols and Notation	211
Tolerance	211
<i>Bilateral Tolerances</i>	211
<i>Unilateral Tolerances</i>	211
<i>Limit Tolerances</i>	213
<i>MMC and LMC</i>	213
<i>Tolerance Specifications</i>	214
Classes of Fit	214
<i>Allowances</i>	214
<i>Classifications of Fits</i>	217

Geometric Dimensioning and Tolerancing (GD&T)	220	Tongue-and-Groove Pliers.....	252
<i>Datum</i>	220	Side Cutting Pliers.....	252
<i>Feature Control Frame</i>	220	Diagonal Cutters.....	252
<i>Interpretation of Geometric Tolerances</i>	220	Hammers.....	252
Summary.....	229	<i>Ball Peen</i>	252
Review Questions.....	230	<i>Soft Face</i>	252
Unit 2 Layout.....	232	Wrenches.....	253
Learning Objectives.....	232	<i>Open-End Wrench</i>	254
Key Terms	232	<i>Box-End Wrench</i>	254
Introduction.....	233	<i>Double-Ended Wrench</i>	254
Layout Fluid (Layout Dye)	233	<i>Adjustable Wrench</i>	254
<i>Layout Fluid Remover</i>	233	<i>Socket Wrench</i>	255
Semi-Precision Layout.....	234	<i>Spanner Wrench</i>	255
<i>Scribers</i>	234	<i>Hex Key Wrench</i>	255
<i>Layout with a Combination Set</i>	235	Bench Vise	256
<i>Divider</i>	235	<i>Bases</i>	256
<i>Trammel</i>	236	<i>Jaws</i>	257
<i>Prick and Center Punches</i>	236	Clamps.....	258
<i>Hermaphrodite Caliper</i>	238	<i>C-Clamp</i>	258
<i>Plain Protractor</i>	238	<i>Parallel Clamp</i>	258
<i>Surface Plate</i>	238	<i>Hinged Clamp</i>	258
<i>Surface Gage</i>	238	Hacksaws.....	258
<i>Workholding Accessories</i>	240	<i>Hacksaw Blades</i>	258
Precision Layout.....	241	<i>Hacksaw Use</i>	258
<i>Height Gage</i>	241	Files.....	259
<i>Precision Angular Layout</i>	241	<i>File Classification</i>	259
Basic Layout Construction and Math	242	<i>Special Files</i>	260
<i>The Layout of Square Shapes</i>	245	<i>File Selection</i>	261
Layout Procedure Guidelines.....	248	<i>General File Use</i>	261
Summary.....	248	<i>Filing Tips</i>	263
Review Questions.....	249	Deburring	263
Unit 3 Hand Tools.....	250	Abrasives	263
Learning Objectives.....	250	Summary	264
Key Terms	250	Review Questions.....	265
Introduction	251		
Screwdrivers.....	251	Unit 4 Saws and Cutoff Machines	266
<i>Phillips</i>	251	Learning Objectives.....	266
<i>Straight</i>	251	Key Terms	266
<i>Offset</i>	251	Introduction	267
<i>Torx</i>	251	Power Hacksaws	267
Pliers	251	Band Sawing Machines	267
<i>Slip Joint Pliers</i>	251	<i>Horizontal Band Saws</i>	267
<i>Needle Nose Pliers</i>	251	<i>Vertical Band Saws</i>	269
<i>Locking Pliers</i>	252	Saw Blade Characteristics and Applications.....	271

Contents

<i>Blade Width</i>	274	<i>Threading and Tapping</i>	298																																																																																																						
<i>Blade Thickness or Gauge</i>	274	<i>Basic Thread Terminology</i>	298																																																																																																						
<i>Rake</i>	274	<i>Thread Designations</i>	301																																																																																																						
<i>Gullet</i>	275	<i>Tap Drills</i>	301																																																																																																						
<i>Tooth Patterns</i>	275	<i>Tapered Pipe Threads</i>	302																																																																																																						
Band Saw Blade Welding	275	<i>Tap Styles</i>	302																																																																																																						
<i>Band Length</i>	275	<i>Tap Use</i>	307																																																																																																						
<i>Band Welding</i>	276	<i>Die Use</i>	309																																																																																																						
Band Saw Blade Mounting/Removal	278	Summary	310																																																																																																						
Blade Speed	279	Review Questions	311																																																																																																						
The Abrasive Cutoff Saw	279																																																																																																								
Metal Cutting Circular (Cold) Saws	281																																																																																																								
Summary	281																																																																																																								
Review Questions	282																																																																																																								
Unit 5 Offhand Grinding	283	 SECTION 4																																																																																																							
Learning Objectives	283	 Drill Press	313																																																																																																						
Key Terms	283	Unit 1 Introduction to the Drill Press	314	Introduction	284	Learning Objectives	314	Grinder Uses	284	Key Terms	314	Abrasive Belt and Disc Machine Uses	285	Introduction	315	Grinding Wheels	285	Upright Drill Press	316	<i>Abrasive Type</i>	285	<i>Drill Press Controls</i>	317	<i>Wheel Grit (Abrasive Grain Size)</i>	286	<i>Gang Drill Press</i>	318	<i>Wheel Size</i>	286	<i>Radial-Arm Drill Press</i>	319	<i>Maximum Wheel Speed</i>	286	<i>Micro Drill Press</i>	319	<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296
Unit 1 Introduction to the Drill Press	314																																																																																																								
Introduction	284	Learning Objectives	314	Grinder Uses	284	Key Terms	314	Abrasive Belt and Disc Machine Uses	285	Introduction	315	Grinding Wheels	285	Upright Drill Press	316	<i>Abrasive Type</i>	285	<i>Drill Press Controls</i>	317	<i>Wheel Grit (Abrasive Grain Size)</i>	286	<i>Gang Drill Press</i>	318	<i>Wheel Size</i>	286	<i>Radial-Arm Drill Press</i>	319	<i>Maximum Wheel Speed</i>	286	<i>Micro Drill Press</i>	319	<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296				
Learning Objectives	314																																																																																																								
Grinder Uses	284	Key Terms	314	Abrasive Belt and Disc Machine Uses	285	Introduction	315	Grinding Wheels	285	Upright Drill Press	316	<i>Abrasive Type</i>	285	<i>Drill Press Controls</i>	317	<i>Wheel Grit (Abrasive Grain Size)</i>	286	<i>Gang Drill Press</i>	318	<i>Wheel Size</i>	286	<i>Radial-Arm Drill Press</i>	319	<i>Maximum Wheel Speed</i>	286	<i>Micro Drill Press</i>	319	<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296								
Key Terms	314																																																																																																								
Abrasive Belt and Disc Machine Uses	285	Introduction	315	Grinding Wheels	285	Upright Drill Press	316	<i>Abrasive Type</i>	285	<i>Drill Press Controls</i>	317	<i>Wheel Grit (Abrasive Grain Size)</i>	286	<i>Gang Drill Press</i>	318	<i>Wheel Size</i>	286	<i>Radial-Arm Drill Press</i>	319	<i>Maximum Wheel Speed</i>	286	<i>Micro Drill Press</i>	319	<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296												
Introduction	315																																																																																																								
Grinding Wheels	285	Upright Drill Press	316	<i>Abrasive Type</i>	285	<i>Drill Press Controls</i>	317	<i>Wheel Grit (Abrasive Grain Size)</i>	286	<i>Gang Drill Press</i>	318	<i>Wheel Size</i>	286	<i>Radial-Arm Drill Press</i>	319	<i>Maximum Wheel Speed</i>	286	<i>Micro Drill Press</i>	319	<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																
Upright Drill Press	316																																																																																																								
<i>Abrasive Type</i>	285	<i>Drill Press Controls</i>	317	<i>Wheel Grit (Abrasive Grain Size)</i>	286	<i>Gang Drill Press</i>	318	<i>Wheel Size</i>	286	<i>Radial-Arm Drill Press</i>	319	<i>Maximum Wheel Speed</i>	286	<i>Micro Drill Press</i>	319	<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																				
<i>Drill Press Controls</i>	317																																																																																																								
<i>Wheel Grit (Abrasive Grain Size)</i>	286	<i>Gang Drill Press</i>	318	<i>Wheel Size</i>	286	<i>Radial-Arm Drill Press</i>	319	<i>Maximum Wheel Speed</i>	286	<i>Micro Drill Press</i>	319	<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																								
<i>Gang Drill Press</i>	318																																																																																																								
<i>Wheel Size</i>	286	<i>Radial-Arm Drill Press</i>	319	<i>Maximum Wheel Speed</i>	286	<i>Micro Drill Press</i>	319	<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																												
<i>Radial-Arm Drill Press</i>	319																																																																																																								
<i>Maximum Wheel Speed</i>	286	<i>Micro Drill Press</i>	319	<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																
<i>Micro Drill Press</i>	319																																																																																																								
<i>Grinding Wheel Storage</i>	287	Summary	320	Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																				
Summary	320																																																																																																								
Pedestal Grinder Setup	287	Review Questions	320	<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																								
Review Questions	320																																																																																																								
<i>Grinding Wheel Ring Testing</i>	287	 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321	<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																												
 Unit 2 Tools, Toolholding, and Workholding for the Drill Press	321																																																																																																								
<i>Grinding Wheel Mounting</i>	288	Learning Objectives	321	<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																
Learning Objectives	321																																																																																																								
<i>Tool Rest and Adjustment</i>	288	Key Terms	321	<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																				
Key Terms	321																																																																																																								
<i>Spark Breaker and Adjustment</i>	289	Introduction	322	<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																								
Introduction	322																																																																																																								
<i>Grinding Wheel Dressing</i>	289	Types Of Cutting-Tool Materials	322	Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																												
Types Of Cutting-Tool Materials	322																																																																																																								
Grinding Procedures	291	Drill Bits	322	Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																
Drill Bits	322																																																																																																								
Summary	291	<i>Twist Drills</i>	322	Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																				
<i>Twist Drills</i>	322																																																																																																								
Review Questions	292	<i>Spotting and Center Drills</i>	325	 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																								
<i>Spotting and Center Drills</i>	325																																																																																																								
 Unit 6 Drilling, Threading, Tapping, and Reaming	293	 Reamers	326	Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																												
 Reamers	326																																																																																																								
Learning Objectives	293	<i>Reamer Parts</i>	326	Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																																
<i>Reamer Parts</i>	326																																																																																																								
Key Terms	293	<i>Reamer Sizes</i>	327	Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																																				
<i>Reamer Sizes</i>	327																																																																																																								
Introduction	294	Countersinks and Counterbores	327	Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																																								
Countersinks and Counterbores	327																																																																																																								
Benchwork Holemaking Operations	294	Toolholding	329	<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																																												
Toolholding	329																																																																																																								
<i>Twist Drilling</i>	294	<i>Morse Taper-Shank Toolholding</i>	329	<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																																																
<i>Morse Taper-Shank Toolholding</i>	329																																																																																																								
<i>Counterboring, Countersinking, and Spotfacing</i>	295	<i>Straight-Shank Toolholding</i>	331	<i>Reaming</i>	296																																																																																																				
<i>Straight-Shank Toolholding</i>	331																																																																																																								
<i>Reaming</i>	296																																																																																																								

Workholding	331	Summary	364
Drill Press Vise	332	Review Questions	365
V-Block	332		
Angle Plate	334		
Hold-Down Clamps	334		
Summary	336		
Review Questions	336		
Unit 3 Drill Press Operations	337		
Learning Objectives	337		
Key Terms	337		
Introduction	338		
General Drill Press Safety	338		
Speed and Feed	338		
<i>Cutting Speed and RPM Calculation</i>	338		
<i>Feed Rates for Drill Press Operations</i>	341		
Locating Holes on the Drill Press	342		
Center Drilling and Spot Drilling	344		
Drilling	345		
<i>Through and Blind Holes</i>	346		
Reaming	348		
Counterboring and Spotfacing	348		
Chamfering and Countersinking	350		
Tapping	350		
Summary	353		
Review Questions	353		
SECTION 5			
Turning	355		
Unit 1 Introduction to the Lathe	356		
Learning Objectives	356	Learning Objectives	387
Key Terms	356	Key Terms	387
Introduction	357	Introduction	388
Headstock	357	Depth of Cut, Speed, Feed, and Time Calculation	388
<i>Spindle</i>	358	<i>Depth of Cut</i>	388
<i>Quick-Change Gear Box</i>	360	<i>Speed</i>	389
Lathe Bed	360	<i>Feed</i>	389
Carriage	360	<i>Roughing and Finishing</i>	389
<i>Saddle</i>	360	<i>Machining Time Calculation</i>	390
<i>Leadscrew and Feed Rod</i>	362	General Lathe Safety	391
<i>Apron</i>	362	Facing and Turning Operations	391
Tailstock	363	<i>Facing and Turning Tools</i>	391
Lathe Size	363	<i>Internal Toolholders for Carbide Inserts</i>	399
<i>Swing</i>	363	<i>Turning</i>	404
<i>Bed Length</i>	363	<i>Shouldering</i>	407
		Filing and Polishing	411
		Center and Spot Drilling	414
		<i>Center Drills</i>	414
		<i>Spotting Drills</i>	414

Holemaking on the Lathe	415	Unit 5 Taper Turning	446
Drilling	415	Learning Objectives	446
Reaming	416	Key Terms	446
Counterboring and Countersinking	416	Introduction	447
Boring	416	Typical Taper Specifications	447
Internal Shouldering	418	Angular Specification	447
Thread Cutting with Taps and Dies	419	Rate-of-Change Specification	447
Form Cutting	419	Taper Dimensions and Calculations	448
Grooving and Cutoff (Parting)	420	Converting TPI or TPF to an Angular Dimension	451
Knurling	422	Converting an Angular Dimension to TPI or TPF	451
Summary	425	Taper Turning Methods	451
Review Questions	425	Tool Bit Method	451
Unit 4 Manual Lathe Threading	427	Compound-Rest Method	451
Learning Objectives	427	Taper Attachment Method	454
Key Terms	427	Offset Tailstock Method	456
Introduction	428	Summary	459
Screw Thread Terminology	428	Review Questions	459
Class of Fit	429		
Determining Thread Data	430		
Major Diameter for External Threads	430		
Minor Diameter for Internal Threads	430		
Compound-Rest In-Feed	430		
Pitch Diameter	430		
Producing Threads on the Lathe	432		
Lathe Setup	432		
Installing the Workpiece	432		
Setting the Quick-Change Gear Box	433		
Setting the Compound Rest	433		
Setting the Spindle Speed	435		
Installing and Aligning the Cutting Tool	435		
Lathe Threading Operation	436		
Referencing the Cutting Tool	436		
Threading Dial and Half-Nuts	436		
Threading Tool In-Feed and Positioning	437		
Methods for Terminating a Thread	438		
Thread Measurement	440		
Thread Ring and Plug Gages	440		
Thread Micrometer	440		
Three-Wire Method	441		
Thread Form Measurement	442		
Other Thread Forms	442		
Acme Thread	442		
Tapered Pipe Threads	442		
Buttress Threads	443		
Summary	444		
Review Questions	444		
SECTION 6			
Milling	461		
Unit 1 Introduction to the Vertical Milling Machine	462		
Learning Objectives	462		
Key Terms	462		
Introduction	463		
Base and Column	464		
Knee	464		
Saddle	465		
Table	465		
Turret	466		
Ram	466		
Head	467		
Spindle	467		
Quill	469		
Head Movements	471		
Optional Features	472		
Summary	475		
Review Questions	475		
Unit 2 Tools, Toolholding, and Workholding for the Vertical Milling Machine	476		
Learning Objectives	476		
Key Terms	476		

Introduction	477
Cutter Shanks and Arbors	477
Cutting-Tool Materials	477
Carbide Inserts	477
Proper Cutting-Tool Storage	481
Endmills	481
Roughing Endmills	482
Ballnose Endmills	482
Radius Endmills	482
Corner-Rounding Cutters	482
Chamfer Endmills	483
Tapered Endmills	483
Flat-Surface Milling Cutters	484
Specialty Milling Cutters	485
T-slot Cutters	485
Dovetail Cutter	485
Woodruff Keyseat Cutter	485
Slitting Saws	485
Form Milling Cutters	486
Toolholding	486
Endmill Toolholders	486
Drill Chucks	487
Morse Taper Adapters	487
Shell Mill Arbors	487
Stub Arbors	488
R-8 Collets	488
Workholding	488
Hold-Down Clamps	488
Milling Vises	490
Chucks/Collet Fixtures	492
Vacuum Plates, Magnetic, and Adhesive-Based Workholding	492
Fixtures	494
Summary	494
Review Questions	495
Unit 3 Vertical Milling Machine Operations	496
Learning Objectives	496
Key Terms	496
Introduction	497
General Milling Machine Safety	497
Tramming The Vertical Milling Machine Head	497
Aligning Workholding Devices	499
Aligning a Milling Vise	499
Aligning Other Workholding Devices and Large Workpieces	501
Speeds and Feeds for Milling Operations	502
Holemaking Operations	504
Locating to a Layout	504
Locating from an Edge	504
Locating the Center of an Existing Part Feature	505
Boring	506
Milling Basics	509
Squaring a Block	510
Milling Side A	510
Milling Side B	512
Milling Side C	512
Milling Side D	513
Milling Sides E and F	514
Squaring a Block Using an Angle Plate	517
Angular Milling	517
Milling with Angled Cutters	517
Milling Angles by Positioning the Workpiece	518
Milling Angles by Tilting the Machine Head	521
Milling Steps, Slots, and Keyseats	522
Basic Step Milling	522
Slot Milling	523
Milling Radii	528
Milling External Radii	529
Milling Internal Radii (Filletts)	530
Pocket Milling	531
Summary	533
Review Questions	534
Unit 4 Indexing and Rotary Table Operations	535
Learning Objectives	535
Key Terms	535
Introduction	536
Parts of The Rotary Table	536
Rotary Table Setup	536
Workpiece Setup for the Rotary Table	537
Rotary Table Operations	538
Angular Positioning for Milling and Drilling	538
Milling Outside and Inside Radii	539
The Indexing Head	539
Parts of the Indexing Head	540
Indexing Head Setup	540
Indexing Head Operations	540
Direct Indexing Head Operations	541
Simple Indexing	542
Summary	544
Review Questions	544

SECTION 7**Grinding** 547

Unit 1 Introduction to Precision Grinding Machines	548
Learning Objectives.....	548
Key Terms	548
Introduction.....	549
Surface Grinders	549
<i>Horizontal Spindle Surface Grinders</i>	549
<i>Vertical Spindle Surface Grinders</i>	550
Cylindrical Grinders	551
<i>The Centerless Grinder</i>	552
Tool and Cutter Grinders.....	553
The Jig Grinder.....	553
Summary.....	553
Review Questions	554

Unit 2 Grinding Wheels for Precision Grinding 555

Learning Objectives.....	555
Key Terms	555
Introduction.....	556
Wheel Shapes.....	556
Grinding-Wheel Specifications.....	557
<i>Abrasive Type</i>	557
<i>Grit Size (Grain Size)</i>	558
<i>Grade</i>	558
<i>Structure</i>	558
<i>Bond Type</i>	558
Superabrasives.....	559
Summary.....	560
Review Questions	560

Unit 3 Surface Grinding Operations.... 561

Learning Objectives.....	561
Key Terms	561
Introduction.....	562
General Surface Grinder Safety	562
Mounting the Grinding Wheel.....	562
Workholding Devices	563
<i>Magnetic Devices</i>	563
Angle Plates, V-Blocks, and Collet Blocks.....	566
<i>Vises</i>	566
Wheel Dressing.....	566

Dressing Aluminum Oxide and Silicon Carbide Wheels.....	566
Dressing Diamond and CBN Wheels	568
Grinding Parallel Surfaces	568
<i>Grinding the Magnetic Chuck</i>	570
Grinding Perpendicular Surfaces.....	570
Grinding Angles.....	571
Side Grinding	572
<i>Dressing the Wheel for Side Grinding</i>	572
Performing Side Grinding	573
Grinding Cylindrical Work	575
Grinding Problems.....	575
<i>Burning of the Work Surface</i>	575
<i>Scratches on the Work Surface</i>	576
<i>Waviness or Chatter on the Work Surface</i>	576
Summary	577
Review Questions	577

SECTION 8**Computer Numerical Control** 578

Unit 1 CNC Basics	580
Learning Objectives.....	580
Key Terms	580
Introduction	581
The CNC Machine Control Unit	582
CNC Motion Control	582
<i>Drive Screws</i>	582
<i>CNC Guideways</i>	583
<i>Servo Motors</i>	584
Coordinate Systems	585
<i>The Cartesian Coordinate System</i>	585
<i>The Polar Coordinate System</i>	586
Positioning Systems	587
<i>The Absolute Positioning System</i>	587
<i>The Incremental Positioning System</i>	587
Codes	587
<i>G-Codes</i>	587
<i>M-Codes</i>	588
<i>Other Word Address Commands</i>	588
<i>Binary Code</i>	590
Conversational-Type Programming	590
Parts of a CNC Program	590
<i>Safe-Start</i>	590
<i>Material Removal</i>	591
<i>Program Ending</i>	591

Summary.....	593	Canned Cycles.....	622
Review Questions.....	593	<i>Holemaking Canned Cycles</i>	622
Unit 2 Introduction to CNC Turning.....	594	<i>Tapping Canned Cycles</i>	624
Learning Objectives.....	594	<i>Rough and Finish Turning Canned Cycles</i>	626
Key Terms	594	<i>Threading Canned Cycles</i>	626
Introduction.....	595	<i>Tool Nose Radius Compensation</i>	629
Types of Turning Machines	597	Summary.....	634
<i>Turret-Type Machines</i>	597	Review Questions	635
<i>Gang-Tool-Type Machines</i>	597		
<i>CNC Lathes</i>	598		
<i>Swiss-Type Turning Center</i>	598		
Tool-Mounting	600		
<i>Cutting Toolholders</i>	600		
Workholding	605		
<i>Workholding Collets</i>	605		
<i>Workholding Chucks</i>	606		
Process Planning.....	606		
Summary.....	607		
Review Questions.....	607		
Unit 3 CNC Turning: Programming.....	609		
Learning Objectives.....	609		
Key Terms	609		
Introduction.....	610		
Coordinate Positioning for Turning.....	610		
Types of Motion for Turning.....	610		
<i>Rapid Traverse for Turning—G0</i>	610		
<i>Linear Interpolation for Turning—G1</i>	610		
<i>Circular Interpolation for Turning—G2 and G3</i>	611		
Non-Axis Motion Commands	614		
<i>Spindle Speed for Turning</i>	614		
<i>Tool-Change Commands</i>	615		
<i>Sequence Numbers</i>	615		
<i>Program Stop Commands</i>	615		
<i>Summary of Safe-Start, Spindle-Start, and Tool-Change/Offset Commands</i>	615		
Machining Operations.....	616		
<i>Coolant M-Codes</i>	616		
<i>Facing</i>	616		
<i>Drilling Operations</i>	616		
<i>Straight Turning</i>	616		
<i>Taper Turning</i>	620		
<i>Contour Turning</i>	620		
<i>Roughing Operations</i>	620		
<i>Finishing</i>	622		
		Unit 4 CNC Turning:	
		Setup and Operation.....	636
		Learning Objectives.....	636
		Key Terms	636
		Machine Control Panel.....	637
		Workholding Setup	638
		Machine and Work Coordinate Systems.....	641
		<i>Power-Up and Homing</i>	641
		Work Offset Setting	642
		Cutting Tools for Turning.....	643
		<i>Cutting-Tool Installation</i>	643
		<i>Cutting-Tool Offsets for Turning</i>	643
		Program Entry for Turning	645
		Turning Machine Operation.....	646
		<i>Program Prove-Out</i>	646
		<i>Auto Mode</i>	647
		Summary.....	647
		Review Questions	648
		Unit 5 Introduction to CNC Milling.....	649
		Learning Objectives.....	649
		Key Terms	649
		Introduction	650
		Types of CNC Milling Machines	650
		<i>ATC Types</i>	650
		Toolholding	653
		<i>CNC Spindle Types</i>	653
		<i>Tool Attachment Styles</i>	654
		<i>Workholding</i>	658
		Process Planning.....	662
		Summary.....	662
		Review Questions	663
		Unit 6 CNC Milling: Programming	664
		Learning Objectives.....	664
		Key Terms	664

Contents

Introduction	665	Program Entry	711
Coordinate Positioning for Milling	665	Machine Operation	711
Speeds and Feed Rates for Milling	666	<i>Program Prove-out</i>	711
<i>Spindle Speed</i>	666	<i>Auto Mode</i>	712
<i>Feed Rates</i>	666	Summary	712
Sequence Numbers	666	Review Questions	713
Types of Motion for Milling	666		
<i>Rapid Traverse—G0</i>	666		
<i>Linear Interpolation—G1</i>	668		
<i>Circular Interpolation</i>	670		
Machining Operations	677		
<i>Coolant M-Codes</i>	677		
<i>Facing</i>	677		
<i>Two-Dimensional Milling</i>	678		
<i>Holemaking Operations</i>	679		
<i>Canned Cycles</i>	681		
Cutter Radius Compensation	694		
Summary	697		
Review Questions	698		
Unit 7 CNC Milling: Setup and Operation	699		
Learning Objectives	699		
Key Terms	699		
Machine Control Panel	700		
Workholding Setup	702		
Machine and Work Coordinate Systems	702		
Power-Up and Homing	702		
Work Offset Setting	703		
<i>Workpiece Z-axis Offset Setting</i>	704		
<i>Workpiece X-axis and Y-axis Offset Setting</i>	704		
Cutting Tools	707		
<i>Cutting-Tool Installation</i>	707		
<i>Cutting-Tool Offset Types</i>	707		
Program Entry	711		
Machine Operation	711		
<i>Program Prove-out</i>	711		
<i>Auto Mode</i>	712		
Summary	712		
Review Questions	713		
Unit 8 Computer-Aided Design and Computer-Aided Manufacturing	714		
Learning Objectives	714		
Key Terms	714		
Introduction	715		
Cad Software Use	715		
<i>Geometry Types</i>	715		
<i>Software Types</i>	716		
Cam Software Use	716		
<i>Toolpaths</i>	716		
<i>Machining Verification/Simulation</i>	720		
<i>Post-Processing</i>	720		
Summary	720		
Review Questions	721		
Appendix A	722		
Appendix B	733		
Appendix C	734		
Appendix D	735		
Appendix E	736		
Appendix F	738		
Glossary	739		
Index	762		