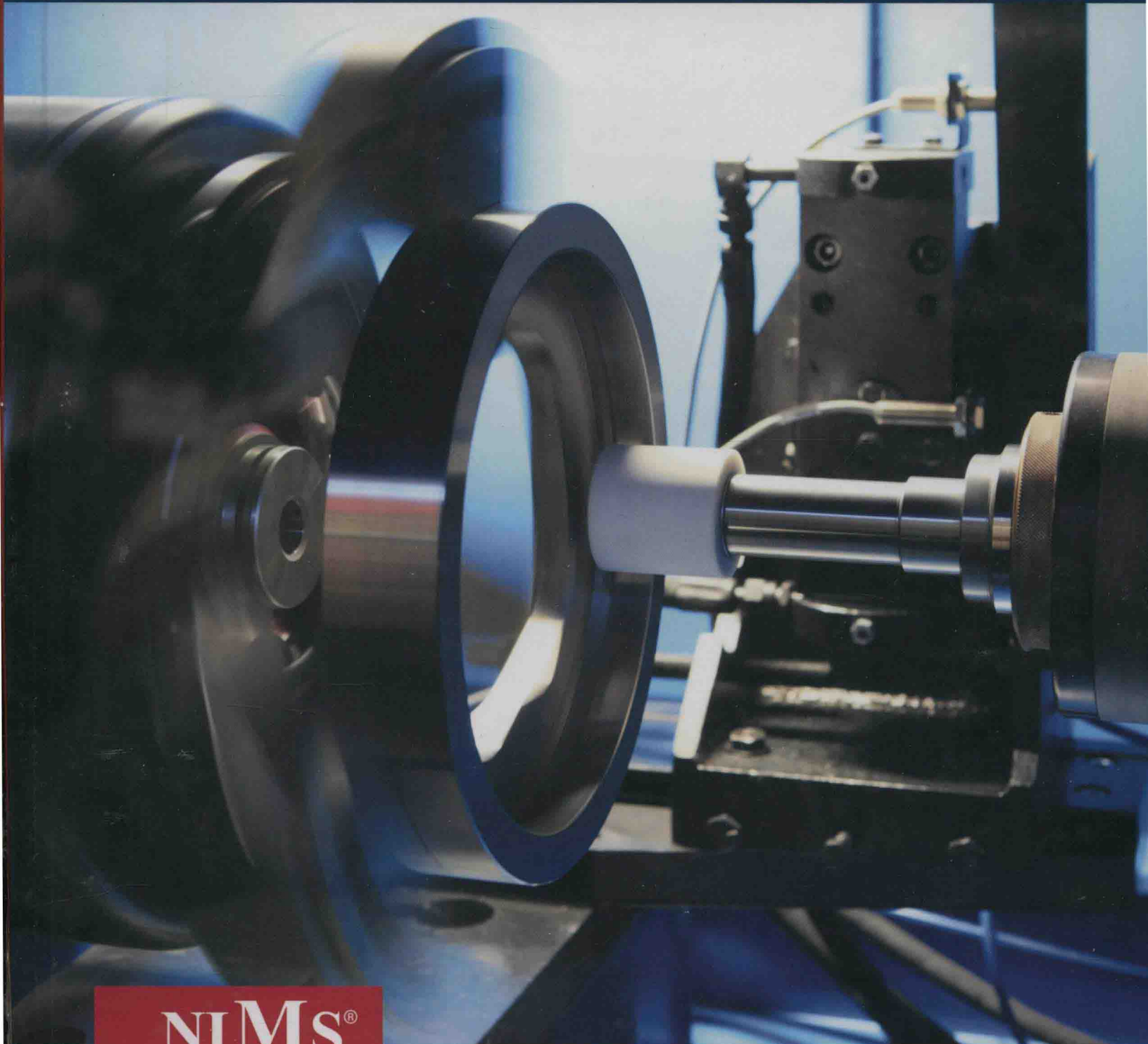


Precision Machining TECHNOLOGY

Second Edition



NIMs[®]

Peter Hoffman • Eric Hopewell • Brian Janes

Precision Machining Technology

Second Edition

Peter J. Hoffman

Berks Career & Technology Center, West Campus, Leesport, PA

Eric S. Hopewell

Berks Career & Technology Center, West Campus, Leesport, PA

Brian Janes

Bowling Green Technical College, Bowling Green, KY



**Precision Machining Technology,
Second Edition****Peter J. Hoffman, Eric S. Hopewell,
Brian Janes**Vice President, General Manager, Skills
and Planning: Dawn Gerrain

Associate Product Manager: Nicole Sgueglia

Senior Product Development Manager:
Larry Main

Senior Content Developer: Sharon Chambliss

Product Assistant: Maria Garguilo

Vice President, Marketing Services: Jennifer
Ann Baker

Marketing Manager: Linda Kuper

Senior Production Director: Wendy Troeger

Production Manager: Mark Bernard

Senior Content Project Manager: Cheri Plasse

Art Director: Cheryl Pearl

© 2015, 2012 Cengage Learning

ALL RIGHTS RESERVED. No part of this work covered by the copyright herein may be reproduced, transmitted, stored, or used in any form or by any means graphic, electronic, or mechanical, including but not limited to photocopying, recording, scanning, digitizing, taping, Web distribution, information networks, or information storage and retrieval systems, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without the prior written permission of the publisher.

For product information and technology assistance, contact us at
Cengage Learning Customer & Sales Support, 1-800-354-9706

For permission to use material from this text or product,
submit all requests online at **www.cengage.com/permissions**.

Further permissions questions can be e-mailed to
permissionrequest@cengage.com.

Library of Congress Control Number: 2014931040

ISBN-13: 978-1-2854-4454-3

ISBN-10: 1-2854-4454-X

Cengage Learning5 Maxwell Drive
Clifton Park, NY 12065-2919
USA

Cengage Learning is a leading provider of customized learning solutions with office locations around the globe, including Singapore, the United Kingdom, Australia, Mexico, Brazil, and Japan. Locate your local office at: international.cengage.com/region

Cengage Learning products are represented in Canada by Nelson Education, Ltd.

To learn more about Delmar, visit **www.cengage.com/delmar**.

Purchase any of our products at your local college store or at our preferred online store
www.cengagebrain.com.

NOTICE TO THE READER

Publisher does not warrant or guarantee any of the products described herein or perform any independent analysis in connection with any of the product information contained herein. Publisher does not assume, and expressly disclaims, any obligation to obtain and include information other than that provided to it by the manufacturer. The reader is expressly warned to consider and adopt all safety precautions that might be indicated by the activities described herein and to avoid all potential hazards. By following the instructions contained herein, the reader willingly assumes all risks in connection with such instructions. The publisher makes no representations or warranties of any kind, including but not limited to, the warranties of fitness for particular purpose or merchantability, nor are any such representations implied with respect to the material set forth herein, and the publisher takes no responsibility with respect to such material. The publisher shall not be liable for any special, consequential, or exemplary damages resulting, in whole or part, from the readers' use of, or reliance upon, this material.

PREFACE

Precision Machining Technology introduces students, both at the secondary and postsecondary levels, to the exciting world of machine tool technology as it is practiced in the 21st century. In writing this text, the authors' main goal is to provide a deep understanding of the fundamental and intermediate machining skills needed for career success in a rapidly changing manufacturing environment. In line with this objective, the author team has taken special care to ensure that the text:

- Has a down-to-earth, practical orientation that covers what students need to know about the field of precision machining as it is practiced today
- Develops modern interpersonal skills that are demanded by the job market
- Covers current career information and trends
- Includes modern shop practices
- Contains specific instructions and examples, with images showing many step-by-step applications
- Provides in-depth knowledge as a base for strong foundational skills without becoming difficult to read or comprehend
- Includes current computer numerical control (CNC) content

This text is written for students of precision machining at the secondary and postsecondary levels who have the opportunity and desire to learn skills required by the machine tool industry and to obtain NIMS certifications. The book is written in such a way that the student needs no prior knowledge of machining to benefit.

Precision Machining Technology has been sponsored and endorsed by NIMS. The text and its supporting supplements fill the need of comprehensively covering all of the material encountered by a student during the NIMS certification process, and were written with the Machining Level I Standards in mind. The text's close adherence to NIMS's nationally recognized skills standards will be especially useful for schools and school districts that wish to comply with the funding requirements of the Carl D. Perkins Career and Technical Education Act of 2006 (Perkins IV).

How the Text Was Developed

In order to create a truly new set of teaching and learning tools, *Precision Machining Technology* was launched with no preconceived notion of how the text should be designed. A large number of instructors at NIMS-accredited programs participated in the initial development of the table of contents, which

then led to the recruitment of the author team, also from NIMS-accredited programs. During the development of the project, over a dozen instructors reviewed drafts of the manuscript and provided useful feedback to the authors. Their input has played a major role in improving the final product. Last, the publisher and NIMS committed to an extra developmental step, class-testing the manuscript at multiple institutions, in order to assure the highest level of accuracy and teaching effectiveness. Reviewers and class-testers are listed in the Acknowledgments section.

To enhance the teaching and learning experience, the authors developed the text with the following objectives in mind:

- Achieve an easy-to-read writing style that assumes the student has no prior knowledge of machining and takes the student all the way through to the intermediate stage
- Include many images to clarify explanations and procedures so students can make visual connections
- Identify key and secondary terms throughout the text to guide students to important points
- Assume that students are taking or have already taken basic geometry, basic algebra, and have good proficiency in computation of fractions, decimals, and order of operations
- Allow for the companion *Workbook/Projects Manual* to provide a beneficial measure of practice to prepare the student for NIMS product creation and the knowledge examination

Organization of the Text

In designing *Precision Machining Technology*, the authors followed the typical progression through the NIMS certifications. For many of the sections, a student should have sufficient knowledge to obtain a NIMS certification at the completion of the sections.

The text is divided into eight major sections, as follows:

- Section 1—Introduction to Machining
- Section 2—Measurement, Materials, and Safety
- Section 3—Job Planning, Benchwork, and Layout
- Section 4—Drill Press
- Section 5—Turning
- Section 6—Milling
- Section 7—Grinding
- Section 8—Computer Numerical Control (CNC)

Each section of the text contains multiple “bite-sized” units, which provide the following teaching and learning aids: learning objectives, key terms, caution safety checks, chapter summary, and review questions.

Special care was taken to make each unit progress in a logical presentation of content for someone with no prior knowledge. The authors took steps to ensure that no new terminology was presented prior to a complete explanation of each term. Each unit builds on another, and many sections build on previous sections. As the text progresses, topics are explored more deeply. Previous knowledge is reinforced through new application of previous information.

What's New in This Edition

- Expanded appendix including more reference material and machining data
- New content reflecting updates to OSHA's Hazard Communication Standard
- Carbide turning insert and holder information
- Carbide milling insert and holder information
- Grinding coolant information
- Teamwork and leadership content
- Updated images

A Note for Students: How to Use This Text

Do not become overwhelmed with all of the information. The text is arranged so that you may take each piece step by step. Pause and think about key and secondary terms while reading.

Supplements for Students and Instructors

The companion *Workbook and Projects Manual* by David Lenzi and James Hillwig contains helpful review material to ensure that students have mastered key concepts in the text, and guided practice operations and projects on a wide range of machine tools that will enhance their NIMS credentialing success. All projects are keyed to NIMS Duties and Standards.

For instructors, Cengage Learning has produced an Instructor Companion Website that contains the following tools: Instructor's Guide, PowerPoint lecture slides containing selected images from the text, an image library, and correlation grids for both the text and workbook to the NIMS Machining Level 1 Standards and Cengage Learning Testing Powered by Cognero—a flexible online system that allows you to:

- author, edit, and manage test bank content from multiple Cengage Learning solutions
- create multiple test versions in an instant
- deliver tests from your LMS, your classroom, or wherever you want

ACKNOWLEDGMENTS

The authors and publisher thank the following individuals for their assistance in the reviewing process.

Reviewers:

Kurt J. Billsten, Harper College, Palatine, IL
Robert G. Cantin, Chicopee Comprehensive High School, Chicopee, MA
Stephen Hadwin, Southern Oklahoma Technology Center, Ardmore, OK
David R. Hall, Bladen Community College, Dublin, NC
David R. McGough, Knox County Career Center, Mount Vernon, OH
Elliot Shuler, Gordon Cooper Technology Center, Shawnee, OK
Robert T. Tanchak, Onondaga Community College, Syracuse, NY

Thank you to the following individuals and companies who provided support, photography, and illustrations for the text:

3M Company	Dykem
American Coatings Association	Everett Industries
American Metal Treating Co.	Flexbar Machine Corp.
Armstrong Tool	Flow International Corporation
AVK Industrial Products	Fred V. Fowler Company, Inc.
Baldor Electric Company	Gage Crib Worldwide Inc.
Behringer Saws, Inc.	Getty Images
Berks Career & Technology Center	Grizzly Industrial, Inc.
Bilz Tool Co.	Haas Automation, Inc.
Brady Corporation	Hardinge, Inc.
Brown & Sharpe division of Hexagon Metrology, Inc.	Industrial Press, Inc.
Cincinnati Millicron	Ingersoll Cutting Tools
Clausing Industrial Inc.	ITW Vortec
Dake Corporation	Jet-Wilton
DE-STA-CO	Justrite Mfg. Co.
Edward Drapatin, Kaynor Technical High School, Waterbury, CT	Kasto, Inc.
	Kennametal, Inc.
	Kool Mist Corporation

Kurt Mfg.	SFS Intec
Lenox	South Bend Lathe Co.
LPS Laboratories	Suburban Tool, Inc.
Lucifer Furnaces, Inc.	Tapmatic Corporation
Lyndex-Nikken, Inc.	The Dunham Tool Company
Mag Americas	The Grieve Corporation
Manluk Industries	The L. S. Starrett Company
Master Chemical Corporation	The Red Wing Shoe Company, Inc.
Mazak Corp.	Tray-Pak Corp.
Mitee-Bite Products	Trimetric Mold & Design
Mitutoyo Corporation	TruTech Systems/Harig Products
NFPA	Vermont Gage
Niagara Cutter, Inc.	Walker Magnetics Group
Oil-Dri Corporation of America	Walton Tools
Palmgren, Inc.	Weldon Solutions
Penske Racing Shocks	Weldon Tool Co., a division of Talbot Holdings Co.
Pernell Parts	Wellsaw, Inc.
PTC Instruments	Mack Williams, Radford High School and Dalton Intermediate School, Radford, VA
Royal Products	Wilson Instruments
Sandvik AB	Yuasa International
Sentry Air Systems, Inc.	
Servo Products Co.	

FROM THE AUTHORS

The authors express their gratitude to the entire production team for their patience, support, and guidance. Special thanks to Sharon Chambliss for coordinating the countless aspects of the project and maintaining patience with all of us.

Pete Hoffman

I thank my loving wife, Reba, who graciously supported me during this project. Thanks to my children Lucas, Niklas, and Autumn for allowing me to be away from them while I was working on the project. And thanks to my parents, Carl and Laureen, who have taught me many great things. I have been richly blessed to have all of you in my life.

Eric Hopewell

I thank my wife, Peg, and my daughters Selena, Lindsey, and Haley for their understanding and patience throughout this project. I appreciate them more than they know, and am truly blessed to have such a family that unconditionally loved and supported me during the entire process.

Brian Janes

To my wife Stacy, my son Bodie, and my parents Bill and Jeanita. I know the journey has been long—thank you all for being so supportive of me while I worked on this project.

ABOUT THE AUTHORS

Peter J. Hoffman, Instructor, Berks Career & Technology Center, West Campus, Leesport, PA

Peter Hoffman holds an associate degree in tool making technology from Pennsylvania College of Technology and a vocational education II teaching certification in Pennsylvania. He has several level I and II NIMS certifications and was a Skills USA National Gold Medalist 2001—Postsecondary Precision Machining Technology, and a National Silver Medalist in 2000. He owns and operates a small machining business.

Eric S. Hopewell, Berks Career & Technology Center, West Campus, Leesport, PA

Eric Hopewell has over 25 years of combined experience in the machine tool and education fields. He holds an AAS degree in machine tool technology from Pennsylvania College of Technology, a BS in business administration from Albright College, an MS in Education from Temple University, and a permanent Pennsylvania vocational teaching certification. He also holds several NIMS machining certifications.

Brian Janes, Bowling Green Technical College, Bowling Green, KY

Brian Janes's career in the machine trades has spanned some 20 years. His experience includes various machining positions in shops as well as in injection molding companies throughout Indiana and Kentucky. Brian has worked as a machinist for several Indy car racing teams and still holds a part-time position with both Team Leader Motor Sports in Indianapolis, Indiana, and Dave McLerran Engineering in Los Angeles, California. He has overseen educational programs in both machine tool and industrial maintenance. His programs have won the Kentucky Technical Education Program of the Year Award, and one of his programs was the first program in Kentucky to receive NIMS accreditation. Brian has an MS degree in engineering technology.

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

<i>Conventional Machinist</i>	22
<i>CNC Machinist</i>	22
<i>Programmer</i>	24
<i>Die Maker, Mold Maker, Toolmaker</i>	24
<i>Supervisory Positions</i>	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
Training Opportunities/Methods	31
<i>Secondary School (High School) Programs</i>	31
<i>Post-Secondary Training</i>	32
<i>Employer-Provided Training</i>	32
<i>Apprenticeships</i>	32
NIMS.....	33
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

Unit 1 Introduction to Safety	44
Learning Objectives.....	44
Key Terms	44
Introduction.....	45
General Safety Guidelines.....	45
<i>OSHA and NIOSH</i>	45
General Clothing for a Machining Environment.....	46
Personal Protective Equipment (PPE).....	46
<i>Eye Protection</i>	47
<i>Hearing Protection</i>	47
<i>Respirators</i>	48
<i>Gloves</i>	48
<i>Hard Hats</i>	49
Housekeeping.....	49
Guards and Barriers	50
Handling and Lifting.....	51
Compressed Air Safety	51
Lockout/Tagout.....	52
<i>Tagout</i>	52
<i>Lockout</i>	52
Hazardous Materials.....	53
<i>Hazardous Material Labeling</i>	53

SDS.....	56
Fire Safety.....	60
<i>The Fire Triangle</i>	60
<i>Fire Extinguishers</i>	60
Safety Documentation	61
Summary	62
Review Questions	63

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
<i>Protractors</i>	92
<i>Bevels</i>	92
<i>Die Maker's Square</i>	95
Fixed Gages	95
<i>Radius and Fillet Gages</i>	95
<i>Angle Gages</i>	96
<i>Screw Pitch Gage</i>	96
Summary	97
Review Questions	97

Unit 4 Precision Measurement..... 99

Learning Objectives	99
Key Terms	100
Introduction	100
What is Precision Measurement?	100
Care of Precision Tools	100
Straight Edges	101
Precision Fixed Gages	101
<i>Thickness Gages</i>	101
<i>Pin or Plug Gages</i>	101
<i>Ring Gages</i>	103
<i>Snap Gages</i>	105
Surface Plates	106
Solid Squares	107
Gage Blocks	108
<i>Selecting Gage Blocks for Builds</i>	109
Vernier Measuring Tools	111
<i>Vernier Calipers</i>	111
<i>Vernier Height Gage</i>	111
<i>Vernier Depth Gage</i>	112
<i>Vernier Gear Tooth Caliper</i>	112
<i>Vernier Protractor</i>	112
<i>Reading Vernier Scales</i>	113
Micrometers	117
<i>Outside Micrometer Caliper</i>	117
<i>Reading Outside Micrometer Calipers</i>	121
<i>Calibration of the Outside</i> <i>Micrometer Caliper</i>	122
<i>Inside Micrometers</i>	125
<i>Depth Micrometers</i>	127
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

Precision Transfer or Helper-Type Measuring Tools	133
<i>Small Hole Gages</i>	133
<i>Telescoping Gages</i>	134
<i>Adjustable Parallels</i>	134
Dial and Digital Indicators	135
<i>Applications of Plunge-Type Indicators</i>	136
<i>Applications of Test Indicators</i>	136
Sine Tools	140
<i>Sine Bars and Sine Blocks</i>	140
<i>Sine Plates</i>	140
<i>Sine Vises</i>	141
Surface Finish Measurement	141
<i>Surface Roughness Comparator</i>	143
<i>Profilometer</i>	143
Optical Comparators	143
Toolmaker's Microscope	144
Coordinate Measuring Machine	145
Summary	145
Review Questions	146

Unit 5 Quality Assurance, Process Planning, and Quality Control..... 147

Learning Objectives	147
Key Terms	147
Introduction	148
Quality Assurance	148
The Process Plan	148
<i>Material Selection</i>	148
<i>Machine Selection and Workholding</i>	148
<i>Tooling Selection</i>	148
<i>Speed and Feed Calculation</i>	150
<i>Other Information</i>	150
Quality Control	150
<i>Sampling Plan</i>	150
<i>Inspection Plan</i>	150
<i>Statistical Process Control (SPC)</i>	150
Summary	156
Review Questions	156

Unit 6 Metal Composition and Classification 157

Learning Objectives	157
Key Terms	157

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
Datum	220	Side Cutting Pliers	252
Feature Control Frame	220	Diagonal Cutters	252
Interpretation of Geometric Tolerances	220	Hammers	252
Summary	229	Ball Peen	252
Review Questions	230	Soft Face	252
Unit 2 Layout	232	Wrenches	253
Learning Objectives	232	Open-End Wrench	254
Key Terms	232	Box-End Wrench	254
Introduction	233	Double-Ended Wrench	254
Layout Fluid (Layout Dye)	233	Adjustable Wrench	254
Layout Fluid Remover	233	Socket Wrench	255
Semi-Precision Layout	234	Spanner Wrench	255
Scribers	234	Hex Key Wrench	255
Layout with a Combination Set	235	Bench Vise	256
Divider	235	Bases	256
Trammel	236	Jaws	257
Prick and Center Punches	236	Clamps	258
Hermaphrodite Caliper	238	C-Clamp	258
Plain Protractor	238	Parallel Clamp	258
Surface Plate	238	Hinged Clamp	258
Surface Gage	238	Hacksaws	258
Workholding Accessories	240	Hacksaw Blades	258
Precision Layout	241	Hacksaw Use	258
Height Gage	241	Files	259
Precision Angular Layout	241	File Classification	259
Basic Layout Construction and Math	242	Special Files	260
The Layout of Square Shapes	245	File Selection	261
Layout Procedure Guidelines	248	General File Use	261
Summary	248	Filing Tips	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	Unit 4 Saws and Cutoff Machines	266
Screwdrivers	251	Learning Objectives	266
Phillips	251	Key Terms	266
Straight	251	Introduction	267
Offset	251	Power Hacksaws	267
Torx	251	Band Sawing Machines	267
Pliers	251	Horizontal Band Saws	267
Slip Joint Pliers	251	Vertical Band Saws	269
Needle Nose Pliers	251	Saw Blade Characteristics and Applications	271
Locking Pliers	252	Blade Material	271
		Tooth Set	273
		Blade Pitch or TPI	273

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