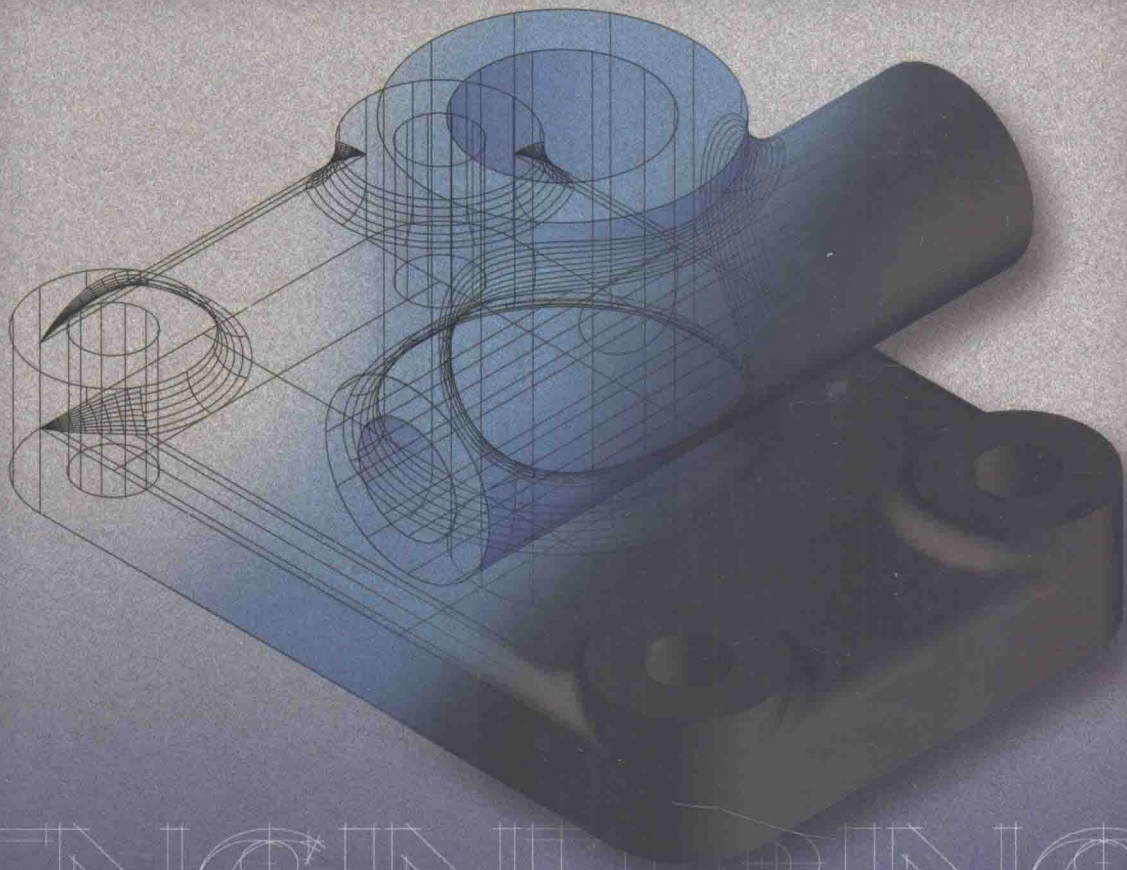


ENGINEERING DRAWING & DESIGN

Seventh Edition



Cecil Jensen • Jay D. Helsel • Dennis R. Short

ENGINEERING Drawing & Design

Seventh Edition

Cecil Jensen

Former Technical Director
R.S. McLaughlin Collegiate and Vocational Institute
Oshawa, Ontario, Canada

Jay D. Helsel

Professor and Chairman Emeritus
Department of Applied Engineering and Technology
California of Pennsylvania
California, University Pennsylvania



Dennis R. Short

Professor of Computer Graphics
Department of Computer Graphics Technology
Purdue University
West Lafayette, Indiana

Boston Burr Ridge, IL Dubuque, IA New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto



ENGINEERING DRAWING AND DESIGN, SEVENTH EDITION

Published by McGraw-Hill, a business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020. Copyright © 2008 by The McGraw-Hill Companies, Inc. All rights reserved. Previous editions 2002, 1996, 1990, 1985, 1976, and 1968. No part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written consent of The McGraw-Hill Companies, Inc., including, but not limited to, in any network or other electronic storage or transmission, or broadcast for distance learning.

Some ancillaries, including electronic and print components, may not be available to customers outside the United States.

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 0 QPV/QPV 0 9 8 7

ISBN 978-0-07-352151-0

MHID 0-07-352151-5

Global Publisher: *Raghothaman Srinivasan*

Executive Editor: *Michael Hackett*

Senior Sponsoring Editor: *Bill Stenquist*

Director of Development: *Kristine Tibbetts*

Developmental Editor: *Lorraine K. Buczek*

Outside Developmental Services: *Rose Kernan, RPK Editorial Services*

Executive Marketing Manager: *Michael Weitz*

Project Manager: *Apri I R. Southwood*

Senior Production Supervisor: *Laura Fuller*

Associate Media Producer: *Christina Nelson/Judi David*

Designer: *Laurie B. Janssen*

(USE) Cover Image: *Digital Vision/Getty Images*

Senior Photo Research Coordinator: *John C. Leland*

Photo Research: *Editorial Image, LLC*

Supplement Producer: *Melissa M. Leick*

Compositor: *Aptara, Inc.*

Typeface: *10/12 Times*

Printer: *Quebecor World Versailles, KY*

The credits section for this book begins on page C-1 and is considered an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Jensen, Cecil Howard, 1925-

Engineering drawing and design / Cecil Jensen, Jay D. Helsel, Dennis R. Short.—7th ed.

p. cm.

Includes index.

ISBN 978-0-07-352151-0—ISBN 0-07-352151-5 (hard copy : alk. paper)

1. Mechanical drawing. 2. Engineering design. I. Helsel, Jay D. II. Short, Dennis R., Professor. III. Title.

T353.J47 2008

604.2--dc22

2007021880



Preface

Engineering Drawing and Design, Seventh Edition, prepares students for drafting careers in modern, technology-intensive industries. Technical drafting, like all technical areas, is constantly changing; the computer has revolutionized the way in which drawings and parts are made. This new edition translates the most current technical information available into the most useful for both instructor and student. The book covers graphic communication, CAD, functional drafting, material representation, shop processes, geometric tolerancing, true positioning, numerical control, electronic drafting, and metrication. The authors synthesize, simplify, and convert complex drafting standards and procedures into understandable instructional units.

Like previous editions, this one is at the cutting edge of drafting and computer technologies. Because board-drafting skills are rapidly being replaced by computer-aided drafting (CAD), this edition provides an enhanced view of CAD while adhering to current ASME, ANSI, CSA, and ISO standards. Drafters must be knowledgeable about CAD and about international standards, for design files can now be electronically transmitted across borders, or around the world.

The reader will find that this book helps build basic skills. It also supplies the technical knowledge required in today's marketplace.

TEXT FEATURES

- **Knowing and Applying Drawing Standards.** A drawing made in the United States must meet the requirements set out in various ASME drawing standards publications. Also, if a firm is involved in international marketing and manufacturing, ISO guidelines (or other standards, such as Canadian drawing standards) must be strictly followed. Drafters will be pleased to see that this book not only covers these standards but also shows how to interpret and apply them. For example, the coverage of geometric tolerancing and true position is more comprehensive than in any other drafting text on the market today.
- **Knowing Manufacturing Materials and Their Processes.** The authors bring together and explain the manufacturing materials that are available for engineering design. They describe the manufacturing processes that influence the shape, appearance, and design of the product.

- **Knowing Fastening Methods.** The correct fastening device plays a very important role in the cost, design, and appearance of a product. Readers can learn about various types of fasteners, both permanent and removable, that are currently available.
- **Providing All the Necessary Information to Complete the Design.** The numerous assignments help the reader gain practice. These assignments can be completed with the help of a variety of Appendix tables reflecting real-world applications.
- **Unit Approach in Teaching the Subject Matter.** The text's unit approach makes it possible for instructors to put together a customized program of instruction that suits the needs of their students and local industry.

KEY FEATURES OF THE SEVENTH EDITION

Many users of the text were consulted before this new edition was undertaken. In response to their suggestions and recommendations, we have made major changes and added new features to this *Seventh Edition*, including:

- The four-color format is easy to read. Color has been used as well to strengthen the important features in the 3000 line drawings and photographs.
- Chapter 2 explains how drawings are produced by computers and peripherals. Computers and the Internet Web have become not only a laboratory but also a limitless technical resource and design facility.
- Solid modeling continues to play an important role in Chap. 15. The power of personal computers and workstations brings 3-D modeling into the classroom, home, CAD office, and on-site manufacturing centers.
- Chapter 16 contains more information on geometric tolerancing and guidance on how to apply it to various drawings. The chapter is up to date with ASME standards and is more understandable to beginning students.
- Chapter 19 covers concurrent engineering and project modeling. Today, engineers and technicians work side by side. All team members are responsible for coordinating efforts to deliver on-time and on-budget finished products.

- The section on stamping in Chap. 23 it covers the process of forming and cutting thicker-gage metals that are used in manufacturing.
- Chapter 27, on electronic drafting, is consistent with solid-state, printed circuit board technology.
- Many chapters include new CAD features. They give students and instructors a clear picture of how CAD can be used in the classroom while maintaining a focus on basic drafting principles. Many CAD features include assignments.
- We have continued to provide the unit approach to teaching, which divides chapters into “mini” teaching units. Instructors find this approach to be a real bonus. By choosing the appropriate units, instructors can put together a customized program that suits the needs of their students and local industry.
- Design concepts are covered in the text through drawing practice. Graduates find that these concepts give them an excellent background in drafting and design. Instructors can choose the units appropriate for their program.
- This text continues to provide the latest drawing standards, indispensable to instructors. Current ANSI/ASME and ISO drawing practices are examined better here than in any other text.
- Numerous Internet assignments appear throughout the book. The Websites, which relate directly to the topic of the unit, are of companies students might select to survey possible career opportunities. Instructors can ask students to describe what they found at the sites or to discuss sites that have the greatest regional career interest. Students can also view various technical product lines.

Each chapter begins with objectives and ends with a chapter summary and list of key terms (both referenced to chapter units) and drafting assignments. A Glossary,

precedes the Appendix. The four-color design highlights the text’s special features. Color is used to enhance the instructional value of the material. Thus, technical material is appealing visually and easy to follow and understand.

ADDITIONAL RESOURCES

We have revised, improved, and added to the program’s ancillary products. Here is what’s new and updated:

Drawing Workbook

The *Workbook for Engineering Drawing and Design, Seventh Edition*, covers all 27 chapters. It contains worksheets that provide a partially completed solution for assignments for each unit of the text. Each worksheet is referenced to a specific chapter and unit number in the text. Instructions are provided that give an overview for each assignment and references it to the appropriate text unit. The drawing problems contain both U.S. customary (decimal inch) and metric (millimeter) units of measurement. The worksheets are perforated for easy removal. Solutions are available to instructors at the book’s website at www.mhhe.com/jensen.

Additional Chapters on Advanced Topics

Three additional chapters, covering advanced topics, are provided on the book’s website:

- Chapter 28—Applied Mechanics
- Chapter 29—Strength of Materials
- Chapter 30—Fluid Power

Comments and suggestions concerning this and future editions of the text are most welcome.

Visit the text website at: www.mhhe.com/jensen for various resources available to instructors and students.



Acknowledgments

The authors are indebted to the members of ASME Y14.5M-1994 (R2004), *Dimensioning and Tolerancing*, and the members of the CAN/CSA-B78.2-M91, *Dimensioning and Tolerancing of Technical Drawings*, for the countless hours they have contributed to making successful standards.

The authors and staff of McGraw-Hill wish to express their appreciation to the following individuals for their responses to questionnaires and their professional reviews of the new edition:

Fred Brasfield
Tarrant County College

Ralph Dirksen
Western Illinois University

James Freygang
Ivy Tech Community College

George Gibson
Athens Technical College

James Haick
Columbus Technical College

Richard Jerz
St. Ambrose University

Bisi Oluyemi
Morehouse College

Robert A. Osnes
Everett Community College

Douglas L. Ramers
University of Evansville

Jeff Raquet
University of North Carolina—Charlotte

Larry Shacklett
Southeastern Community College

Warner Smidt
University of Wisconsin-Platteville

James Stokes
Ivy Tech Community College of Indiana

Slobodan Urdarevik
Western Michigan University

Dean Zirwas
Indian River Community College



About the Authors

Cecil H. Jensen

Cecil H. Jensen authored or coauthored many successful technical books, including *Engineering Drawing and Design*, *Fundamentals of Engineering Drawing*, *Fundamentals of Engineering Graphics* (formerly called *Drafting Fundamentals*), *Interpreting Engineering Drawings*, *Geometric Dimensioning and Tolerancing for Engineering and Manufacturing Technology*, *Architectural Drawing and Design for Residential Construction*, *Home Planning and Design*, and *Interior Design*. Some of these books

were printed in three languages and are popular in many countries.

Mr. Jensen was a member of the Canadian Standards Committee (CSA) on Technical Drawings (which includes both mechanical and architectural drawing) and headed the Committee on Dimensioning and Tolerancing. He was Canada's ANSI representative. He represented Canada at two world ISO conferences in Oslo and Paris on the standardization of technical drawings. Cecil Jensen passed away in April, 2005.

Jay D. Helsel

Jay D. Helsel is professor emeritus of applied engineering and technology at California University of Pennsylvania. He earned the master's degree from Pennsylvania State University and a doctoral degree in educational communications and technology from the University of Pittsburgh. He holds a certificate in airbrush techniques and technical illustration from the Pittsburgh Art Institute. He has worked in industry and has also taught drafting, metalworking, woodworking,

and a variety of laboratory and professional courses at both the secondary and the college levels.

Dr. Helsel is now a full-time writer. He coauthored *Engineering Drawing and Design*, *Fundamentals of Engineering Drawing*, *Programmed Blueprint Reading*, the popular high school drafting textbook *Mechanical Drawing: Board and CAD Techniques*, now in its thirteenth edition, and *Interpreting Engineering Drawings*.

Dennis R. Short

Dennis R. Short is professor of computer graphics technology at the School of Technology, Purdue University. He completed his undergraduate and graduate work at Purdue University and also studied at the University of Maryland, College Park. He enjoys teaching traditional engineering design and drafting, computer-aided drafting and design, computer-integrated manufacturing (CIM), and advanced modeling and animation. While at Purdue, he implemented

the first instructional CAD system for the School of Technology, as well as the first networked PC-based CAD laboratory. In addition to teaching undergraduates, he is on the graduate faculty. He codirects the Purdue International Center for Entertainment Technology (PICET), a university-level interdisciplinary research and development center. Dr. Short prepared the *Instructor Wraparound Edition for Engineering Drawing and Design*, Fifth and Sixth Editions.

Contents

Preface	xii
Acknowledgments	xiv
About the Authors	xv

PART 1

BASIC DRAWING AND DESIGN 1

Chapter 1

Engineering Graphics as a Language 2

- 1-1 The Language of Industry 2
 - Drawing Standards 3
- 1-2 Careers in Engineering Graphics 4
 - The Student 4
 - Places of Employment 4
 - Training, Qualifications, and Advancement 5
 - Employment Outlook 5
- 1-3 The Drafting Office 5
- 1-4 Board Drafting 7
 - Drafting Furniture 7
 - Drafting Equipment 7
- Review and Assignments 15

Chapter 2

Computer-Aided Drawing (CAD) 18

- 2-1 Overview 18
- 2-2 Components of a CAD System 19
 - Hardware 19
 - Software 24
- 2-3 Communication Environment 27
 - Local Area Networks (LANs) 27
 - Wide Area Networks (WANs) and the World Wide Web (WWW) 27
 - Cooperative Work Environments 28
- 2-4 Computer-Aided Manufacturing (CAM) 28
 - Computer Numerical Control 28
 - Robotics 28

Computer-Integrated Manufacturing (CIM)	29
Review and Assignments	30

Chapter 3

Drawing Media, Filing, Storage, and Reproduction 32

- 3-1 Drawing Media and Format 32
 - Drawing Media 32
 - Standard Drawing Sizes 32
 - Drawing Format 33
- 3-2 Filing and Storage 36
 - Filing Systems 36
 - CAD 37
- 3-3 Drawing Reproduction 38
 - Reproduction Equipment 38
- Review and Assignments 42

Chapter 4

Basic Drafting Skills 43

- 4-1 Straight Line Work, Lettering, and Erasing 43
 - Engineering Drawing Standards and Conventions 43
 - Board Drafting 44
 - CAD 54
 - Coordinate Input 50
- 4-2 Circles and Arcs 51
 - Center Lines 51
 - CAD 51
 - Drawing Circles and Arcs 51
 - CAD 53
- 4-3 Drawing Irregular Curves 53
 - CAD 54
- 4-4 Sketching 54
 - Sketching Paper 54
 - Basic Steps to Follow When Sketching 57
- Review and Assignments 58

Chapter 5

Applied Geometry 70

- 5-1 Beginning Geometry: Straight Lines 70
- 5-2 Arcs and Circles 73
- 5-3 Polygons 75
- 5-4 Ellipse 76
- 5-5 Helix and Parabola 77
 - Helix 77
 - Parabola 78
- Review and Assignments 79

Chapter 6

Theory of Shape Description 86

- 6-1 Orthographic Representations 86
 - Theory of Shape Description 86
 - Orthographic Representations 86
 - Methods of Representation 87
 - CAD Coordinate Input for Orthographic Representation 90
- 6-2 Arrangement and Construction of Views 92
 - Spacing the Views 92
 - Use of a Miter Line 93
 - CAD 94
- 6-3 All Surfaces Parallel and All Edges and Lines Visible 94
- 6-4 Hidden Surfaces and Edges 95
- 6-5 Inclined Surfaces 96
- 6-6 Circular Features 96
 - Center Lines 96
- 6-7 Oblique Surfaces 97
- 6-8 One- and Two-View Drawings 98
 - View Selection 98
 - One-View Drawings 98
 - Two-View Drawings 99
- 6-9 Special Views 99
 - Partial Views 99
 - Rear Views and Enlarged Views 99
- 6-10 Conventional Representation of Common Features 101
 - Repetitive Details 101
 - Repetitive Parts 101
 - Square Sections 101
- 6-11 Conventional Breaks 102
- 6-12 Materials of Construction 102
 - Transparent Materials 102
- 6-13 Cylindrical Intersections 102
- 6-14 Foreshortened Projection 102
 - Holes Revolved to Show True Distance from Center 102

- 6-15 Intersections of Unfinished Surfaces 103
- Review and Assignments 105

Chapter 7

Auxiliary Views and Revolutions 132

- 7-1 Primary Auxiliary Views 132
 - Dimensioning Auxiliary Views 134
- 7-2 Circular Features in Auxiliary Projection 135
- 7-3 Multi-Auxiliary-View Drawings 136
- 7-4 Secondary Auxiliary Views 137
- 7-5 Revolutions 140
 - Reference Planes 140
 - Revolutions 140
 - The Rule of Revolution 142
 - True Shape of an Oblique Surface Found by Successive Revolutions 142
 - Auxiliary Views and Revolved Views 143
 - True Length of a Line 144
- 7-6 Locating Points and Lines in Space 145
 - Points in Space 145
 - Lines in Space 145
 - True Length of an Oblique Line by Auxiliary View Projection 146
 - Point on a Line 146
 - Point-on-Point View of a Line 148
- 7-7 Planes in Space 148
 - Locating a Line in a Plane 148
 - Locating a Point on a Plane 149
 - Locating the Piercing Point of a Line and a Plane—Cutting-Plane Method 150
 - Locating the Piercing Point of a Line and a Plane—Auxiliary View Method 150
- 7-8 Establishing Visibility of Lines in Space 152
 - Visibility of Oblique Lines by Testing 152
 - Visibility of Lines and Surfaces by Testing 152
 - Visibility of Lines and Surfaces by Observation 153
- 7-9 Distances between Lines and Points 154
 - Distance from a Point to a Line 154
 - Shortest Distance between Two Oblique Lines 154
- 7-10 Edge and True View of Planes 157
 - Planes in Combination 158
- 7-11 Angles between Lines and Planes 160
 - The Angle a Line Makes with a Plane 160
 - Edge Lines of Two Planes 161
- Review and Assignments 163

Chapter 8

Basic Dimensioning 177

- 8-1 Basic Dimensioning 177
 - Dimensioning 177
 - Units of Measurement 181

Dual Dimensioning 182
 Angular Units 182
 Reading Direction 183
 Basic Rules for Dimensioning 183
 Symmetrical Outlines 184
 Reference Dimensions 184
 Not-to-Scale Dimensions 184
 Operational Names 184
 Abbreviations 184

8-2 Dimensioning Circular Features 185

Diameters 185
 Radii 186

8-3 Dimensioning Common Features 189

Repetitive Features and Dimensions 189
 Chamfers 189
 Slopes and Tapers 190
 Knurls 191
 Formed Parts 191
 Undercuts 192
 Limited Lengths and Areas 192
 Wire, Sheet Metal, and Drill Rod 192

8-4 Dimensioning Methods 192

Rectangular Coordinate Dimensioning 193
 Polar Coordinate Dimensioning 193
 Chordal Dimensioning 193
 True-Position Dimensioning 193
 Chain Dimensioning 193
 Datum or Common-Point Dimensioning 195

8-5 Limits and Tolerances 195

Key Concepts 196
 Tolerancing 197
 Additional Rules for Dimensioning 200

8-6 Fits and Allowances 201

Fits 201
 Allowance 201
 Description of Fits 201
 Interchangeability of Parts 202
 Standard Inch Fits 202
 Basic Hole System 204
 Basic Shaft System 205
 Preferred Metric Limits and Fits 205

8-7 Surface Texture 208

Surface Texture Characteristics 209
 Surface Texture Symbol 209
 Application 211
 Machined Surfaces 211

Review and Assignments 216

Chapter 9

Sections 235

9-1 Sectional Views 235

Cutting-Plane Lines 235
 Full Sections 237
 Section Lining 237

9-2 Two or More Sectional Views on One Drawing 238

9-3 Half-Sections 239

9-4 Threads in Section 240

Threaded Assemblies 240

9-5 Assemblies in Section 241

Section Lining on Assembly Drawings 241

9-6 Offset Sections 242

9-7 Ribs, Holes, and Lugs in Section 243

Ribs in Sections 243
 Holes in Sections 243
 Lugs in Section 243

9-8 Revolved and Removed Sections 245

Placement of Sectional Views 245

9-9 Spokes and Arms in Section 247

9-10 Partial or Broken-Out Sections 248

9-11 Phantom or Hidden Sections 248

9-12 Sectional Drawing Review 248

Review and Assignments 249

PART 2

FASTENERS, MATERIALS, AND FORMING PROCESSES 269

Chapter 10

Threaded Fasteners 270

10-1 Simplified Thread Representation 270

Screw Threads 271
 Thread Forms 271
 Thread Representation 271
 Right- and Left-Hand Threads 272
 Single and Multiple Threads 272
 Simplified Thread Representation 273
 Threaded Assemblies 273
 Inch Threads 273
 Metric Threads 276
 Pipe Threads 278

10-2 Detailed and Schematic Thread Representation 278

Detailed Thread Representation 278
 Threaded Assemblies 279
 Schematic Thread Representation 279

10-3 Common Threaded Fasteners 280

Fastener Selection 280
 Fastener Definitions 281
 Fastener Configuration 281
 Head Styles 281
 Property Classes of Fasteners 282

- Drawing a Bolt and Nut 284
- Studs 285
- Washers 285
- Terms Related to Threaded Fasteners 285
- Specifying Fasteners 286

10-4 Special Fasteners 287

- Setscrews 287
- Keeping Fasteners Tight 287
- Locknuts 288
- Captive or Self-Retaining Nuts 290
- Inserts 290
- Sealing Fasteners 290

10-5 Fasteners for Light-Gage Metal, Plastic, and Wood 291

- Tapping Screws 291
- Special Tapping Screws 291

Review and Assignments 295

Chapter 11

Miscellaneous Types of Fasteners 305

11-1 Keys, Splines, and Serrations 305

- Keys 305
- Splines and Serrations 306

11-2 Pin Fasteners 308

- Semipermanent Pins 309
- Quick-Release Pins 311

11-3 Retaining Rings 312

- Stamped Retaining Rings 312
- Wire-Formed Retaining Rings 313
- Spiral-Wound Retaining Rings 313

11-4 Springs 313

- Types of Springs 313
- Spring Drawings 315
- Spring Clips 315

11-5 Rivets 317

- Standard Rivets 317
- Large Rivets 317
- Rivets for Aerospace Equipment 317
- Small Rivets 318
- Blind Rivets 318

11-6 Welded Fasteners 323

- Resistance-Welded Fasteners 323
- Arc-Welded Studs 323

11-7 Adhesive Fastenings 325

- Adhesion versus Stress 325
- Joint Design 325

11-8 Fastener Review for Chapters 10 and 11 327

Review and Assignments 328

Chapter 12

Manufacturing Materials 341

12-1 Cast Irons and Ferrous Metals 341

- Ferrous Metals 341
- Cast Iron 341

12-2 Carbon Steel 343

- Carbon and Low-Alloy Cast Steels 343
- High-Alloy Cast Steels 343
- Carbon Steels 343
- Steel Specification 343
- SAE and AISI-Systems of Steel Identification 345
- High-Strength Low-Alloy Steels 348
- Low- and Medium-Alloy Steels 348
- Stainless Steels 348
- Free-Machining Steels 348

12-3 Nonferrous Metals 349

- Manufacturing with Metals 349
- Aluminum 349
- Copper 350
- Nickel 350
- Magnesium 350
- Zinc 351
- Titanium 351
- Beryllium 351
- Refractory Metals 351
- Precious Metals 351

12-4 Plastics 352

- Thermoplastics 352
- Thermosetting Plastics 352
- Machining 352
- Material Selection 352
- Forming Processes 354

12-5 Rubber 357

- Material and Characteristics 357
- Kinds of Rubber 357
- Assembly Methods 357
- Design Considerations 358

Review and Assignments 359

Chapter 13

Forming Processes 364

13-1 Metal Castings 364

- Forming Processes 364
- Casting Processes 364
- Selection of Process 368
- Design Considerations 369
- Drafting Practices 371
- Casting Datums 373
- Machining Datums 374

13-2 Forgings 375

- Closed-Die Forging 375

General Design Rules 376
Drafting Practices 377

13-3 Powder Metallurgy 380

Design Considerations 380

13-4 Plastic Molded Parts 380

Single Parts 380
Assemblies 383
Drawings 386

Review and Assignments 387

PART 3

WORKING DRAWINGS AND DESIGN 397

Chapter 14

Detail and Assembly Drawings 398

14-1 Drawing Quality Assurance 398

Review Considerations 398
Drawing Considerations 399
Fabrication Considerations 400
Assemble Considerations 400

14-2 Functional Drafting 400

Procedural Shortcuts 400
Reducing the Number of Drawings Required 402
Simplified Representations in Drawings 402
Reproduction Shortcuts 403
Photodrawings 404

14-3 Detail Drawings 405

Detail Drawing Requirements 405
Drawing Checklist 405
Qualifications of a Detailer 405
Manufacturing Methods 405

14-4 Multiple Detail Drawings 407

14-5 Drawing Revisions 409

14-6 Assembly Drawings 410

Design Assembly Drawings 410
Installation Assembly Drawings 411
Assembly Drawings for Catalogs 411
Item List 411

14-7 Exploded Assembly Drawings 412

14-8 Detail Assembly Drawings 413

14-9 Subassembly Drawings 415

Review and Assignments 416

Chapter 15

Pictorial Drawings 457

15-1 Pictorial Drawings 457

Axonometric Projection 457
Isometric Drawings 460

Nonisometric Lines 460

Dimensioning Isometric Drawings 460

Isometric Sketching 461

Basic Steps to Follow for Isometric
Sketching (Fig. 15-12) 462

15-2 Curved Surfaces in Isometric 464

Circles and Arcs in Isometric 464
Drawing Irregular Curves in Isometric 464

15-3 Common Features in Isometric 465

Isometric Sectioning 465
Fillet and Rounds 467
Threads 467
Break Lines 467
Isometric Assembly Drawings 467

15-4 Oblique-Projection 467

Inclined Surfaces 468
Oblique Sketching 468
Basic Steps to Follow for Oblique
Sketching (Fig. 15-29) 470
Dimensioning Oblique Drawings 470

15-5 Common Features in Oblique 471

Circles and Arcs 471
Oblique Sectioning 472
Treatment of Conventional Features 472

15-6 Parallel, or One-Point, Perspective 474

Perspective Projection 474
Types of Perspective Drawings 475
Parallel, or One-Point, Perspective 476
Basic Steps to Follow for Parallel Perspective
Sketching (Fig. 15-47) 477

15-7 Angular, or Two-Point, Perspective 480

Angular-Perspective Sketching 481
Basic Steps to Follow for Angular- Perspective
Sketching (Fig. 15-58) 483
CAD 483

15-8 Solid Modeling 484

Wire-Frame Modeling 484
Surface Modeling 486
Solid Modeling 486
Image Generation 488
Data Extraction 489

Review and Assignments 491

Chapter 16

Geometric Dimensioning and Tolerancing 510

16-1 Modern Engineering Tolerancing 510

Basic Concepts 511
Size of Dimensions 511
Interpretation of Drawings and
Dimensions 513
Assumed Datums 513

16-2 Geometric Tolerancing	517	Profile Symbols	569
Feature Control Frame	517	Profile-of-a-Line Tolerance	569
Placement of Feature Control Frame	517	Profile-of-a-Surface Tolerance	571
Form Tolerances	518		
Straightness	519	16-14 Correlative Tolerances	574
16-3 Flatness	522	Coplanarity	574
Flatness of a Surface	522	Concentricity	575
Flatness per Unit Area	522	Coaxiality	577
Two or More Flat Surfaces in One Plane	522	Symmetry	578
16-4 Straightness of a Feature of Size	523	Runout	578
Features of Size	523	16-15 Positional Tolerancing for Noncylindrical Features	580
Material Condition Symbols (Modifiers)	524	Noncircular Features at MMC	580
Applicability of RFS, MMC, and LMC	525	16-16 Positional Tolerancing for Multiple Patterns of Features	584
Straightness of a Feature of Size	527	Composite Positional Tolerancing	587
16-5 Datums and the Three-Plane Concept	529	16-17 Formulas for Positional Tolerancing	591
Datums	529	Floating Fasteners	591
Datums for Geometric Tolerancing	529	Calculating Clearance	592
Three-Plane System	531	Fixed Fasteners	592
Identification of Datums	532	Unequal Tolerances and Hole Sizes	594
16-6 Orientation Tolerancing of Flat Surfaces	535	Coaxial Features	594
Reference to a Datum	535	Perpendicularity Errors	595
Angularity Tolerance	535	16-18 Summary of Rules for Geometric Tolerancing	595
Perpendicularity Tolerance	535	When to Use Geometric Tolerancing	595
Parallelism Tolerance	535	Basic Rules	595
Examples of Orientation Tolerancing	535	Review and Assignments	598
Control in Two Directions	536		
16-7 Datum Features Subject to Size Variation	537		
Parts with Cylindrical Datum Features	537		
RFS and MMC Applications	538		
16-8 Orientation Tolerancing for Features of Size	542		
Angularity Tolerance	543		
Parallelism Tolerance	543		
Perpendicularity Tolerance	543		
Control in Two Directions	543		
Control on an MMC Basis	543		
Internal Cylindrical Features	545		
External Cylindrical Features	548		
16-9 Positional Tolerancing	549		
Tolerancing Methods	549		
Coordinate Tolerancing	550		
Positional Tolerancing	553		
16-10 Projected Tolerance Zone	559		
16-11 Datum Targets	561		
Datum Target Symbol	562		
Identification Targets	562		
Targets Not in the Same Plane	563		
Partial Surfaces as Datums	565		
Dimensioning for Target Location	565		
16-12 Circularity and Cylindricity	565		
Circularity	565		
Cylindricity	567		
16-13 Profile Tolerancing	569		
Profiles	569		

Chapter 17

Drawings for Numerical Control 629

- 17-1 Two-Axis Control Systems** 629
 - Computer Numerical Control (CNC) 629
 - Dimensioning for Numerical Control 630
 - Dimensioning for a Two-Axis Coordinate System 631
- 17-2 Three-Axis Control Systems** 633
 - Dimensioning and Tolerancing 633
- Review and Assignments** 636

Chapter 18

Welding Drawings 641

- 18-1 Designing for Welding** 641
 - Welding Processes 641
- 18-2 Welding Symbols** 643
 - The Design of Welded Joints 648
- 18-3 Fillet Welds** 650
 - Fillet Weld Symbols 650
 - Size of Fillet Welds 653

18-4 Groove Welds 654

- Use of Break in Arrow of Bevel and J-Groove Welding Symbols 655
- Groove Weld Symbols 655
- Groove Joint Design 662

18-5 Other Basic Welds 660

- Plug Welds 662
- Slot Welds 663
- Spot Welds 664
- Seam Welds 668
- Surfacing Welds 669
- Flanged Welds 670
- Stud Welds 671

Review and Assignments 673*Chapter 19***Design Concepts 686****19-1 The Design Process 686**

- The Design Process 686
- The Engineering Approach to Successful Design 687
- Part Specifications 688
- Do's and Don'ts for Designers 689

19-2 Assembly Considerations 690

- Cost of Assembly 690
- Attachments 691
- Design Checklist 697
- Design Approach to a Fabricated Structure 697

19-3 Concurrent Engineering 698

- Concurrent Engineering through Computers 699
- Green Engineering 699

19-4 Project Management 699

- Online Project Management 702
- Assignments 702

Review and Assignments 703**PART 4****POWER TRANSMISSIONS 707***Chapter 20***Belts, Chains, and Gears 708****20-1 Belt Drives**

- Flat Belts 708
- Conventional Flat Belts 709
- V-Belts 710
- How to Select a Light-Duty V-Belt Drive 712

20-2 Chain Drives 717

- Basic Types 717
- Sprockets 719
- Design of Roller Chain Drives 719

20-3 Gear Drives 730

- Spur Gears 730

20-4 Power-Transmitting Capacity of Spur Gears 736

- Selecting the Spur Gear Drive 736

20-5 Rack and Pinion 738**20-6 Bevel Gears 739**

- Working Drawings of Bevel Gears 740

20-7 Worm and Worm Gears 740

- Working Drawings of Worm and Worm Gears 740

20-8 Comparison of Chain, Gear, and Belt Drives 744

- Chains 744
- Gears 744
- Belts 744
- Chain Drives Compared with Gear Drives 744
- Chain Drives Compared with Belt Drives 745
- Conclusion 745

Review and Assignments 746*Chapter 21***Couplings, Bearings, and Seals 756****21-1 Couplings and Flexible Shafts 756**

- Couplings 756
- Flexible Shafts 758

21-2 Bearings 759

- Plain Bearings 759

21-3 Antifriction Bearings 760

- Bearing Loads 760
- Ball Bearings 760
- Roller Bearings 762
- Bearing Selection 763
- Bearing Classifications 763
- Shaft and Housing Fits 763
- Bearing Symbols 766

21-4 Premounted Bearings 767**21-5 Lubricants and Radial Seals 769**

- Lubricants 769
- Grease and Oil Seals 770
- Radial Seals 771

21-6 Static Seals and Sealants 775

- O-Ring Seals 775
- Flat Nonmetallic Gaskets 776
- Metallic Gaskets 777
- Sealants 777
- Exclusion Seals 777

Review and Assignments 780

Chapter 22

Cams, Linkages, and Actuators 792

22-1 Cams, Linkages, and Actuators 792

- Cam Nomenclature 793
- Cam Followers 794
- Cam Motions 794
- Simplified Method for Laying Out Cam Motion 798
- Cam Displacement Diagrams 798

22-2 Plate Cams 799

- Conjugate Cams 800
- Timing Diagrams 801
- Dimensioning Cams 801
- Cam Size 804

22-3 Positive-Motion Cams 805

22-4 Drum Cams 806

22-5 Indexing 808

22-6 Linkages 810

- Locus of a Point 810
- Cams versus Linkages 810
- Straight-Line Mechanism 811
- Systems Having Linkages and Cams 812

22-7 Ratchet Wheels 813

Review and Assignments 875

PART 5

SPECIAL FIELDS OF DRAFTING 823

Chapter 23

Developments and Intersections 824

23-1 Surface Developments 824

- Sheet-Metal Development 824
- Straight-Line Development 826

23-2 The Packaging Industry 827

23-3 Radial Line Development of Flat Surfaces 828

23-4 Parallel Line Development of Cylindrical Surfaces 831

23-5 Radial Line Development of Conical Surfaces 834

23-6 Development of Transition Pieces by Triangulation 836

23-7 Development of a Sphere 839

23-8 Intersection of Flat Surfaces—Lines Perpendicular 840

23-9 Intersection of Cylindrical Surfaces 843

23-10 Intersecting Prisms 844

23-11 Stampings 847

Design Considerations 847

Review and Assignments 853

Chapter 24

Pipe Drawings 867

24-1 Pipes

- Pipe Drawings 867
- Kinds of Pipes 867
- Pipe Joints and Fitting 868
- Valves 869
- Piping Drawings 871

24-2 Isometric Projection of Piping Drawings 875

24-3 Supplementary Piping Information 877

Review and Assignments 880

Chapter 25

Structural Drafting 887

25-1 Structural Drafting 887

- The Building Process 877
- Structural Steel—Plain Material 888
- Structural Drawing Practices 893

25-2 Beams 894

- Assembly Clearances 895
- Simple Square-Framed Beams 896

25-3 Standard Connections 898

- Bolted Connections 898

25-4 Sectioning 905

- Bottom Views 905
- Elimination of Top and Bottom Views 905
- Right- and Left-Hand Details 906

25-5 Seated Beam Connections 907

25-6 Dimensioning 909

- Bills of Material 910
- Calculations of Weights (Masses) 911

Review and Assignments 912

Chapter 26

Jigs and Fixtures 919

26-1 Jig and Fixture Design 919

- Jigs 919
- Drill Jigs 921
- Drill Bushings 921

26-2 Drill Jig Components 923

- Jig Body 923
- Cap Screws and Dowel Pins 923
- Locating Devices 924
- Clamping Devices 926

Locking Pins 927
Miscellaneous Standard Parts 927
Design Examples 927

26-3 Dimensioning Jig Drawings 929

26-4 Fixtures 930

Milling Fixtures 930
Fixture Components 931
Fixture Design Considerations 932
Sequence in Laying Out a Fixture 935
Review and Assignments 936

Chapter **27**
Electrical and Electronics Drawings 940

27-1 Electrical and Electronics Drawings 940

Standardization 940
Using CAD for Electrical Drawings 941

27-2 Schematic Diagrams 942

Laying Out a Schematic Diagram 942
Graphic Symbols 942

27-3 Wiring (Connection) Diagrams 945

Basic Rules for Laying Out a Wiring Diagram 947

27-4 Printed Circuit Boards 947

CAD for Printed Circuit Boards 949
Basic Rules for Laying Out a Printed Circuit 951

27-5 Block and Logic Diagrams 951

Block Diagrams 951
Logic Diagrams 952
Graphic Symbols 952

Review and Assignments 956

Glossary G-1

Appendix—Standard Parts and Technical Data A-1

Index I-1

PART 1

BASIC DRAWING AND DESIGN

OVERVIEW

Chapter 1	Engineering Graphics as a Language	2
Chapter 2	Computer-Aided Drawing (CAD)	18
Chapter 3	Drawing Media, Filing, Storage, and Reproduction	32
Chapter 4	Basic Drafting Skills	43
Chapter 5	Applied Geometry	70
Chapter 6	Theory of Shape Description	86
Chapter 7	Auxiliary Views and Revolutions	132
Chapter 8	Basic Dimensioning	177
Chapter 9	Sections	235