SIXTH EDITION

ENGINEERING DRAWING & DESIGN

David A. Madsen
David P. Madsen

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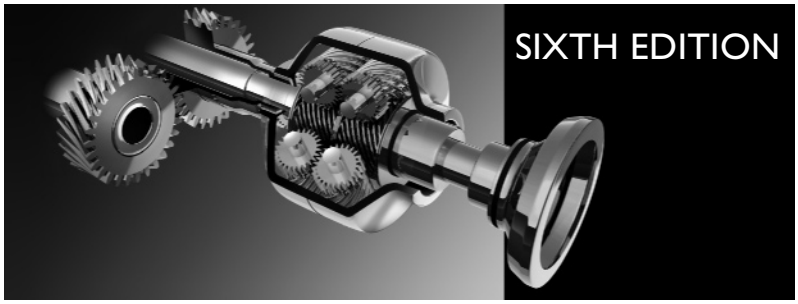
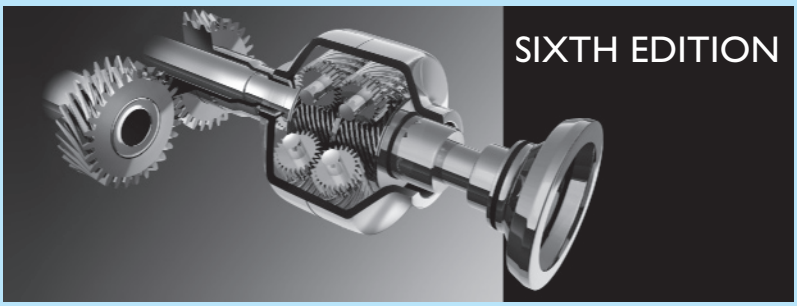
ENGINEERING DRAWING & DESIGN



ENGINEERING DRAWING & DESIGN



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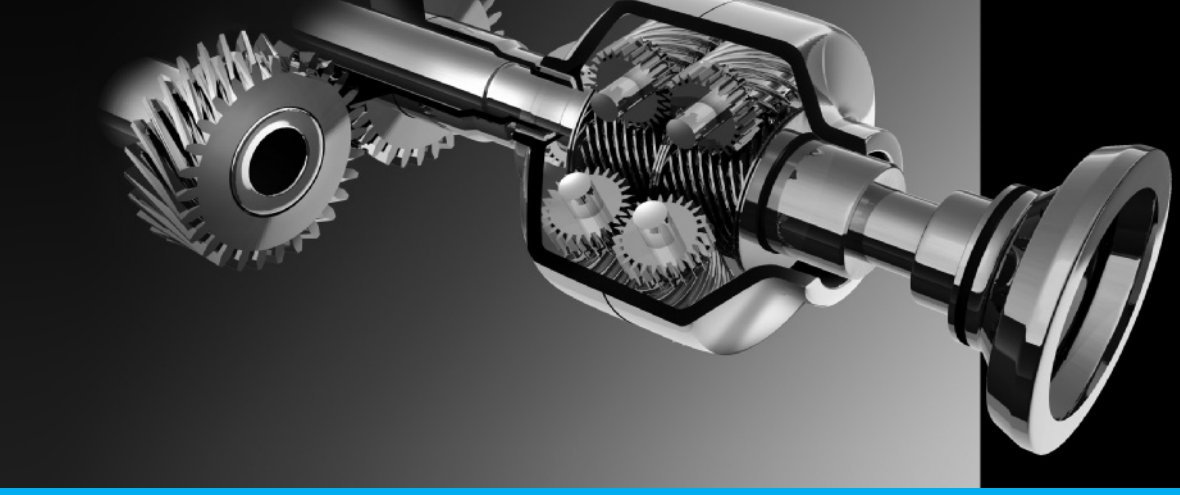

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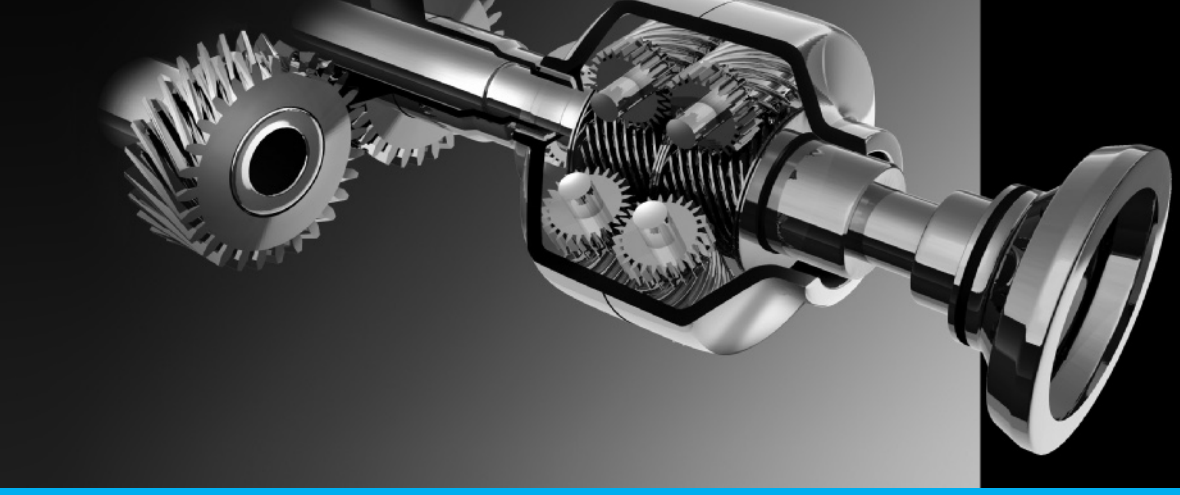

Preface

For more than 25 years, students have relied on *Engineering Drawing and Design* for its easy-to-read, comprehensive coverage of drafting and design instruction that complies with industry standards. The Sixth Edition continues its tradition of excellence with a multitude of actual quality industry drawings that demonstrate content coverage and the addition of new problems to the hundreds already on-hand for real-world, practical application. The engineering design process featured in this revision contains new material related to production practices that eliminate waste in all phases from design through manufacturing to marketing and distribution. Also described are practices that seek to improve the quality of process outputs by identifying and removing the causes of defects and minimizing manufacturing variables using quality management methods. Actual product designs are taken from concept through manufacturing and to marketing. This is the most comprehensive product design analysis found in any discipline-related textbook. More than 1,000 drafting and design problems are found throughout for basic to advanced challenging applications or for use individually or for team projects. New and current features of this textbook are described throughout this Preface.

NEW TO THIS EDITION

- Up-to-Date Computer-aided Design and Drafting (CADD) Content

  CADD refers to the entire range of design and drafting with the aid of a computer, from drawing basic 2-D objects to preparing complex 3-D models and animations. Computer-aided design and computer-aided drafting refer to specific aspects of the CADD process.

  CADD offers solutions to most engineering drawing and design problems, and it allows for increasingly complex projects. Industries, disciplines, engineering firms, and educational institutions related to engineering and architecture use Professionals have come to rely on the power and convenience of CADD in all aspects of design and drafting. CADD systems include tools to accomplish any drawing and design requirement, such as 2-D drawings, 3-D models, animations, and virtual reality applications.

- Latest Introduction to Additive Manufacturing (AM)

  Additive manufacturing (AM), also known as **3-D printing**, is a manufacturing process by which a physical 3-D model of an object is made directly from 3-D CAD model data using a **3-D printer**. AM has revolutionized product design and manufacture. Chapter 3, *Computer-Aided Design and Drafting (CADD)*, introduces **rapid prototyping**, which is an AM application used to create a physical 3-D prototype. Increasingly, AM is being used to produce functioning end use parts and products, such as medical implants, dental restorations, consumer products, and automobile and aircraft parts. AM offers exciting opportunities for a variety of industries and has major implications for the engineering design process. Now, 3-D printers can be used to build complex 3-D geometry that is not possible with any other manufacturing technique. A design can move from an idea to a 3-D CAD model to a finished product in significantly less time when compared to traditional manufacturing systems. In other words, 3-D printed products can be built on-demand, typically wasting less material and requiring fewer resources than other forms of manufacturing. In many cases, AM eliminates standard manufacturing procedures, such as tooling, mold making, and machining. AM can also complement other manufacturing processes such as the use of 3-D printed patterns and molds for investment casting and tools for machining. Advancements in AM technology have resulted in more, improved, and less expensive 3-D printing materials used to generate larger sized, more complex shaped, and multicolor printed objects.

- Team Problems

  Advanced problems can be assigned as team problems as determined by the instructor and course objectives. Team problems are provided that can be used as projects that help foster leadership and cooperation between team members to design and draw complete sets of working drawings for a product. Teams are established with any desired number of members based on the project and curriculum goals. Additional information about Team Problems is provided later in the Preface.

- PowerPoint Presentation Problems

  The PowerPoint feature is found throughout the textbook, providing students the opportunity to create their own PowerPoint slides directly related to each chapter content and

examples. Use chapter content and examples to create one PowerPoint slide demonstrating each of the given chapter applications. The completed PowerPoint presentations can be used for classroom discussion, or by the instructor for teaching aids.

- Actual Engineering Design Process Applications

  Engineering Drawing and Design, Sixth Edition, continues the tradition of providing real-world engineering design processes, taking product designs from ideas through manufacturing and marketing. These actual engineering design process examples are found in Chapter 25, *The Engineering Design Process*.

  The Sixth Edition's Chapter 25 content is expanded to introduce additional engineering design practices typically found in industry, along with new engineering design examples provided by companies. The new engineering design examples include the development of a portable vascular imaging product that allows a medical practitioner to visualize and observe the **subcutaneous vasculature** system in real-time. Subcutaneous vasculature system refers to the human vasculature system under the skin.

  Another engineering design process example is a CPR training advancement for the design and manufacture of a device that fits in the palm of your hand and automatically monitors and helps improve a student's CPR technique by reporting when compressions and breaths are executed correctly.

  Electric vehicles are on the cutting edge of energy conservation and transportation technology, providing exciting opportunities for new engineering design projects. An electric vehicle design application is provided in this edition to push the limits of energy efficiency in transportation engineering.

  Previous edition engineering design applications taking products from ideas through manufacturing and marketing are found on the Student Companion Website.

- Expanded Glossary

  Every important term is bold and defined in content and in the complete glossary. This is the most comprehensive glossary found in any engineering drafting and design textbook. The glossary can be used as a quick reference to terminology used in the professional engineering drafting and design industry.

FEATURES FOUND IN ENGINEERING DRAWING AND DESIGN, SIXTH EDITION

- Detailed history of drafting.
- A **Standards** feature box describes the specific standards used as related to chapter content.
- **Engineering Design Applications** features written by industry professionals.
- Updated American Society of Mechanical Engineers (ASME) and discipline-related standards.
- Updated CADD standards.
- Comprehensive coverage of ASME Y14.5-2009, *Dimensioning and Tolerancing*, including the most comprehensive geometric dimensioning and tolerancing content found in any textbook.
- CADD file templates for standard ASME inch and metric drawings, and architectural and civil inch and metric drawings.
- Content related to production practices that eliminate waste in all phases from design through manufacturing and to marketing and distribution.
- Current practices that seek to improve the quality of process outputs by identifying and removing the causes of defects and minimizing manufacturing variables using quality management methods.
- CADD theory and applications highlighted in an expanded, full-color chapter.
- CADD applications that demonstrate advances made in this industry.
- Hundreds of drafting and design problems provided throughout the textbook and on the **Student Companion Website**.
- **Note** boxed features provide expanded side information relative to specific features and current applications.
- Protecting the environment is one of the most important worldwide issue today. A flagship feature called **Green Technology Application** is found throughout this textbook, providing current practical and experimental energy-efficient design, construction and manufacturing techniques resulting in a significant reduction in energy consumption and harmful emissions.
- Comprehensive **Glossary**. Every important term is defined in text and in the complete glossary.
- Improved content based on comprehensive technical reviews. Professional discipline–related technical reviewers were commissioned to evaluate content and provide input about accuracy and expanded coverage.
- Chapter tests on the Student Companion Website are revised to correspond with new and updated content.
- Chapter problems on the Student Companion Website have been evaluated for accuracy and new problems added to reflect changes in drafting standards, and for real-world applications provided by technical reviewers.
- Manual drafting content is moved to the **Student Companion Website**.
- Expanded material selection criteria, manufacturing processes, and engineering design applications have been added to the *Manufacturing Materials and Processes* chapter and throughout the textbook.
- **Professional Perspectives** provide real-world content written by industry professionals.
- Engineering Design Applications.
- CADD Applications throughout.

- Hundreds of illustrative examples supporting text content.
- Actual industry drawing examples to pull chapter content together.
- Professional Perspectives.
- Math Applications throughout and comprehensive design drafting-related math instruction on the **Student Companion Website**.
- Step-by-step layout methods.
- Engineering layout techniques.
- Practical and useful appendixes.
- More than 1,000 real-world chapter-related problems on the Student Companion Website.
- Chapter tests for examination or review on the **Student Companion Website**.
- ASME drafting and print reading problems on the **Student Companion Website**.

Engineering Drawing and Design presents engineering drafting standards developed by the ASME and accredited by the American National Standards Institute (ANSI). This textbook also references International Organization for Standardization (ISO) engineering drafting standards and discipline-specific standards when appropriate, including American Welding Society (AWS) standards, the American Society for Testing Materials (ASTM), the American Institute for Steel Construction (AISC), the Construction Specifications Institute (CSI), and the United States National CAD Standard (NCS). Also presented, when appropriate, are standards and codes for specific engineering fields. One important foundation to engineering drawing and design, and the implementation of a common approach to graphics nationwide, is the standardization in all levels of drawing and design instruction. Chapter 1, *Introduction to Engineering Drawing and Design*, provides a detailed introduction to drafting standards, and specific content-related standards are described throughout this textbook. When you become a professional, this text can serve as a valuable desk reference.

AMERICAN DESIGN DRAFTING ASSOCIATION (ADDA)–APPROVED PUBLICATION

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The content of this text is considered a fundamental component of the design drafting profession by the American Design Drafting Association. This publication covers topics and related material as stated in the ADDA Curriculum Certification Standards and the ADDA Certified Drafter Examination Review Guide. Although this publication is not conclusive with respect to ADDA standards, it should be considered a key reference tool in pursuit of a professional design-drafting career.

ENGINEERING DRAWING AND DESIGN CURRICULUM OPTIONS

The conversational-style content is easy to read and easy to use. This textbook is comprehensive and can be used in the entire curriculum. The chapters can be used as presented or rearranged to fit any of the following courses:

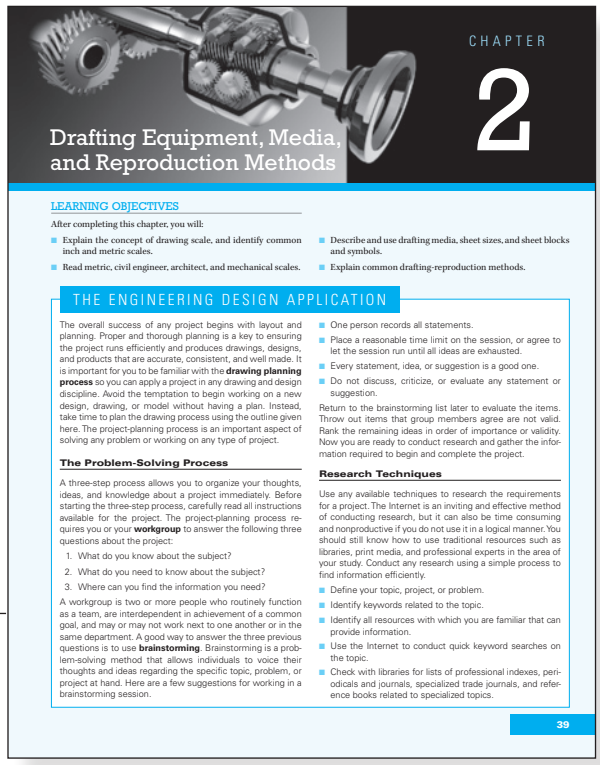
- Drafting Fundamentals
- Engineering Drafting
- The Engineering Design Process
- Engineering Graphics
- Computer-Aided Design and Drafting (CADD)
- Mechanical Drafting
- Descriptive Geometry
- Manufacturing Materials and Processes
- Welding Processes and Weldment Drawings
- Geometric Dimensioning and Tolerancing (GD&T)
- Tool Design
- Mechanisms: Linkages, Cams, Gears, and Bearings
- Belt and Chain Drives
- Pictorial Drawings and Technical Illustration
- 3-D CAD and Modeling, Animation, and Virtual Reality
- Structural Drafting
- Civil Drafting
- Industrial Pipe Drafting
- Heating, Ventilating, and Air-Conditioning (HVAC)
- Pattern Development
- Precision Sheet Metal Drafting
- Fluid Power
- Engineering Charts and Graphs
- Electrical Drafting
- Electronics Drafting
- Drafting Math

CHAPTER FORMAT

Each chapter provides realistic examples, illustrations, and related tests and problems. The tests and problems are available on the Student Companion Website only. The examples illustrate recommended drafting and design presentation based on ASME standards and other related national standards and codes, with actual industry drawings used for reinforcement. The correlated text explains drawing techniques and provides professional tips for skill development. Step-by-step examples provide a logical approach to setting up and completing the drawing problems. Each chapter has the following special features.

Engineering Design Application

The Engineering Design Application leads the content of every chapter. This section gives you an early understanding of the type of engineering project that is found in the specific design and drafting area discussed in the chapter.


CHAPTER 2

Drafting Equipment, Media, and Reproduction Methods

LEARNING OBJECTIVES

After completing this chapter, you will:

- Explain the concept of drawing scale, and identify common inch and metric scales.
- Read metric, civil engineer, architect, and mechanical scales.
- Describe and use drafting media, sheet sizes, and sheet blocks and symbols.
- Explain common drafting-reproduction methods.

THE ENGINEERING DESIGN APPLICATION

The overall success of any project begins with layout and planning. Proper and thorough planning is a key to ensuring the project runs efficiently and produces drawings, designs, and products that are accurate, consistent, and well made. It is important for you to be familiar with the **drawing planning process** so you can apply a project in any drawing and design discipline. Avoid the temptation to begin working on a new design, drawing, or model without having a plan. Instead, take time to plan the drawing process using the outline given here. The project-planning process is an important aspect of solving any problem or working on any type of project.

The Problem-Solving Process

A three-step process allows you to organize your thoughts, ideas, and knowledge about a project immediately. Before starting the three-step process, carefully read all instructions available for the project. The project-planning process requires you or your **workgroup** to answer the following three questions about the project:

1. What do you know about the subject?
2. What do you need to know about the subject?
3. Where can you find the information you need?

A workgroup is two or more people who routinely function as a team, are interdependent in achievement of a common goal, and may or may not work next to one another or in the same department. A good way to answer the three previous questions is to use **brainstorming**. Brainstorming is a problem-solving method that allows individuals to voice their thoughts and ideas regarding the specific topic, problem, or project at hand. Here are a few suggestions for working in a brainstorming session.

- One person records all statements.
- Place a reasonable time limit on the session, or agree to let the session run until all ideas are exhausted.
- Every statement, idea, or suggestion is a good one.
- Do not discuss, criticize, or evaluate any statement or suggestion.

Return to the brainstorming list later to evaluate the items. Throw out items that group members agree are not valid. Rank the remaining ideas in order of importance or validity. Now you are ready to conduct research and gather the information required to begin and complete the project.

Research Techniques

Use any available techniques to research the requirements for a project. The Internet is an inviting and effective method of conducting research, but it can also be time consuming and nonproductive if you do not use it in a logical manner. You should still know how to use traditional resources such as libraries, print media, and professional experts in the area of your study. Conduct any research using a simple process to find information efficiently.

- Define your topic, project, or problem.
- Identify keywords related to the topic.
- Identify all resources with which you are familiar that can provide information.
- Use the Internet to conduct quick keyword searches on the topic.
- Check with libraries for lists of professional indexes, periodicals and journals, specialized trade journals, and reference books related to specialized topics.

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THE ENGINEERING DESIGN APPLICATION

CADD Applications

CADD Applications are provided in each chapter to illustrate how the use of CADD is streamlining the design and drafting process. Both 2-D and 3-D CADD Applications demonstrate advances made in discipline-related discussions and examples.

CADD APPLICATIONS

CADD APPLICATIONS

CNC MACHINE TOOLS

Computer-aided design and drafting (CADD) has a direct link to computer-aided manufacturing in the form of computer numerical control (CNC) machine tools. CNC refers to a computer controller that reads G-code instructions and drives the machine tool. G-code is a computer code used to establish the operation performed on the machine tool. CAM provides a direct link between CADD and CNC machine tools. Figure 4.29 shows a flowchart for the CNC process. Figure 4.30 shows a CNC machine. In most cases, the drawing is generated in a computer, and this information is sent directly to the machine tool for production.

Many CNC systems offer a microcomputer base that incorporates a monitor display and full alphanumeric keyboard, making programming and online editing easy and fast. For example, data input for certain types of machining may result in the programming of one of several identical features while the other features are oriented and programmed automatically, such as the five equally spaced blades of the centrifugal fan shown in Figure 4.31. Among the advantages of CNC machining are increased productivity, reduction of production costs, and manufacturing versatility.

There is a special challenge when preparing drawings for CNC machining. The drawing method must coordinate with a system of controlling a machine tool by instructions in the form of numbers. The types of dimensioning systems that relate directly to CNC applications are tabular, arrowless, datum, and related coordinate systems. The main emphasis is to coordinate the dimensioning system with the movement of the machine tools. This can be best accomplished with datum dimensioning systems in which each dimension originates from a common beginning point. Programming the CNC system requires that cutter compensation be provided for contouring. This task is automatically calculated by computer in some CNC machines, as shown in Figure 4.32, or in software programs such as the CNC Software, Inc., product Mastercam and the SmartCAMcnc product SmartCAM. Definitions and examples of the dimensioning systems are discussed in Chapter 10, *Dimensioning and Tolerancing*.

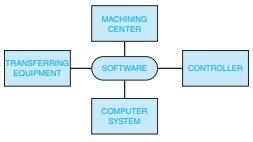


FIGURE 4.29 The computer numerical control (CNC) process.


FIGURE 4.30 A CNC machine.

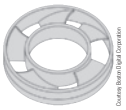


FIGURE 4.31 CNC programming of a part with five equally spaced blades. This figure demonstrates the CNC programming or one of the five equally spaced blades and the automatic orientation and programming of the other four blades.

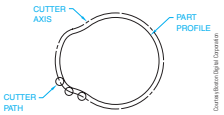


FIGURE 4.32 Automatic cutter compensation for profile machining.

Standards

Specific drafting standards are identified throughout the textbook as they relate to chapter content.

STANDARDS

STANDARDS

AISI/SAE The American Iron and Steel Institute and the Society of Automotive Engineers (SAE) provide similar steel-numbering systems. Steels are identified by four numbers, except for some chromium steels, which have five. For a steel identified as SAE 1020, the first two numbers (10) identify the type of steel, and the last two numbers (20) specify the approximate amount of carbon in hundredths of a percent (0.20% carbon). The letters L or B can be placed between the first and second pair of numbers. L means that lead is added to improve machinability, and B identifies a boron steel. The prefix E means that the steel is made using the electric-furnace method. The prefix H indicates that the steel is produced to hardenability limits. Steel that is degassed and deoxidized before solidification is referred to as **killed steel**, and it is used for forging, heat-treating, and difficult stampings. Steel that is cast with little or no degasification is known as **rimmed steel** and has applications where sheets, strips, rods, and wires with excellent surface finish or drawing requirements are needed.

later in this chapter. For more information about AISI or to order standards, go to the AISI Website at www.aisi.org. For more information about SAE or to order standards, go to the SAE Website at www.sae.org.

Hardening of Steel

The properties of steel can be altered by **heat-treating**. Heat-treating is a process of heating and cooling steel using specific controlled conditions and techniques. Steel is fairly soft when initially formed and allowed to cool naturally. **Normalizing** is a process of heating the steel to a specified temperature and then allowing the material to cool slowly by air, which brings the steel to a normal state. To harden the steel, the metal is first heated to a specified temperature, which varies with different steels. Next, the steel is **quenched**, which means it is cooled suddenly by plunging it into water, oil, or other liquid. Steel can also be **case hardened** using a process known as **carburization**. **Case hardening** refers to the hardening of the surface layer of the metal. Carburization is a process in which carbon is introduced into the metal by heating to a specified temperature range while in contact with a solid, liquid, or gas material consisting of carbon. This process is often followed by quenching to enhance the hardening process. **Tempering** is a process of reheating normalized or hardened steel through a controlled process of heating the metal to a specified temperature, followed by cooling at a

Note

A special Note box feature is used where appropriate to provide additional explanation, helpful tips, professional information, or alternate practice.

NOTE

Some companies use both methods at different times, depending on the purpose of the drawings and the type of product. For example, it is more common for the parts of a weldment to be drawn grouped on sheets rather than one part per sheet, because the parts can be fabricated at one location in the shop.

NOTE: Multidetail drawing practice is commonly used for one-of-a-kind products with components that are not used on other products. This can also be true in a set of drawings. Most companies have a single detail drawing for each component. This drawing has its own drawing number and is not associated as a specific sheet in the assembly. This allows the use of the single drawing to be fabricated **in-house** or sent outside for manufacture. Each component can be treated individually. The individual component drawing can reference the assembly on which it is used. In-house refers to any operations conducted in a company's own facility instead of being outsourced.

view Chapter 11, *Fasteners and Springs*; Chapter 12, *Sections, Revolutions, and Conventional Breaks*; and Chapter 13, *Geometric Dimensioning and Tolerancing*. The information and examples in these chapters set the foundation for everything you do when creating a set of working drawings.

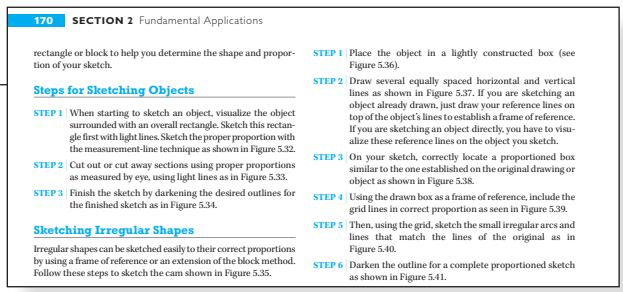
Detail Drawing Manufacturing Information

Detail drawings are created to suit the needs of the manufacturing processes. A detail drawing shows all of the information necessary to manufacture the part. For example, casting and machining information can be together on one drawing. In some situations, a completely dimensioned machining drawing can be sent to the pattern or die maker. The pattern or die is then made to allow for extra material where machined surfaces are specified. When company standards require, two detail drawings are prepared for each part. One detail gives views and dimensions that are necessary only for the casting or forging process. Another detail is created that does not give the previous casting or forging dimensions but provides only the dimensions needed to perform the machining operations on the part. Examples of these drawings are given in Chapter 10, *Dimensioning and Tolerancing*.

Step-by-Step Drafting Procedures and Techniques

Each chapter has step-by-step instructions for applying drafting techniques to the chapter-related content.

STEP-BY-STEP DRAFTING PROCEDURES AND TECHNIQUES



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rectangle or block to help you determine the shape and proportion of your sketch.

Steps for Sketching Objects

STEP 1 When starting to sketch an object, visualize the object surrounded with an overall rectangle. Sketch this rectangle first with light lines. Sketch the proper proportion with the measurement-line technique as shown in Figure 5.32.

STEP 2 Cut out or cut away sections using proper proportions as measured by eye, using light lines as in Figure 5.33.

STEP 3 Finish the sketch by darkening the desired outlines for the finished sketch as in Figure 5.34.

Sketching Irregular Shapes

Irregular shapes can be sketched easily to their correct proportions by using a frame of reference or an extension of the block method. Follow these steps to sketch the cam shown in Figure 5.35.

STEP 1 Place the object in a lightly constructed box (see Figure 5.36).

STEP 2 Draw several equally spaced horizontal and vertical lines as shown in Figure 5.37. If you are sketching an object already drawn, just draw your reference lines on top of the object's lines to establish a frame of reference. If you are sketching an object directly, you have to visualize these reference lines on the object you sketch.

STEP 3 On your sketch, correctly locate a proportioned box similar to the one established on the original drawing or object as shown in Figure 5.38.

STEP 4 Using the drawn box as a frame of reference, include the grid lines in correct proportion as seen in Figure 5.39.

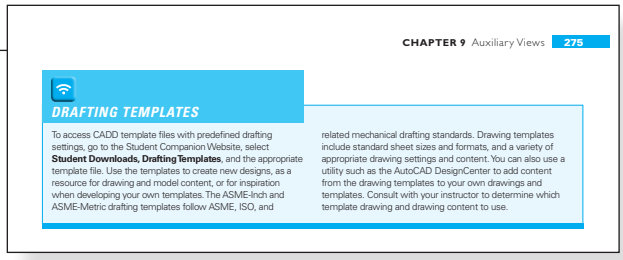
STEP 5 Then, using the grid, sketch the small irregular arcs and lines that match the lines of the original as in Figure 5.40.

STEP 6 Darken the outline for a complete proportioned sketch as shown in Figure 5.41.

Drafting Templates

Standard CADD file template with predefined drafting settings are available on the **Student Companion Website**. Use the templates to create new designs, as a resource for drawing and model content, or for inspiration when developing your own templates. The ASME-Inch and ASME-Metric drafting templates follow ASME, ISO, and related mechanical drafting standards. Architectural and civil drafting templates are also available for use with your electrical, piping, HVAC, structural, and civil drawings. Drawing templates include standard sheet sizes and formats and a variety of appropriate drawing settings and content. You can also use a utility such as the AutoCAD DesignCenter to add content from the drawing templates to your own drawings and templates. Consult with your instructor to determine which template drawing and drawing content to use.

DRAFTING TEMPLATES



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DRAFTING TEMPLATES

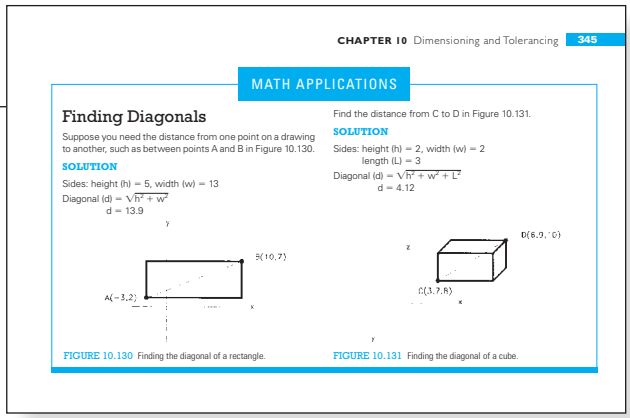
To access CADD template files with predefined drafting settings, go to the Student Companion Website, select **Student Downloads, Drafting Templates**, and the appropriate template file. Use the templates to create new designs, as a resource for drawing and model content, or for inspiration when developing your own templates. The ASME-Inch and ASME-Metric drafting templates follow ASME, ISO, and related mechanical drafting standards. Drawing templates include standard sheet sizes and formats, and a variety of appropriate drawing settings and content. You can also use a utility such as the AutoCAD DesignCenter to add content from the drawing templates to your own drawings and templates. Consult with your instructor to determine which template drawing and drawing content to use.

To access CADD file templates with predefined drafting settings, go to the **Student Companion Website**, select **Student Downloads, Drafting Templates**, and then the appropriate file template.

Math Applications

Practical drafting-related math applications and math problems appear in every chapter and are correlated with the chapter content. These elements provide examples and instruction on how math is used in a specific discipline.

MATH APPLICATIONS



CHAPTER 10 Dimensioning and Tolerancing 345

MATH APPLICATIONS

Finding Diagonals

Suppose you need the distance from one point on a drawing to another, such as between points A and B in Figure 10.130.

SOLUTION

Sides: height (h) = 5, width (w) = 13

Diagonal (d) = $\sqrt{h^2 + w^2}$

d = 13.9

FIGURE 10.130 Finding the diagonal of a rectangle.

Find the distance from C to D in Figure 10.131.

SOLUTION

Sides: height (h) = 2, width (w) = 2

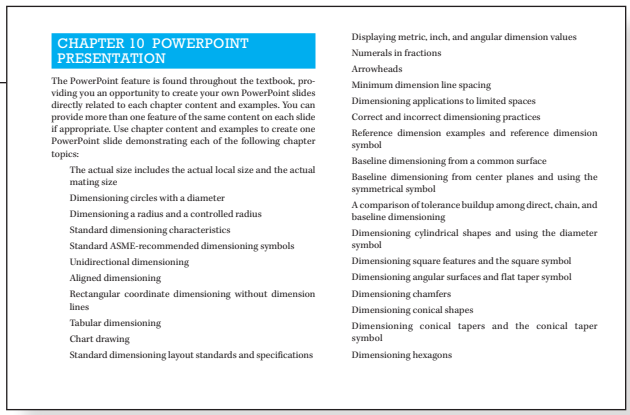
length (L) = 3

Diagonal (d) = $\sqrt{h^2 + w^2 + L^2}$

d = 4.12

FIGURE 10.131 Finding the diagonal of a cube.

POWERPOINT PRESENTATION



CHAPTER 10 POWERPOINT PRESENTATION

The PowerPoint feature is found throughout the textbook, providing you an opportunity to create your own PowerPoint slides directly related to each chapter content and examples. You can provide more than one feature of the same content on each slide if appropriate. Use chapter content and examples to create one PowerPoint slide demonstrating each of the following chapter topics:

- The actual size includes the actual local size and the actual mating size
- Dimensioning circles with a diameter
- Dimensioning a radius and a controlled radius
- Standard dimensioning characteristics
- Standard ASME-recommended dimensioning symbols
- Unidirectional dimensioning
- Aligned dimensioning
- Rectangular coordinate dimensioning without dimension lines
- Tabular dimensioning
- Chart drawing
- Standard dimensioning layout standards and specifications
- Displaying metric, inch, and angular dimension values
- Numerals in fractions
- Arrowheads
- Minimum dimension line spacing
- Dimensioning applications to limited spaces
- Correct and incorrect dimensioning practices
- Reference dimension examples and reference dimension symbol
- Baseline dimensioning from a common surface
- Baseline dimensioning from center planes and using the symmetrical symbol
- A comparison of tolerance buildup among direct, chain, and baseline dimensioning
- Dimensioning cylindrical shapes and using the diameter symbol
- Dimensioning square features and the square symbol
- Dimensioning angular surfaces and flat taper symbol
- Dimensioning chamfers
- Dimensioning conical shapes
- Dimensioning conical tapers and the conical taper symbol
- Dimensioning hexagons

Engineering Drawing and Design Math Applications

This content provides comprehensive math instruction for engineering design and drafting and related fields. The content parallels the math applications and problems in chapters throughout this textbook and on the Student Companion Website. The material is presented with numerous examples in a manner that is easy to use and understand.

For complete information and instructions for *Engineering Drawing and Design Math Applications*, go to the **Student Companion Website**, select **Student Downloads, Reference Material, Engineering Drawing**, and then **Design Math Applications**.

Metric Applications

Values presented in the content are in inches and are identified with (in.). Related metric values are given in parentheses using the appropriate equivalencies. Specific metric applications are given throughout this textbook. Metric applications are a very important part of the drafting and design industry. Chapter problems are also given for inch and metric applications and are labeled accordingly with (inch) or (metric). Illustrative examples provided throughout the text are displayed using metric values in millimeters, unless otherwise specified.

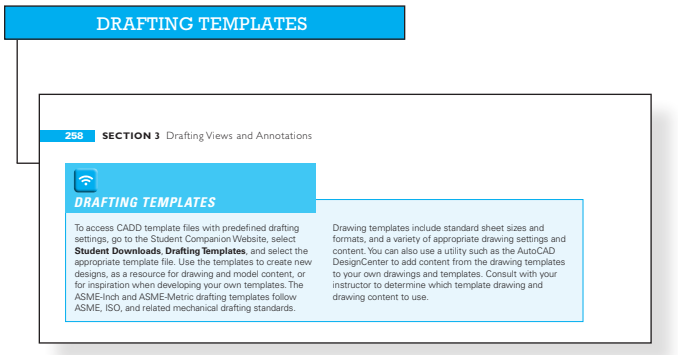
Chapter-Related Tests

Related chapter tests appear on the **Student Companion Website** for examination or review. The tests ask for short answers, sketches, or drawings to confirm your understanding of chapter content.

To access a chapter test, go to the **Student Companion Website**, select **Student Downloads**, **Chapter Tests and Problems,** and then the chapter. Answer the questions with short complete statements, sketches, or drawings as needed. Confirm the preferred submittal process with your instructor.

Chapter-Related Problems

Each chapter ends with numerous real-world drafting and design problems for you to practice what you have learned. This book contains more than 1,000 problems that range from basic to complex. Problems are presented as real-world engineering sketches, pictorial engineering layouts, and actual industry projects. Advanced problems are given for challenging applications or for use as team projects. Problems are so numerous that they cannot all be placed in the textbook. All chapter-ending tests and problems are now solely on the Student Companion Website for access. Most problems require you to use standards sheet sizes, borders, and sheet blocks related to the specific discipline.



To access the chapter problems, go to the **Student Companion Website**, select **Student Downloads**, **Chapter Tests and Problems**, and the chapter and then open the problem of your choice or as assigned by your instructor. Solve the problems using the instructions provided, unless otherwise specified by your instructor.

Advanced Team Problems

Advanced problems can be assigned as team problems as determined by the instructor and course objectives.

Team problems are provided that can be used as projects that help foster leadership and cooperation between team members to design and draw complete sets of of working drawings for a product. Teams are established with any desired number of members based on the project and curriculum goals. Teams can select an **engineer** by voting in a democratic process, by selecting the person with the highest course evaluation, or as determined by the instructor. An engineer is the person in charge of the project. The engineer coordinates the team work, monitors the progress, and provides answers and instructions to the team members in cooperation with the instructor. The engineer divides the project into tasks and assigns portions of the project to the drafting team members. The engineer works with team members to establish design alternatives. Team members are drafters, with one drafter responsible for sheet layout and reproduction. Each drafter is assigned specific drawing for the completion of the entire set of drawings. The engineer provides coordination between team members to confirm all parts of the project match. Final team assignments and members are determined by your instructor. A **checker** is selected using criteria similar to choosing the engineer. The checker works with drafting team members to advice on the proper use of standards. The checker evaluates each completed drawing to make sure drafting standards are properly applied. The checker can redline a print with requested corrections that are returned to drafting for final completion. The checker coordinates and consults with the engineer and instructor to make sure drawings are completed in accordance with design requirements and industry standards.

Team Evaluation Criteria

Team project evaluation includes:

Project coordination: organization of project assignments.

Project completion: complete set of working drawings finished.

Team member cooperation.

Project quality: drawings completed accurately and in a professional manner.

Engineering decisions:

- Project properly interpreted.
- Design decisions properly evaluated and completed.

Professional Perspective

The Professional Perspective is a boxed article at the end of chapters that explains how to apply the skills and knowledge discussed in the chapter to a real-world, job-related setting. Professional perspectives are written by industry professionals and give you an opportunity to hear what actual engineers, designers, and drafters have to say about the design drafting industry and what you can expect as a drafter in the chapter-related discipline.

PROFESSIONAL PERSPECTIVE

CHAPTER 10 Dimensioning and Tolerancing 343

PROFESSIONAL PERSPECTIVE

The proper placement and use of dimensions is one of the most difficult aspects of drafting. It requires careful thought and planning. First, you must determine the type of dimension that fits the application and then correctly place the dimension on the drawing. Although the CADD system makes the actual placement of dimensions quick and easy, it does not make the planning process any easier. Making preliminary sketches is critical before beginning a drawing. The preliminary sketch allows you to select and place the views and then place the dimensions.

One of the big issues an entry-level drafter faces is determining which dimensions are important and where the dimensions should be placed. In many cases, dimensioning requirements are underestimated. In addition, try to avoid creating a drawing that is crowded with dimensions. As a rule of thumb, if you think the drawing is crowded on a particular size sheet, then play it safe and use the next larger size sheet to help reduce crowding. Most companies want the drawing information spread out and easy to read, but some companies want the drawing crowded with as much information as you can get on a sheet. This text supports a clean and easy-to-read drawing that is not crowded. Out on the job, however, you must do what is required by your employer. If you are creating an uncrowded drawing, you should consider leaving about one-quarter of the drawing space clear of view and dimensional information. Usually this space is above and to the left of the title block. This clear space provides adequate room for general notes and engineering changes. Engineering changes are covered in Chapter 15, *Working Drawings*.

Follow the dimensioning rules, guidelines, and examples discussed in this chapter and use proper dimensioning standards. Try hard to avoid breaking dimensioning standards. The following are some of the pitfalls to watch out for when placing dimensions as a beginning drafter.

- Do not crowd dimensions. Keep your dimension line spacing equal and far enough apart to separate the dimension numerals clearly.
- Do not dimension to hidden features. This also means do not dimension to the centerline of a hole in the hidden view. Always dimension to the view where the feature appears as a visible object line.
- Dimension to the view that shows the most characteristic shape of an object or feature. For example, dimension shapes where you see the contour, dimension holes to the circular view, and dimension cylindrical shapes in the rectangular view.
- Do not stack adjacent dimension numerals. Stagger dimension numerals so they are easier to read.
- Group dimensions as much as you can. It is better to keep dimensions concentrated to one location or one side of a feature rather than spread around the drawing. This makes the drawing easier to read.
- Create a standard symbol library or use software with symbols available. Symbols speed up the drafting process, and they clearly identify the feature. For example, if you draw a single view of a cylinder, the diameter Ø dimension is identified in the rectangular view and drawing the circular view may not be necessary. Most CADD programs automatically recognize a diameter dimension and properly place the symbol, but you may need to create some symbols.
- Look carefully at the figures in this text and use them as examples as you prepare your drawings.

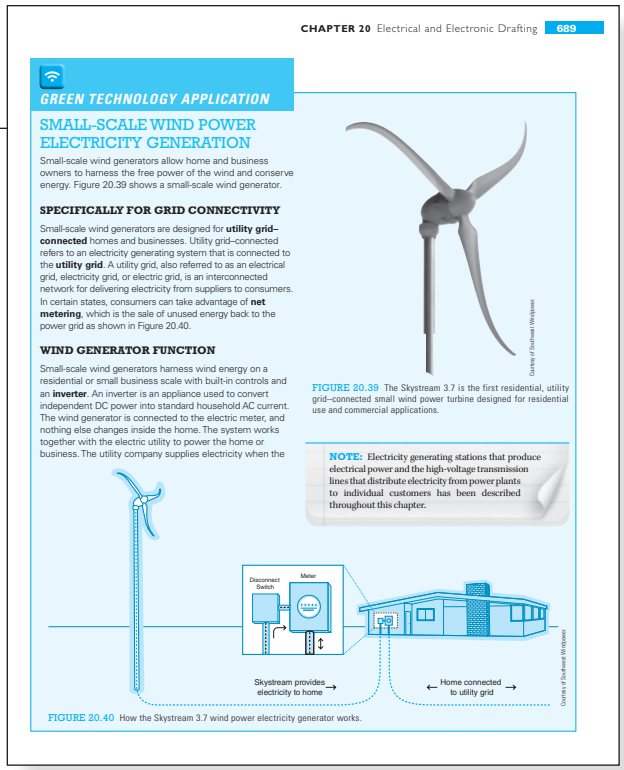
Try to put yourself in the place of the person who has to read and interpret your drawing. Make the drawing as easy to understand as possible. Keep the drawing as uncluttered and as simple as possible yet still complete. Figure 10.129 shows an industry drawing of a complex part. Notice how the drafter carefully selected views and dimension placement to make the drawing as easy to read as possible.

Now go back to the beginning of this chapter and read the Engineering Design Application segment again. The steps used to lay out a dimensioned multiview drawing were presented to give you a general idea about the process a drafter goes through when converting an engineering sketch into a formal drawing. Read the steps again and look at Figures 10.1 through 10.6. This review, along with spending some time looking at the complex actual industry drawing in Figure 10.129, helps you pull together the dimensioning basics that you learned throughout this chapter.

Green Technology Application

Protecting the environment is one of the most important worldwide issues today. A flagship feature called **Green Technology Application** is found throughout this textbook, providing current practical and experimental energy-efficient design, construction and manufacturing techniques resulting in a significant reduction in energy consumption. As industry grows to meet the demands of our increasing population, there is a strong need to take care of the environment and allow for current and future development. As a student, it is very important for you to learn what is available today and to find ways to improve energy efficiency in design and construction into the future in an effort to protect Earth. National and local programs have been established to meet this need. Modern advances are available to designers, builders, manufacturers and owners who want to use green technology and make the most of environmental protection in our industries. A focus is on **sustainable development** that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development is economic development that is conducted without the depletion of natural resources. **Sustainability** includes projects that can be produced without permanent and unacceptable change in the natural environment on which it and other economic activities depend, over the life of the project.

GREEN TECHNOLOGY APPLICATION



CHAPTER 20 Electrical and Electronic Drafting 689

GREEN TECHNOLOGY APPLICATION

SMALL-SCALE WIND POWER ELECTRICITY GENERATION

Small-scale wind generators allow home and business owners to harness the free power of the wind and conserve energy. Figure 20.39 shows a small-scale wind generator.

SPECIFICALLY FOR GRID CONNECTIVITY

Small-scale wind generators are designed for **utility grid–connected** homes and businesses. Utility grid–connected refers to an electricity generating system that is connected to the **utility grid**. A utility grid, also referred to as an electrical grid, electricity grid, or electric grid, is an interconnected network for delivering electricity from suppliers to consumers. In certain states, consumers can take advantage of **net metering**, which is the sale of unused energy back to the power grid as shown in Figure 20.40.

WIND GENERATOR FUNCTION

Small-scale wind generators harness wind energy on a residential or small business scale with built-in controls and an **inverter**. An inverter is an appliance used to convert independent DC power into standard household AC current. The wind generator is connected to the electric meter, and nothing else changes inside the home. The system works together with the electric utility to power the home or business. The utility company supplies electricity when the

FIGURE 20.39 The Skystream 3.7 is the first residential, utility grid–connected small wind power turbine designed for residential use and commercial applications.

NOTE: Electricity generating stations that produce electrical power and the high-voltage transmission lines that distribute electricity from power plants to individual customers has been described throughout this chapter.

FIGURE 20.40 How the Skystream 3.7 wind power electricity generator works.

Related Appendixes

Each chapter refers to the key appendixes for your reference and use in problem solving. The appendixes contain the types of charts, tables, and information used daily in the engineering design and drafting environment. Appendixes can be copied for use as desk references as needed. These appendixes include common fastener types and data, fits and tolerances, metric conversion charts, tap drill charts, and other manufacturing information used on engineering drawings. There is a complete list of abbreviations and a comprehensive glossary. It is also recommended that you learn to use other resources such as the *Machinery's Handbook*, ASME standards, other specific industry standards related to chapter content, and appropriate vendors' catalogs.

Glossary

The most comprehensive glossary available is at the end of this textbook. Glossary terms are **bold** in chapter content, where they are defined immediately and also placed in the glossary for additional reference. Each term is clearly defined using descriptions that are related to engineering drafting and design applications.

PULLING IT ALL TOGETHER

Looking at actual industry drawings is an excellent way to pull together what you have learned. Chapters have actual industry drawings placed along with other illustrative examples so you can see how the specific application is accomplished in the real world. Chapters also often end with an example of a fairly complex industry drawing, allowing you to see how previously learned content is applied in industry. These drawings have been selected for their quality and characteristics related to the chapter content and their compliance with national and industry standards. You should spend as much time as possible looking at actual industry drawings in an effort to help you visualize the thought that goes into creating drawings.

STUDENT COMPANION WEBSITE ACCOMPANYING ENGINEERING DRAWING AND DESIGN

Material on the Student Companion Website

The **Student Companion Website** available with *Engineering Drawing and Design*, Sixth Edition, contains a variety of valuable features for you to use as you learn engineering drawing and design. The **Student Companion Website** icon  , placed throughout this textbook, directs you to features found on the **Website**.

How to Use the Student Companion Website instructions are provided in Section 7 on page 973.

Student Companion Website Contents

- All Appendixes
- ASME Print Reading or Drawing Exercises
- Chapter Tests and Problems
- Drafting Templates
- Reference Material
  - Descriptive Geometry I
  - Descriptive Geometry II
  - Engineering Charts and Graphs
  - Engineering Drawing and Design Math Applications
  - Fluid Power
- Supplemental Material

INDUSTRY APPROACH TO PROBLEM SOLVING

Your responsibility as a drafter is to convert engineering sketches or instructions to formal drawings. This text explains how to prepare drawings from engineering sketches by providing you with the basic guides for layout and arrangement in a knowledge-building format. One concept is presented before the next is introduced. Problem assignments are presented in order of difficulty within each chapter and throughout the text. The concepts and skills learned in one chapter are built on and used in following chapters. By the end of the textbook, you have the ability to solve problems using a multitude of previously learned discussions, examples, applications, and activities. The problems are presented as pictorial or actual industrial layouts in a manner that is consistent with the engineering environment. Early problems provide suggested layout sketches. It is not enough for you to duplicate drawings from given assignments. You must be able to think through the process of drafting development. The goals and objectives of each problem assignment are consistent with recommended evaluation criteria and based on the progression of learning activities.

COMPUTER-AIDED DESIGN AND DRAFTING

Computer-aided design and drafting (CADD) is presented throughout this textbook. CADD topics include:

- CADD terminology and hardware supplement found on the **Student Companion Website**,
- CADD software used in drafting and design,
- CADD standards,
- CADD practices for specific engineering drafting applications,
- 2-D and 3-D CADD techniques and applications used in industry,
- increased productivity with CADD, and
- the CADD environment in industry.

DESIGN PROJECTS

Chapters contain projects that let you practice your design knowledge and skills. These advanced problems require you to systematically determine a desired solution. There are challenges in manufacturing knowledge, tolerances, accuracy, and other issues related to the specific discipline. Advanced problems may have errors intentionally introduced as a challenge for you to find and correct.

TEAM PROJECTS

Some projects are designed to be solved in a team approach. Groups of students can develop their own team organization and establish the best course of action to assign team member responsibilities and create the desired solutions.

COURSE PLAN

Section 1: Introduction to Engineering Drawing and Design

Introduction to Engineering Drawing and Design

Chapter 1 provides a detailed look at drafting as a profession and includes a brief history, occupations, professional organizations, occupational levels, opportunities, career requirements, seeking employment, CADD issues, workplace ethics, copyrights, patents, trademarks, and a **Professional Perspective** from a leading person in the drafting and design industry.

Drafting Equipment, Media, and Reproduction Methods

Chapter 2 covers drafting equipment, materials, and reproduction methods for drafting, with specific instruction on how to use tools and equipment provided in the Supplemental Material for Chapter 2 on the **Student Companion Website**. The major emphasis of this chapter is the discussion, description, and professional use of ASME-recommended drawing sheet sizes, border lines, and sheet blocks.

Computer-Aided Design and Drafting (CADD)

Chapter 3 introduces computer-aided design and drafting (CADD) and related technology. This chapter provides CADD software manufactures and products, explains and compares CADD formats, and identifies disciplines and industry concepts related to CADD. The use of prototyping, animation, and virtual reality in the design process is covered. This chapter demonstrates the variety of CADD techniques found in industry, including 2-D drafting, surface modeling, and solid modeling. Content also includes information about CADD standards, productivity with CADD, and sustainable design and CAD practices. For computer terminology and hardware information, go to the Supplemental Material for Chapter 3 on the **Student Companion Website**.

Manufacturing Materials and Processes

Chapter 4 gives you the most complete coverage of manufacturing materials and processes found in any textbook of this type. The chapter includes product development, manufacturing materials, material selection, sustainable materials, material numbering systems, hardness and testing, casting and forging methods, metal stamping, manufacturing and design of plastics, design and drafting related to manufacturing processes, complete machining processes, computer numerical control, computer-integrated manufacturing, machine features and drawing representations, surface texture, design of machine features, and statistical process control. A solid understanding of materials and processes will prove to be a valuable asset as you continue your education in drafting and design using this textbook.

Section 2: Fundamental Applications

Sketching, Lines, Lettering, and Drafting Geometry

Chapters 5, 6, and 7 explain and detail sketching, lines, lettering, and drafting geometry extensively. These chapters show you how to properly draw lines and lettering in accordance with ASME standards. The sketching techniques you learn in Chapter 5 will continue to be used throughout your drafting and design education and into the profession. Sketching skills are important in preparation for creating drawings and for communication with others in the industry. Lines and lettering make up the foundation of engineering drawings. Proper application of lines and lettering based on correct national standards is important for you to learn now and use throughout your career. Drafting geometry is the basis of all geometric shapes and drafting applications. These fundamentals will be used throughout your drafting and design education and into the profession.

Section 3: Drafting Views and Annotations

Multiviews and Auxiliary Views

Chapters 8 and 9 provide a complete study of multiviews and auxiliary views, in accordance with ASME standards, with accurate and detailed instruction on topics such as view selection and placement, first- and third-angle projection, and viewing techniques. These chapters provide step-by-step examples that describe how to lay out multiview and auxiliary view drawings.

Dimensioning and Tolerancing

Chapter 10 is developed in accordance with ASME Y14.5-2009 and provides complete coverage on dimensioning systems, rules, specific and general notes, tolerances, symbols, inch and metric limits and fits, drawing specifications, dimensioning castings, forgings, plastic drawings, and dimensioning for computer-aided design (CAD) and computer-aided manufacturing (CAM). You are provided with a step-by-step example showing how to lay out a fully dimensioned multiview drawing. Additional coverage includes the basics of tool design and drafting applications.

Fasteners and Springs

Chapter 11 presents fastener and spring terminology. The complete range of fastening devices is covered, including screw threads, thread cutting, thread forms, thread representations and notes, washers, dowels, pins, rings, keys and keyseats, and rivets. Types of springs, spring ends, and spring applications are included. Fasteners and springs are covered after dimensioning practices so you can apply dimensions to your spring drawings, and then sectioning techniques follow so you can apply fastening systems to future drawings.

Sections, Revolutions, and Conventional Breaks

Chapter 12 explains every type of sectioning practice available to the mechanical engineering drafter. This chapter also includes proper representation of sectioned features that should remain unsectioned in a sectional view, conventional revolutions, and conventional breaks. Section views can be used as needed in drafting problems throughout the rest of this textbook.

Geometric Dimensioning and Tolerancing (GD&T)

Chapter 13 provides the most comprehensive coverage found in any textbook, including geometric tolerancing symbols, terms, and applications presented in accordance with ASME Y14.5-2009. This chapter features datums, feature control, basic dimensions, geometric tolerances, material condition, position tolerance, virtual condition, geometric tolerancing applications, and CADD usage. Geometric dimensioning and tolerancing education follows dimensioning and sectioning so you can apply these concepts as needed throughout your continued drafting and design education.

Pictorial Drawings and Technical Illustrations

Chapter 14 provides a complete review of three-dimensional drafting techniques used in drafting. The chapter includes extensive discussion of isometric, diametric, trimetric, perspective, exploded drawings, and shading methods. Current technical illustration practices are described and illustrated. The content of this chapter can be introduced here or earlier in your education, depending on course objectives.

Section 4: Working Drawings

Working Drawings

Working drawings, introduced in Chapter 15, pull together everything you have learned, including multiviews, auxiliary views, sectioning practices, dimensioning techniques, and fasteners, allowing you to draw a complete product with all of its individual parts, an assembly of the product, and a parts list that includes all of the parts listed, identified, and correlated with the detail and assembly drawings. Working drawings include details, assemblies, and parts lists, along with the most extensive discussion on engineering changes available.

Also provided is a complete analysis of how to prepare a set of working drawings from concept to final product and how to implement an engineering change. This is the most comprehensive engineering change content found in any textbook. A large variety of problem projects are based on actual products found in a variety of applications in the real world. The working drawing section continues with assemblies created with linkages, cams, gears, bearings, and weldments.

Mechanisms: Linkages, Cams, Gears, Bearings, Belt and Chain Drives

Chapters 16 and 17 provide you with extensive coverage of linkage mechanisms, cams, gears, bearings, and belt and chain drives. The content includes how to design and draw these features as details and in assembly. Special attention is given to design calculations for gears and cams. Detailed information is given on the selection of bearings and lubricants. The use of vendors' catalog information is stressed in the design of belt and chain drive systems. Actual mechanical engineering design problems are provided for gear train and cam plate design.

Welding Processes and Representations

Welding coverage in Chapter 18 provides an in-depth introduction to processes, welding drawings and symbols, weld types, symbol usage, weld characteristics, weld testing, welding specifications, and prequalified welded joints.

Section 5: Specialty Drafting and Design

Engineering Drafting and Design Fields of Study

Chapters 19 through 24 provide you with instruction in specific engineering drawing and design fields. These chapters can be used individually for complete courses or combined with previous chapters as needed to fit your curriculum objectives. These chapters contain comprehensive instruction, problems, and tests. These fields include:

Precision Sheet Metal Drafting—Chapter 19 provides complete coverage of the different formats used to create precision sheet metal drawing in industry. Coverage continues with bend allowances calculations, and characteristics found in precision sheet metal drawings.

Electrical and Electronics Drafting—Chapter 20 provides the only coverage of its type in electrical power transmission. The content is specific to electrical drafting of wiring diagrams, cable assemblies, one-line and elementary diagrams, electrical power system symbols, plot plans, bus layouts, ground layouts, conduit layouts, electrical floor plan symbols, power-supply plans, and schematics. Chapter 20 also offers detailed content related to the electronics industry. Topics include block diagrams, electronic components and symbols, engineer's sketches, component numbering, operational amplifier schematics, integrated circuit systems, logic diagrams, large-scale integration schematics, surface-mount technology, printed circuit technology, electronics artwork, layers, marking, drilling, assembly drawings, photo drafting, and pictorial diagrams.

Industrial Process Pipe Drafting—Chapter 21 provides explanations and detailed examples of pipe and fittings, piping symbols, valves and instrumentation, pumps, tanks and equipment, flow diagrams, piping plans and elevations, piping isometrics, and piping spools. Process flow diagrams (PFDs) and a subset of PFDs is the process and instrumentation diagram (P&ID) are described and illustrated with more details about the instrumentation schematics used in the plant.

Structural Drafting—Chapter 22 covers reinforced and precast concrete, truss and panelized framing, timbers, laminated beams, steel joists and studs, prefabricated systems, structural steel, structural welding, and structural details. You have the option of completing one of several sets of complete structural drawings for light commercial buildings.

Heating, Ventilating, and Air-Conditioning (HVAC)—Chapter 23 provides complete coverage of HVAC systems, heat exchangers, HVAC symbols, single- and double-line ducted systems, and working from an engineer's sketch to create HVAC plans, sections and details, and cutsheets. The chapter continues

with common sheet metal pattern developments and sheet metal intersections using step-by-step layout procedures.

Civil Drafting—Chapter 24 discusses and describes the complete discipline of mapping, including legal descriptions, survey terminology, and drawing site plans. Civil drafting includes road layout, cuts and fills, and plan and profile drawings. You will go through the step-by-step process for drafting a road layout, road cuts and fills, plan and profile drawings, site plan, topography contours, and a site grading plan.

Section 6: Engineering Design

The Engineering Design Process

The engineering design process chapter is placed at the end of the textbook specifically to allow you an opportunity to learn a vast amount about drafting and design theory and skills before proceeding with your own designs or the designs of your school or company.

Chapter 25 provides an introduction to several engineering design systems, including lean manufacturing and Six Sigma. You can observe the design of a product from engineering sketches through production, implementing CAD/CAM, parametric design, rapid prototyping, computer-aided engineering (CAE), concurrent engineering, collaborative engineering, reverse engineering, team projects, and other innovative topics. Creativity, collaboration, and the design process are emphasized in this chapter. Detailed discussion about typical engineering design and manufacturing processes are followed by three real-world engineering design process examples. The engineering design examples include the development of a portable vascular imaging product that allows a medical practitioner to visualize and observe the subcutaneous vasculature system in real-time. Subcutaneous vasculature system refers to the human vasculature system under the skin.

Another engineering design process example is a CPR training advancement for the design and manufacture of a device that fits in the palm of your hand and automatically monitors and helps improve a student's CPR technique by reporting when compressions and breaths are executed correctly.

Electric vehicles are on the cutting edge of energy conservation and transportation technology, providing exciting opportunities for new engineering design projects. An electric vehicle design application is provided in this edition to push the limits of energy efficiency in transportation engineering.

The **Student Companion Website** provides detailed coverage with step-by-step use of the phase gate design process. You will see how all aspects of the design process fit together. Paralleling the general design process information is the tracking of an actual new product design from concept through full-production manufacturing. The product used for this design sequence example is the Milwaukee Electric Tool Corporation's V28 Lithium-Ion Sawzall® reciprocating saw. An additional green technology product is taken from idea through design and drafting and into manufacturing and marketing.

Section 7: Engineering Drawing and Design Student Companion Website

Reference Material: Comprehensive Resources

Descriptive Geometry I—**Descriptive geometry** is a drafting method used to study 3-D geometry with 2-D drafting applications where planes of projections analyze and describe the true geometric characteristics. Descriptive geometry principles are valuable for determining true shapes of planes, angles between two lines, two planes, or a line and a plane, and for locating the intersection between two planes, a cone and a plane, or two cylinders. Problems are solved graphically by projecting points onto selected adjacent projection planes in an imaginary projection system.

Descriptive Geometry II—This reference content continues from Descriptive Geometry I, allowing you to solve many engineering problems where the direction of lines and planes must be determined. The direction of lines and planes is identified in space by a variety of ways, depending on their uses.

Engineering Charts and Graphs—This reference content provides you with the most comprehensive coverage available on the design and drafting of engineering charts and graphs.

Engineering Drawing and Design Math Applications—This reference content provides you with comprehensive math instruction for engineering design and drafting and related fields. The content parallels the math applications and problems in chapters throughout this textbook. This supplemental material is presented with numerous examples in a manner that is easy to use and understand.

Fluid Power—This reference content provides you with complete coverage of fluid power drafting and design applications, including hydraulic, fluid power, and pneumatic terminology, rules, symbols, systems, and diagrams.

CHAPTER LENGTH

Chapters are presented in individual learning segments that begin with basic concepts and build until each chapter provides complete coverage of each topic. The content of each chapter generally should be divided into logical teaching segments, providing you with an opportunity to create basic drawing as you progress into problems that are more complex.

Applications

This text contains CADD discussion and examples, engineering layout techniques, working from engineer's sketches, professional practices, and actual industry examples. The problem assignments are based on actual real-world products and designs. Special emphasis has been placed on providing realistic problems. Problems are presented as 3-D drawings, engineering sketches, and layouts in a manner that is consistent with industry practices. Many of the

problems have been supplied by industry. Each problem solution is based on the step-by-step layout procedures provided in the chapter discussions. Problems are given in order of complexity so you gain exposure to a variety of engineering experiences. Early problems recommend the layout to help you save time. Advanced problems require you to go through the same thought process that a professional faces daily, including drawing scale, sheet size and sheet block selection, view selection and layout, dimension placement, sectioning placement, and many other applications. All problems should be solved in accordance with recommended ASME or other discipline-related industry practices and standards.

A Special Notice About Problems

You should always approach a problem with critical analysis based on view selection and layout and dimension placement when dimensions are used. Do not assume that problem information is presented exactly as the intended solution. Problems can be deliberately presented in a less-than-optimal arrangement. Beginning problems provide given layout examples, allowing you to solidify your knowledge before advancing on your own. Advanced problems often require you to evaluate the accuracy of provided information. Never take the given information or accuracy of the engineering sketch for granted. This is also true as you progress into industry.

Real-world chapter-related drafting and design problems follow each chapter. All problems are located on the Student Companion Website. Problems are presented as engineering sketches, dimensioned 3-D illustrations, and written descriptions consistent with the method used in industry. Problems range in difficulty from basic through advanced providing a variety of knowledge-building opportunities while learning engineering drafting and design. Advanced chapter-related problems provide students with an opportunity to work in teams in a manner that is similar to industry. Chapter problems conclude with content-related math problems that are based on the Math Application found at the end of each chapter. Watch for the (web icon) identifying problems found on the Student Companion Website. The following instructions direct you to the problems on the Student Companion Website.

Chapter Problems

To access the chapter problems, go to the **Student Companion Website** and select **Student Downloads, Chapter Tests and Problems**, then **Chapter**, and then open the problem of your choice or as assigned by your instructor. Solve the problems using the instructions provided, unless otherwise specified by your instructor.

Using Chapter Tests

Chapter tests provide complete coverage of each chapter and can be used for instructional evaluation, as study questions, or for review. The chapter tests are located on the **Student Companion Website**. Chapter Tests and Problems are available on the Student Companion Website in MS Word and PDF format. Watch for the . Instructions, such as the following, direct you to the **Student Companion Website** test:

Chapter Test—To access the chapter tests, go to the **Student Companion Website**, select **Student Downloads**, **Chapter Tests and Problems**, and then select **Chapter**. Answer the questions with short, complete statements, sketches, or drawings as needed. Confirm the preferred submittal process with your instructor.

APPENDIXES

The appendixes contain the types of charts and information used daily in the engineering design and drafting environment. In addition to using the appendixes found on the Student Companion Website for this textbook, it is recommended that you learn to use other resources, such as the *Machinery's Handbook*, ASME standards, other specific industry standards related to chapter content, and appropriate vendors' catalogs. The textbook Student Companion Website appendices include:

- Abbreviations
- Conversion Charts
- Mathematical Rules Related to the Circle
- General Applications of SAE Steels
- Surface Roughness Produced by Common Production Methods
- Wire Gages (Inches)
- Sheet Metal Gages (Inch)
- Sheet Metal Thicknesses (Millimeters)
- Standard Allowances, Tolerances, and Fits
- Unified Screw Thread Variations
- Metric Screw Thread Variations
- ASTM and SAE Grade Markings for Steel Bolts and Screws
- Cap Screw Specifications
- Machine Screw Specifications
- Set Screw Specifications
- Hex Nut Specifications
- Key and Keyseat Specifications
- Tap Drill Sizes
- Concrete Reinforcing Bar (Rebar) Specifications
- Common Welded Wire Reinforcement Specifications
- ASTM A500 Square and Rectangular Structural Tubing Specifications
- Structural Metal Shape Designations
- Corrosion-Resistant Pipe Fittings
- Valve Specifications

- PVC Pipe Dimensions in Inches
- Rectangular and Round HVAC Duct Sizes
- Spur and Helical Gear Data
- Metric Coordinate to Positional Tolerance Conversion
- Inch Coordinate to Positional Tolerance Conversion
- CADD Drawing Sheet Sizes, Settings, and Scale Factors

Student Companion Website Appendixes— For appendixes found on the **Student Companion Website**, go to the **Website** and select the desired appendix.

Access the **Student Companion Website** for the following appendixes:

- American National Standards of Interest to Designers, Architects, and Drafters
- ASME Standard Line Types
- Dimensioning and Tolerancing Symbols and ASME Dimensioning Rules
- Designation of Welding and Allied Processes by Letters
- Symbols for Pipe Fittings and Valves

ASME Print Reading or Drawing Exercises

The ASME Print Reading or Drawing Exercises found on the **Student Companion Website** are actual industry drawing files containing intentional ASME errors. You can correct the drawing files using CADD or redline prints to conform to accepted ASME standards. This provides a valuable supplement for learning ASME standards. Searching actual industry drawings in an effort to find errors helps you form a keen eye for correct drafting presentation and compliance with national standards. This activity is the function of a **drafting checker** in industry. A drafting checker is the person who takes a completed drawing from the drafter and evaluates the drawing for proper standards, technical details, and accuracy for product design and dimensioning applications. After checking, the drawing goes back to the drafter for final completion before going to the design engineer for approval and on to manufacturing. The checker often uses red lines to mark drawing errors and required edits on a print or on the CADD file. The drafter then systematically checks off each item as corrections are made to ensure that every item is correctly edited. Possessing this skill allows you to become more familiar with proper ASME standards, correct drawing layout, and proper dimension placement when creating your own drawings and when correcting drawings created by others.

TO THE STUDENT

Engineering Drawing and Design is designed for you. The development and presentation format have been tested in conventional and individualized classroom instruction. The information presented is based on engineering drafting practices and standards, drafting room practice, and trends in the design and drafting industry. This textbook is the only engineering drafting and design reference that you will need. Use the text as a learning tool while in school, and take it along as a desk reference when you enter the profession. The amount of written text is comprehensive but kept as concise as possible. Examples and illustrations are used extensively. Drafting is a graphic language, and most drafting students learn best by observing examples. The following are a few helpful hints to use as you learn engineering drawing and design using this textbook:

1. **Read the text.** The text content is intentionally designed for easy reading. Sure, it does not read the same as an exciting short story, but it does give the facts in a few easy-to-understand words. Do not pass up the reading, because the content helps you understand theory and how to create proper drawings.
2. **Look carefully at the examples.** The figure examples are presented in a manner that is consistent with drafting standards. Look at the examples carefully in an attempt to understand the intent of specific applications. If you are able to understand why something is done a certain way, it is easier for you to apply the concepts to the drawing problems in school and on the job. Drafting is a precise technology based on rules and guidelines. The goal of a drafter is to prepare drawings that are easy to interpret. There are situations when rules must be altered to handle a unique situation. You will have to rely on judgment based on your knowledge of accepted standards. Drafting is often like a puzzle, and there may be more than one way to solve a problem.
3. **Use the text as a reference.** Few drafters know everything about drafting standards, techniques, and concepts, so always be ready to use the reference if you need to verify how a specific application is handled. Become familiar with the definitions and use of technical terms. It is difficult to memorize everything in this textbook, but after considerable use of the concepts, engineering drafting applications should become second nature.
4. **Learn each concept and skill before you continue to the next.** The text is presented in a logical learning sequence. Each chapter is designed for learning development, and chapters are sequenced so that drafting knowledge grows from one chapter to the next. Problem assignments are presented in the same learning sequence as the chapter content and also reflect progressive levels of difficulty.
5. **Practice.** Development of good drafting skills depends to a large extent on practice. Some individuals have an inherent talent for computer use, and others need more time to master the computer and applications. Most CADD software programs have features that range from easy to use to very complex. It can take several months of continuous use and training to become proficient with the system and function.

Additional time and practice is needed to become familiar with company practices and standards when you become employed in the drafting industry.

6. **Use sketches or preliminary drawings.** When you are drawing manually or with a computer, the proper use of a sketch or preliminary drawing can save time in the long run. Prepare a layout sketch or preliminary layout for each problem. This gives you a chance to organize thoughts about drawing scale, view selection, dimension and note placement, and sheet size. After you become a drafting veteran, you may be able to design a sheet layout in your head, but until then use sketches to help you get started.
7. **Use professional equipment and materials.** For the best possible learning results and skill development, use professional equipment and CADD software. Most drafting technology programs in schools have quality professional computers, peripherals, and software. Compare programs and evaluate the facilities and use of current software before starting. CADD software manufacturers revise their software as often as annually. The school program should be using a fairly recent software release to keep pace with industry. In many cases, the technology used in schools exceeds what is used in some companies.

The magnitude of information found in this textbook is enormous. The content is the most comprehensive, innovative, well organized, and accurate found in any discipline-related textbook. More than 1,000 drafting problems offer you variety from basics through advanced applications. The authors, general reviewers, technical reviewers, and editors have worked hard to minimize errors, but some errors may still exist. In an effort to help us make this textbook perfect, consider submitting errors that you find. Feel free to also let us know if you have suggestions for improving the next edition. You can submit feedback to:

Delmar Cengage Learning
Care of author of Engineering Drawing and Design
Executive Woods
5 Maxwell Drive
Clifton Park, NY 12065

SUPPLEMENTS

For Instructors

Instructor Companion Website

The Instructor Companion Website, found on cengagebrain.com, includes the following components to help minimize instructor preparation time and engage students:

- Syllabus

  Syllabi templates created for use in the development of specific courses. You can modify the syllabi templates to match your course format, length, and teaching style.

- Chapter Hints

  Objectives and teaching hints provide you with ideas for activities to use when teaching each chapter of this textbook in your courses.

- PowerPoint® Presentations

  The *Engineering Drawing and Design,* Sixth Edition, PowerPoint® presentations are the most comprehensive set available in this discipline. A presentation is available for and corresponds exactly to the content of each chapter in the textbook. The PowerPoint® slides provide the basis for a lecture outline that helps the instructor present concepts and material in an effective and visually motivating manner. The presentations are excellent teaching tools that allow the instructor to highlight key points and concepts graphically. Slides aid student retention of textbook material, enhance lecture presentation, help maintain student attention, and support note taking and classroom discussions. The *Engineering Drawing and Design*, Sixth Edition, PowerPoint® presentations include:

  - slides that address all major topics in the chapter,
  - concise format that parallels and compliments chapter content,
  - visually pleasing and inspiring slide design and layout,
  - considerable number of illustrations, and
  - key terms hyperlinked to glossary slides.

  View the presentations using Microsoft Office PowerPoint® Viewer, available as a free download from the Microsoft Download Center. View and edit the presentations using Microsoft Office PowerPoint® software. Many key terms throughout each presentation are hyperlinked to glossary slides at the end of the presentation. During a slide show, pick the hyperlinked term to view the corresponding glossary slide. Then pick anywhere on the glossary slide to return to the previous slide. Glossary slides are hidden so they do not appear at the end of the slide show. Some slides include hyperlinks to previous slides within the presentation. Pick the hyperlinked reference to view the corresponding slide. Pick anywhere on the reference slide to return to the previous slide.

- ASME Print Reading or Drawing Exercises

  The same ASME Print Reading or Drawing Exercises found on the **Student Companion Website** are also located on the Instructor Companion Website with accompanying solution drawings.

- Image Gallery

  A database of all the images from the text that can be used for enhancing lecture presentations.

- Solutions Manual

  A solutions manual is available with answers to end-of-chapter test questions and solutions to end-of-chapter problems found on the Student Companion Website.

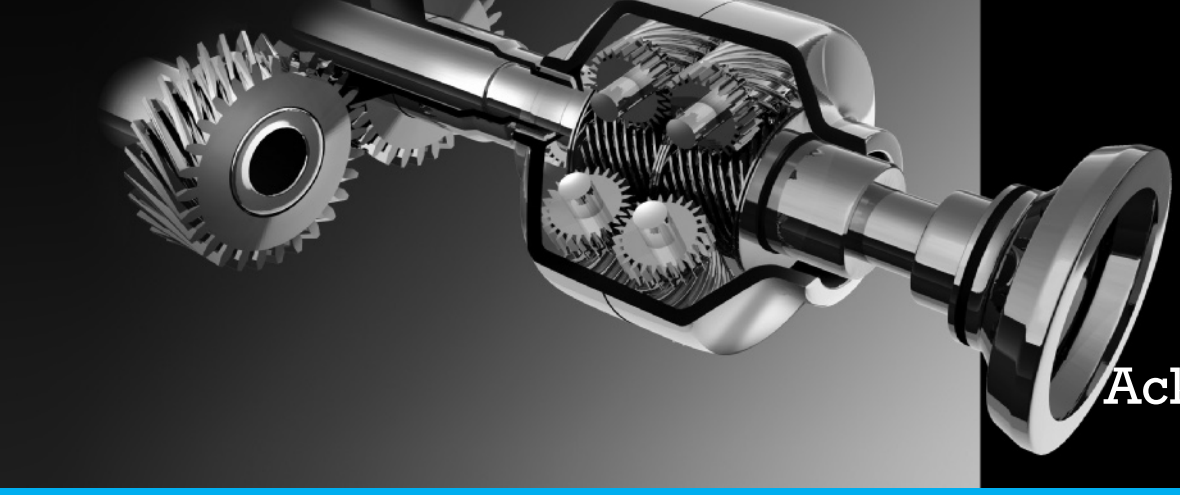
Cengage Learning Testing Powered by Cognero is a flexible, online system that allows you to:

- Author, edit, and manage test bank content from multiple Cengage Learning solutions.
- Create multiple test version in an instant.
- Deliver tests from your LMS, your classroom, or wherever you want.

MINDTAP FOR ENGINEERING DRAWING AND DESIGN

MindTap is a personalized teaching experience with relevant assignments that guide students to analyze, apply, and improve thinking, allowing you to measure skills and outcomes with ease.

- *Personalized Teaching*: Become YOURS with a Learning Path that is built with key student objectives. Control what students see and when they see it—match your syllabus exactly by hiding, rearranging, or adding your own content.
- *Guide Students*: Goes beyond the traditional "lift and shift" model by creating a unique learning path of relevant readings, multimedia, and activities that move students up the learning taxonomy from basic knowledge and comprehension to analysis and application.
- *Measure Skills and Outcomes*: Analytics and reports provide a snapshot of class progress, time on task, engagement, and completion rates.



Acknowledgments

The following is dedicated to all professionals and companies that participated in making *Engineering Drawing and Design* the best textbook available in this discipline.

General Reviews

The following people provided general reviews and comments for the improvement of this textbook:

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- Editing outdated content with revised and new current technology, including new and better drawing and illustrative figures.
- Writing new content for the Engineering Design Applications based on actual industry experience.
- Developing and illustrating new CADD Applications.
- Creating new Professional Perspectives based on real-world experience, advice, words of wisdom, and specific content about the discipline.
- Providing new actual industry problems.
- Creating new Green Technology Applications features.

Larry Bell and Bruce Dalton, Enercon Technologies (www.enercontechnologies.com)

Larry Bell, VP Sales and Marketing, has also worked in product development for various market segments, initially in a design engineering capacity, and more recently in business development for the contract manufacturing of consumables and capital equipment. Bruce Dalton, Engineering Director, has experience in product development of complex electromechanical devices spans medical, industrial, automotive, and military technology.

Founded in 1980, Enercon Technologies focuses on electronics product development, contract manufacturing, and related value-added services. They focus on the medical, defense, and industrial segments, supporting the development and manufacture of printed circuit board assemblies, integrated device assemblies, product testing, direct fulfillment, service depot, and vendor managed inventory requirements.

Dorota Shortell, Simplexity Product Development Inc. (www.simplexitypd.com)
Frank Powers, Health and Safety Institute (HSI) (www.hsi.com)

Dorota Shortell is the president of Simplexity Product Development. She graduated top of her class from Loyola Marymount University and earned her master's degree in mechanical engineering from Stanford University with a focus in design. She is a National Science Foundation fellow, Tau Beta Pi Fellow, and Institute for the Advancement of Engineering Fellow. She has worked actively as a mechanical design engineer, instructor of New Product Design and Development courses, and project

manager before taking over as president of Simplexity from the founder. Dorota was recognized in 2012 by the Portland Business Journal as one of the region's top business leaders as a Forty Under 40 Award winner.

Special thanks also to Simplexity engineers Ethan Vella and Doug Harriman for their involvement in the engineering design process project. Ethan Vella is a mechanical engineer at Simplexity Product Development and the lead mechanical designer of the HSI CPR device. He has a bachelors' degree in physics from Lewis and Clark College and a master's degree in mechanical engineering from Portland State University, and he specializes in creative mechanical design for consumer and industrial products. Doug Harriman is a managing partner at Simplexity Product Development, where he leads the firmware development team. He holds a master's degree in mechanical engineering from the University of California–Berkeley specializing in Automatic Control Systems, and a bachelor's degree in mechanical engineering from Oklahoma State University. Doug joined Simplexity in 2012 after working at Xzeres Wind as the Senior Systems Engineer, and at Hewlett-Packard for 14 years as a lead in the Motion Control Technology team for HP's Ink Jet Printers. On the HSI Loop project, Doug was responsible for all firmware, low level software, and data processing algorithm development.

Simplexity Product Development is an engineering design services company located in San Diego, California, and Vancouver, Washington. It specializes in the development of electromechanical systems for corporate clients. Simplexity's "simpler is better" engineering approach reduces costs while improving the life cycle of customer products, thereby saving money in development, manufacturing, and product sustainability. Simplexity listens carefully to understand clients' most important challenges and delivers tailored solutions that leverage decades of mechanical, firmware, electrical, and software engineering experience.

Frank Powers, Chief Technology Officer for Health and Safety Institute (HSI) HSI is a leading provider of corporate CPR, AED, and first aid training programs, with a special focus on standardized, convenient workplace training.

Brad Dotson, B&D Consulting (www.b-dconsulting.com)

Brad Dotson provided extensive review and support for the HVAC content. Brad is the owner of B&D Consulting, in Dietrich, Idaho. B&D Consulting specializes in 3-D imaging and detailing of shop drawings and production drawings for the HVAC sheet metal industry. Brad has more than 32 years experience in drafting, detailing, estimating, project management, and general management in the HVAC industry, with more than 20 years experience in 3-D CAD/CAM applications. Brad is an owner–member in the Sheet Metal Worker's International Association.

Cristofer Morley and Tom Hawley, O'Neil & Associates, Inc. (www.oneil.com)

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O'Neil & Associates, Inc., founded in 1947, is a global leader in the development of product support documentation.

David Cvengros, Synerject North America (www.synerject.com)

David E. Cvengros provided extensive technical support for the revision of this textbook using the guidelines of design and drafting principles established by ASME. David is the supervisor of the engineering design services department at Synerject North America headquartered in Newport News, Virginia. He reports directly to the engineering manager, James A. Kimmel. Synerject is a global provider of engine management solutions for the scooter and recreational vehicle market worldwide and has locations on three continents with more than 200 employees.

David is responsible for the quality and integrity of all drawings, CAD models, and data management within the Newport News headquarters. David also manages design engineering principles throughout the Synerject global engineering base.

David has more than 29 years of experience in metal fabrication, welding and brazing, mechanical design, and the skilled trade of drafting. He has worked for Ford Motor Company, Eaton Corporation, and, most notably, Synerject. David is an American Design Drafting Certified Mechanical Drafter and a member of the American Design Drafting Association (ADDA) board of directors. David is a member of the Thomas Nelson Community College (Newport News, Virginia) CAD board of advisors. David is retired from the U.S. Navy, for which he honorably served on both active and reserve duty. Additional thanks to John Walters, BSME Synerject Principal Engineer, Synerject North America, Newport News, Virginia, for a CADD application based on assigning different material to a solid part model to explore design performance under load. A special thanks is also given to the following for their insight into rapid prototyping:

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Dennis Alan Schwartz provided extensive review and support for the revision of this textbook using the ASME Y14.5-2009 standard and the technical review of many chapters in this textbook. Dennis is the director of engineering services at Wright Medical Technology, Inc., in Arlington, Tennessee. Wright is a global manufacturer and distributor of orthopedic products. Dennis is responsible for all U.S. engineering drawings and CAD models and manages engineering changes required on drawings. Dennis has more than 35 years of mechanical design and drafting experience. Dennis is an ADDA-certified drafter and an American Society of Mechanical Engineers (ASME) certified senior level GD&T professional. He is a member of the ADDA board of directors.

Olen K. Parker, Executive Director and Corporate Operations Officer, ADDA International (www.adda.org)

Olen worked for one of the top 500 engineering and construction firms in the United States for 23 years, starting as a tracer duplicating details and sections to drawings. Olen was a professional drafter, detailer, chief drafter, and graphic arts director. He was appointed to the ADDA board of directors, appointed chair of several committees, and was elected secretary, vice president, and president. Olen is the executive director and corporate operations officer for the ADDA and ADDA International. The ADDA staff, board of directors, and governors assist thousands of students and professionals reach new goals in their career every year. Olen's vision is simple: If he can make one person have a better life by helping his or her career or designing a better product or home, then he has succeeded.

Milwaukee Electric Tool Corporation (www.milwaukeetool.com)

A special thanks is given to Milwaukee Electric Tool Corporation for helping with the specific design process information and the tracking of an actual product design from concept through manufacturing (see the Student Companion Website). The product used for this design sequence example is the Milwaukee Electric Tool Corporation's V28 Lithium-Ion Sawzall® reciprocating saw.

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Paralleling the general design process information in Chapter 25 is the examination of a case study on a new product design from concept through production. The product used for this design sequence example is the Solid Enginyeria's PT-005 Roof Solar Tracker®. Solid Enginyeria Ltd. is dedicated to designing, prototyping, and testing positioning and power transmission mechanisms. Created in 1999 and based in Barcelona, Spain, Solid Enginyeria's main objective is to provide integral engineering services to a wide range of industries.

The product used for this design sequence example is Solid Enginyeria's Roof Solar Tracker. Special thanks is given here to Francesc Civit, senior design engineer; Marc Fernández, design engineer; and Pau Guarro, mechanical engineer with Solid Enginyeria; and their colleagues who supported this content.

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Terry Schultz, Chairman of the ADDA Executive Committee (www.adda.org)

Terry Schultz provided an extensive review and support for the revision of the HVAC and structural chapters in this textbook. Terry is the chairman of the ADDA executive committee as well as past president of the ADDA. The ADDA is the only international, not-for-profit, professional membership and educational association that supports drafters and designers of all disciplines, technical illustrators, and graphic illustrators. Terry is responsible for directing the executive committee in the daily overview of the operation of the association. Terry has more than 20 years experience working with all disciplines, but his

emphasis has been in mechanical, electrical, and plumbing (MEP) and structural disciplines, usually in conjunction with architectural and commercial projects. Terry is an ADDA-certified mechanical drafter.

Zane Pucylowski and Shane Saunders, Phoenix Engineering and Consulting, Inc. (www.phoenixengineering.com)

Initiated by Zane Pucylowski, president of Phoenix Engineering and Consulting, Inc., Shane Saunders, engineering technician, participated in the technical review, providing information, creating copy, and preparing drawings for several chapters throughout this textbook. Phoenix provides professional engineering, general consulting, design, analysis, and evaluation services to solve a wide range of problems.

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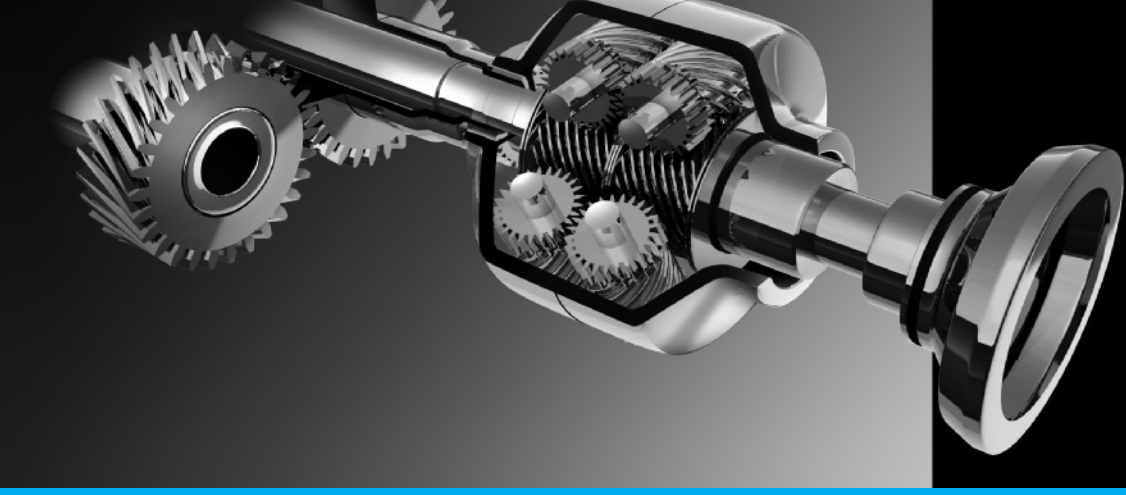
Descriptive Geometry

Special thanks if given to J. Lee Turpin, the original author of the descriptive geometry content found on the Student Companion Website. Lee Turpin is a former Drafting Technology Instructor/Department Chair, and Vocational Counselor at Clackamas Community College, Oregon City, Oregon. Lee has more than 30 years of experience, including industry, teaching, and counseling. Lee presents descriptive geometry to students in a manner that is easy to follow and understand.

Architectural Drafting and Design

Many figures appearing in Chapters 22 and 23 were reprinted from Jefferis and Madsen, *Architectural Drafting and Design*, Fifth and Sixth Editions, published by Cengage Delmar Learning.



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Madsen Design Inc.

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David is Faculty Emeritus of Drafting Technology and the Autodesk Premier Training Center at Clackamas Community College in Oregon City, Oregon. David was an instructor and department Chairperson at Clackamas Community College for nearly 30 years. In addition to community college experience, David was a Drafting Technology instructor at Centennial High School in Gresham, Oregon. David is a former member of the American Design and Drafting Association (ADDA) Board of Directors, and was honored by the ADDA with Director Emeritus status at the annual conference in 2005. David has extensive experience in mechanical drafting, architectural design and drafting, and building construction. David holds a Master of Education degree in Vocational Administration and a Bachelor of Science degree in Industrial Education. David is the author of *Engineering Drawing and Design, Geometric Dimensioning and Tolerancing*, and *Print Reading for Engineering and Manufacturing Technology,* and he is the coauthor of *Architectural AutoCAD, Architectural Desktop and Its Applications, Architectural Drafting and Design, Architectural Drafting Using AutoCAD, AutoCAD and Its Applications: Basics, Advanced, and Comprehensive, AutoCAD Architecture and Its Applications, AutoCAD Essentials, Civil Drafting Technology,* and *Print Reading for Architecture and Construction Technology*.

David P. Madsen

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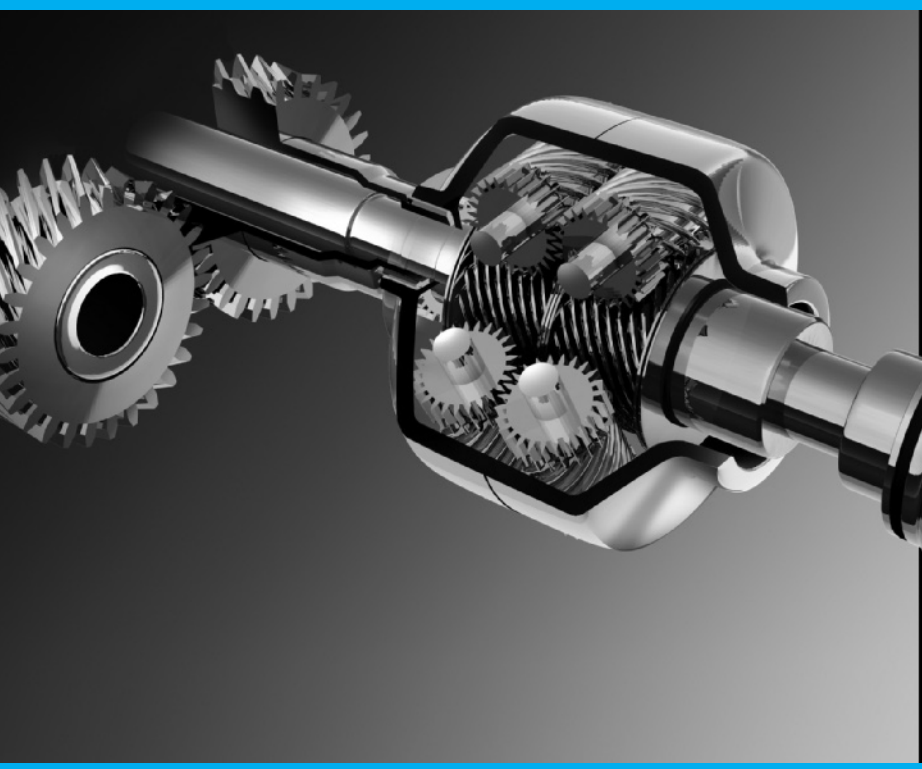
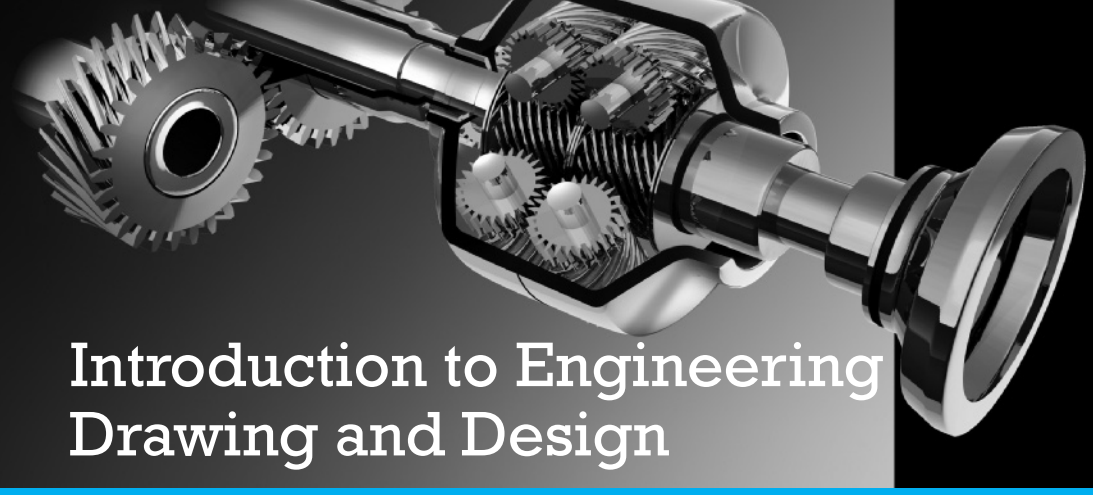
Engineering Drafting & Design, Inc.

David P. Madsen is the president of Engineering Drafting & Design, Inc. and the vice president of Madsen Designs Inc. (www.madsendesigns.com). Dave provides drafting and design consultation and training for all disciplines. He has been a professional design drafter since 1996 and has extensive experience in a variety of drafting, design, and engineering disciplines. Dave has provided drafting and computer-aided design and drafting instruction to secondary and postsecondary learners since 1999, and has considerable curriculum, and program coordination and development experience. Dave holds a Master of Science degree in Educational Policy, Foundations, and Administrative Studies with a specialization in Postsecondary, Adult, and Continuing Education; a Bachelor of Science degree in Technology Education; and an Associate of Science degree in General Studies and Drafting Technology. Dave is the author of *Inventor and Its Applications,* and coauthor of *Architectural Drafting and Design, Architectural Drafting Using AutoCAD, AutoCAD and Its Applications: Basics and Comprehensive, Civil Drafting Technology, Engineering Drawing and Design, Geometric Dimensioning and Tolerancing, Print Reading for Architecture and Construction Technology,* and *Print Reading for Engineering and Manufacturing Technology*.



1

Introduction to Engineering Drawing and Design



CHAPTER

1

Introduction to Engineering Drawing and Design

LEARNING OBJECTIVES

After completing this chapter, you will:

- Explain topics related to the history of engineering drafting.
- Define drafter and other related terminology.
- Identify categories and disciplines related to drafting.
- Describe the requirements for becoming a drafter.
- List and explain points to consider when seeking employment.
- Identify the professional organization that is dedicated to the advancement of design and drafting.
- Explain workplace ethics and related issues.
- Identify topics related to copyrights, patents, and trademarks.

THE ENGINEERING DESIGN APPLICATION

Engineering drawing and design is a broad subject that includes a wide range of theory and practice. Many different forms of drawing exist. Drawing occurs while at the lunch table as a basic sketch of a new product idea drawn on a napkin. Drawing also occurs in the form of a series of complex models for a new automotive design and as hundreds of formal drawings needed for the construction of a skyscraper. You will learn the purpose of and requirements for creating meaningful engineering drawings as you use this textbook to study engineering drawing and design.

Each chapter in this textbook begins with a special feature titled "The Engineering Design Application." Each engineering design application provides an introductory topic or study relating the engineering drawing and design process to chapter content. Engineering design applications offer early explanation and systematic problem-solving techniques applied to specific engineering projects or general design and drafting concepts. The engineering design application in this chapter guides you through a basic example of an engineering design process, beginning with an idea and basic sketch and ending with the manufacture of an actual product.

From an Idea to a Product

Design ideas and engineering projects are often already established or occur in informal settings. For instance, the engineer of a hand-tool manufacturing company was using a typical adjustable wrench to complete a common home-repair task. While using the wrench, the engineer discovered that it was difficult to access a confined location to remove a nut on a piece of equipment. The engineer imagined how the company could design, manufacture, and market a new wrench with features that help make the tool usable in cramped locations. The next day, the engineer and a colleague from the drafting department met for coffee. The engineer sketched the idea for the new wrench on a napkin to communicate the design to the drafter. The sketch in Figure 1.1 shows the idea of taking an existing tool design and creating a new handle with an **ogee**, or S-shaped curve design.

Later the same day, the drafter opens the three-dimensional (3-D) **solid model** files of the existing wrench design on the computer-aided design and drafting (CADD) system as shown in Figure 1.2a. A solid model in CADD contains information about object edges, the intersection of those edges and surfaces, and data about object volume and mass. The drafter copies and then revises the existing design according to the engineer's sketch as shown in Figure 1.2b. The drafter presents the new model to the engineer, who is pleased with the results and requests a rapid prototype. **Rapid prototyping (RP)** is the process of creating a physical and functional model from a computer-generated 3-D model,

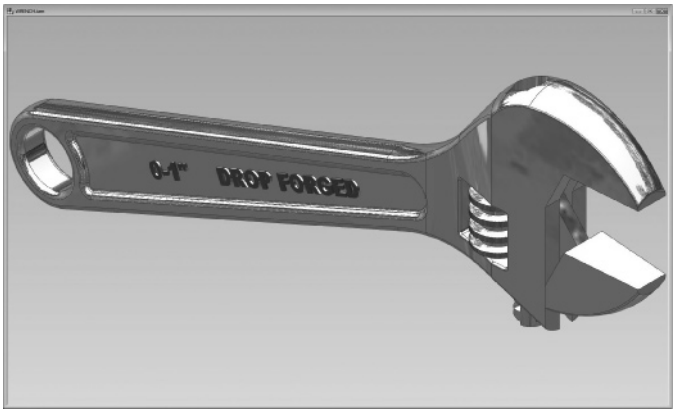
Continued

FIGURE 1.1 An engineer sketching a design idea on a napkin. The sketch communicates the idea of taking an existing tool and creating a new handle with an ogee, or S-shaped curve design.

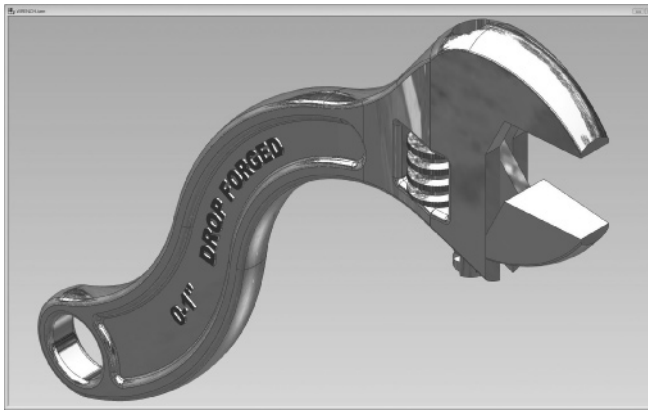
FIGURE 1.3 A rapid prototype of the new product design.

using an RP machine also known as a **3-D printer**. RP machines are available that build prototypes from various materials such as paper and liquid polymer. If the hand-tool company does not have an RP machine, then the drafter sends files of the design to a company that specializes in RP. The drafter and engineer receive a prototype two days later. Figure 1.3 shows the prototype of the new wrench design. The design team tests the prototype in an application similar to what the engineer experienced at home. The prototype works as expected. Both 3-D modeling and rapid prototyping are described in detail later in this textbook.

By the next afternoon, the drafter completes the set of working drawings shown in Figure 1.4 and sends the drawings to the manufacturing department to manufacture and assemble the new product. The manufacturing department needs **lead time** to design and make the **forging** dies required to reproduce the parts. Lead time is the time interval between the initiation and the completion of a production process. Forging is the process of shaping malleable metals by hammering or pressing between dies that duplicate the desired shape. The hand-tool company is small, so the drafter is also responsible for creating catalog art and copy for marketing the product shown in Figure 1.5. Less than two months after the engineer had the initial idea, the first production run of new wrenches is ready to sell. Figure 1.6 shows the finished product.



(a)



(b)

FIGURE 1.2 (a) The drafter opens the three-dimensional (3-D) solid model files of the existing wrench design on the computer-aided design and drafting (CADD) system. (b) The drafter revises the existing tool design according to the engineer's sketch shown in Figure 1.1.

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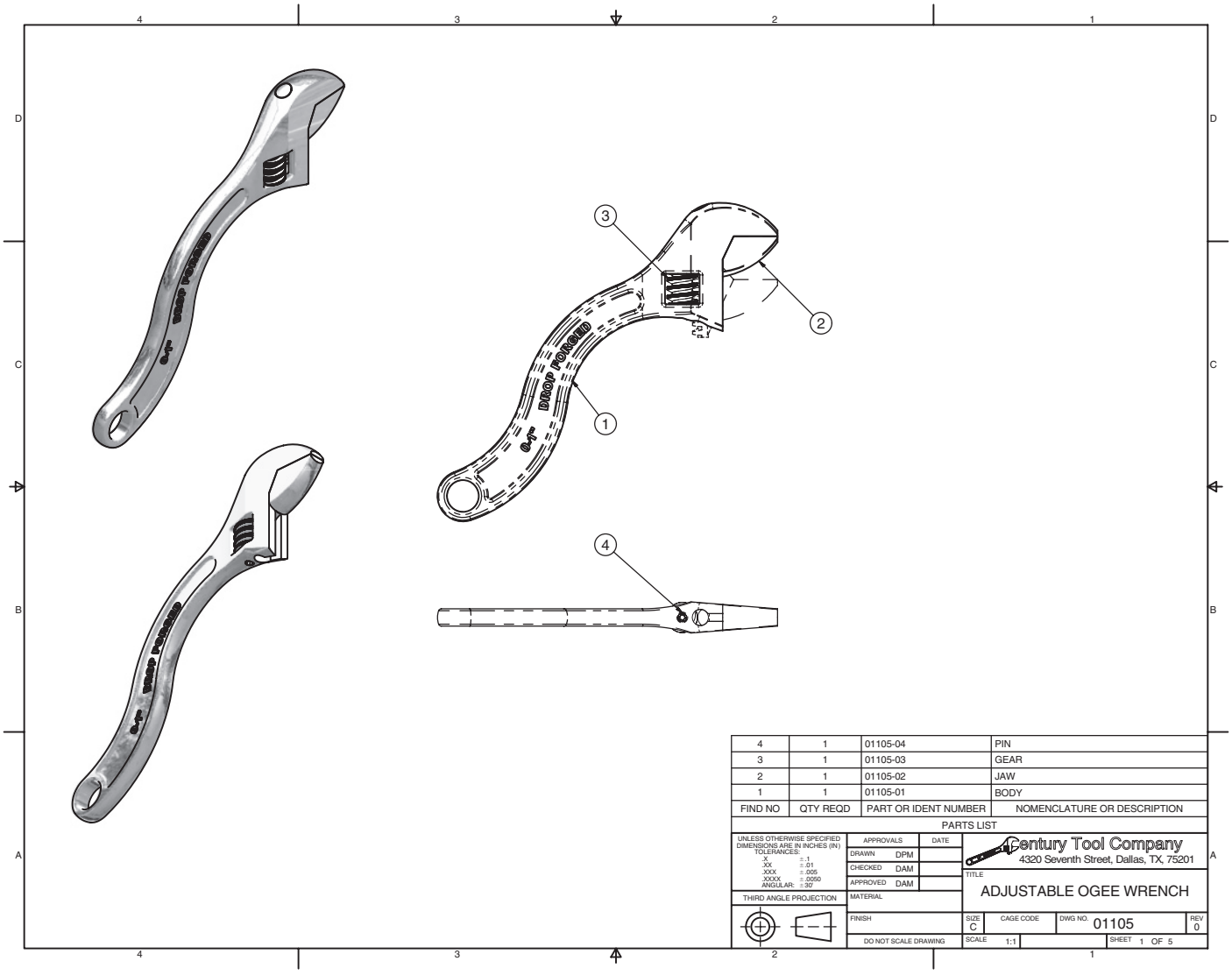


FIND NO	QTY REQD	PART OR IDENT NUMBER	NOMENCLATURE OR DESCRIPTION
4	1	01105-04	PIN
3	1	01105-03	GEAR
2	1	01105-02	JAW
1	1	01105-01	BODY

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES (IN)
TOLERANCES:
.X ± .1
.Xx ± .01
.XXX ± .005
.XXXX ± .0050
ANGULAR: ± 30'

THIRD ANGLE PROJECTION

APPROVALS	DATE
DRAWN DPM	
CHECKED DAM	
APPROVED DAM	
MATERIAL	
FINISH	
DO NOT SCALE DRAWING	

Century Tool Company
4320 Seventh Street, Dallas, TX, 75201

TITLE
ADJUSTABLE OGEE WRENCH

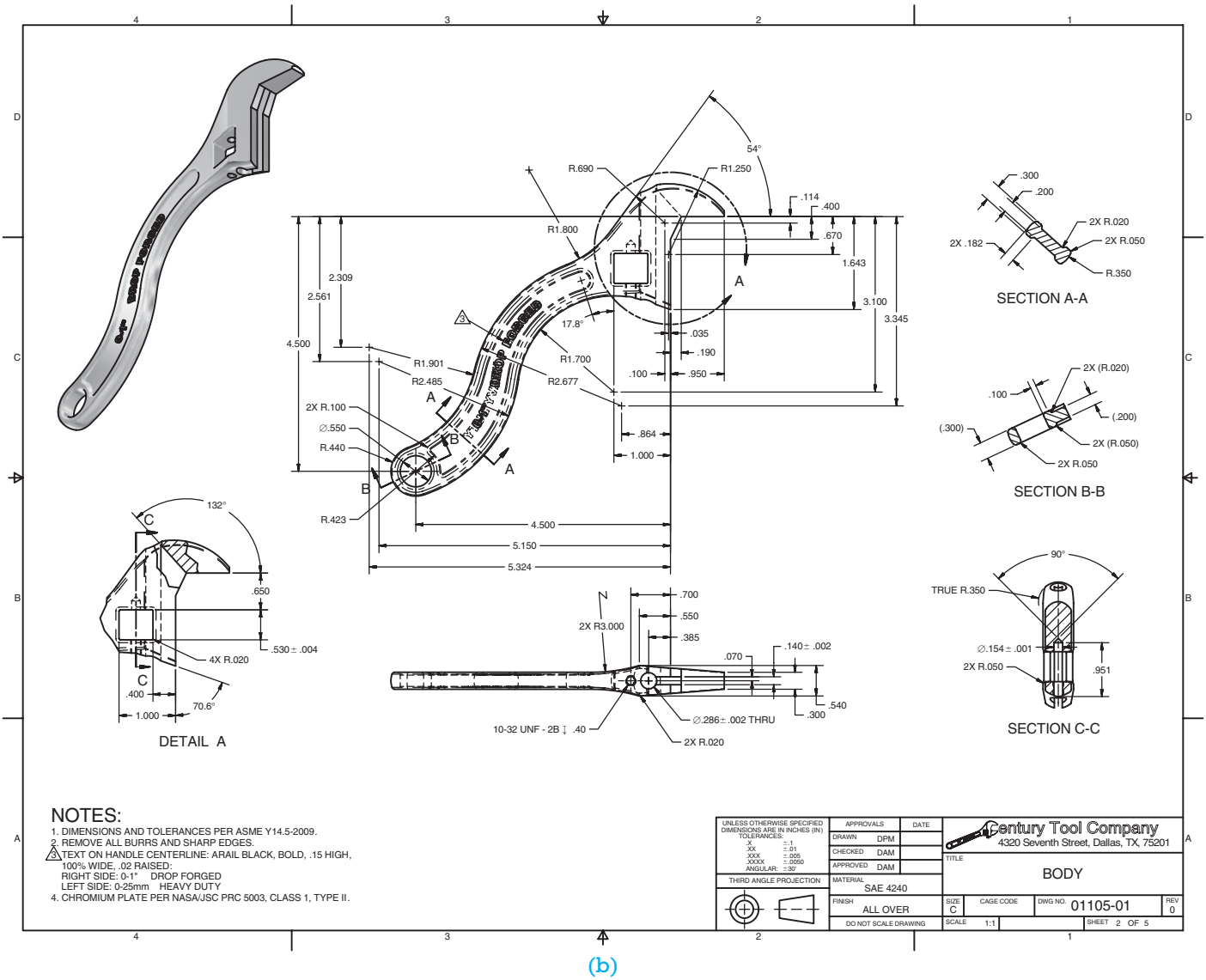
SIZE	CAGE CODE	DWG NO.	REV
C		01105	0

SCALE 1:1 SHEET 1 OF 5

(a)

FIGURE 1.4 A set of working drawings for the new wrench design. (a) Assembly drawing and parts list. (*Continued*)

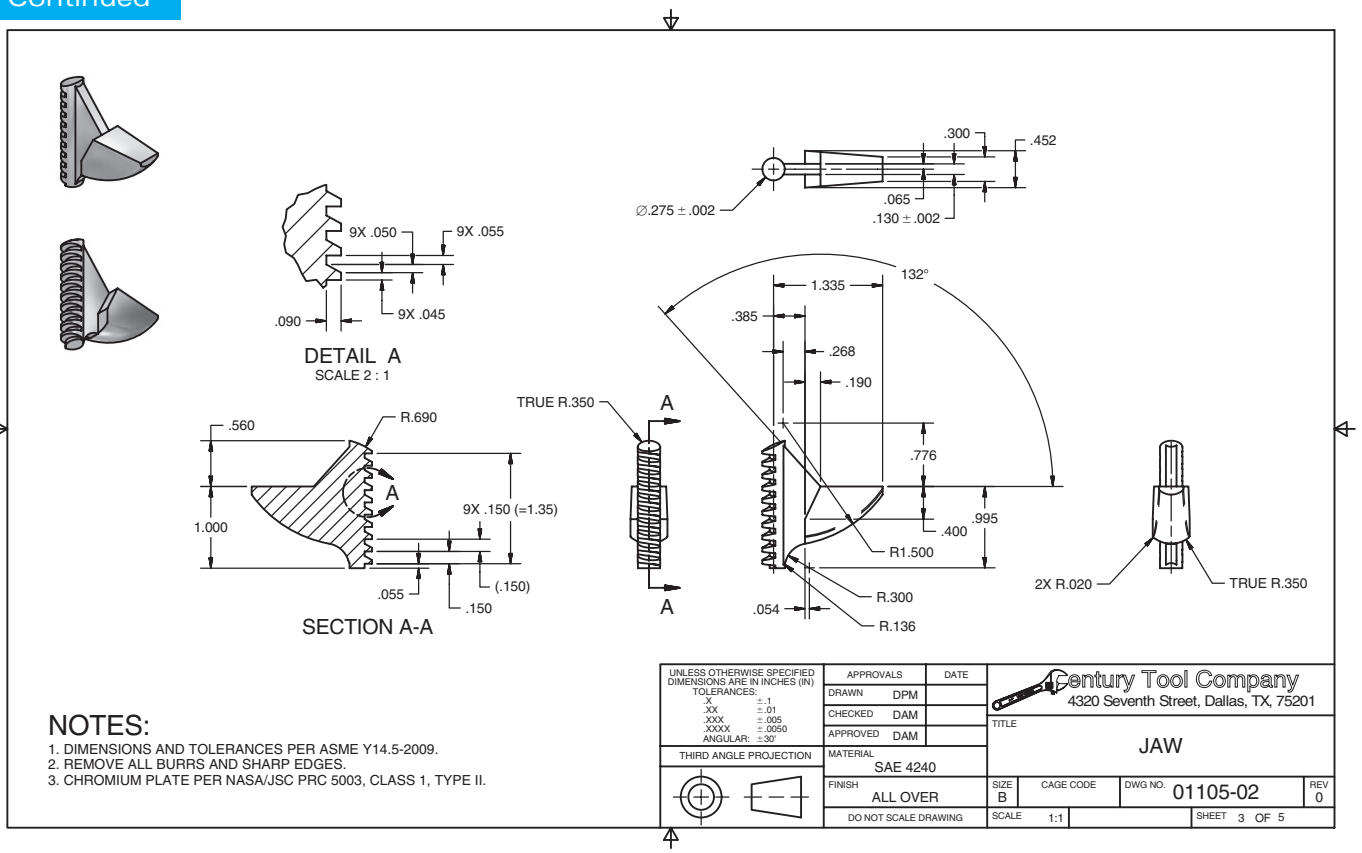
Continued



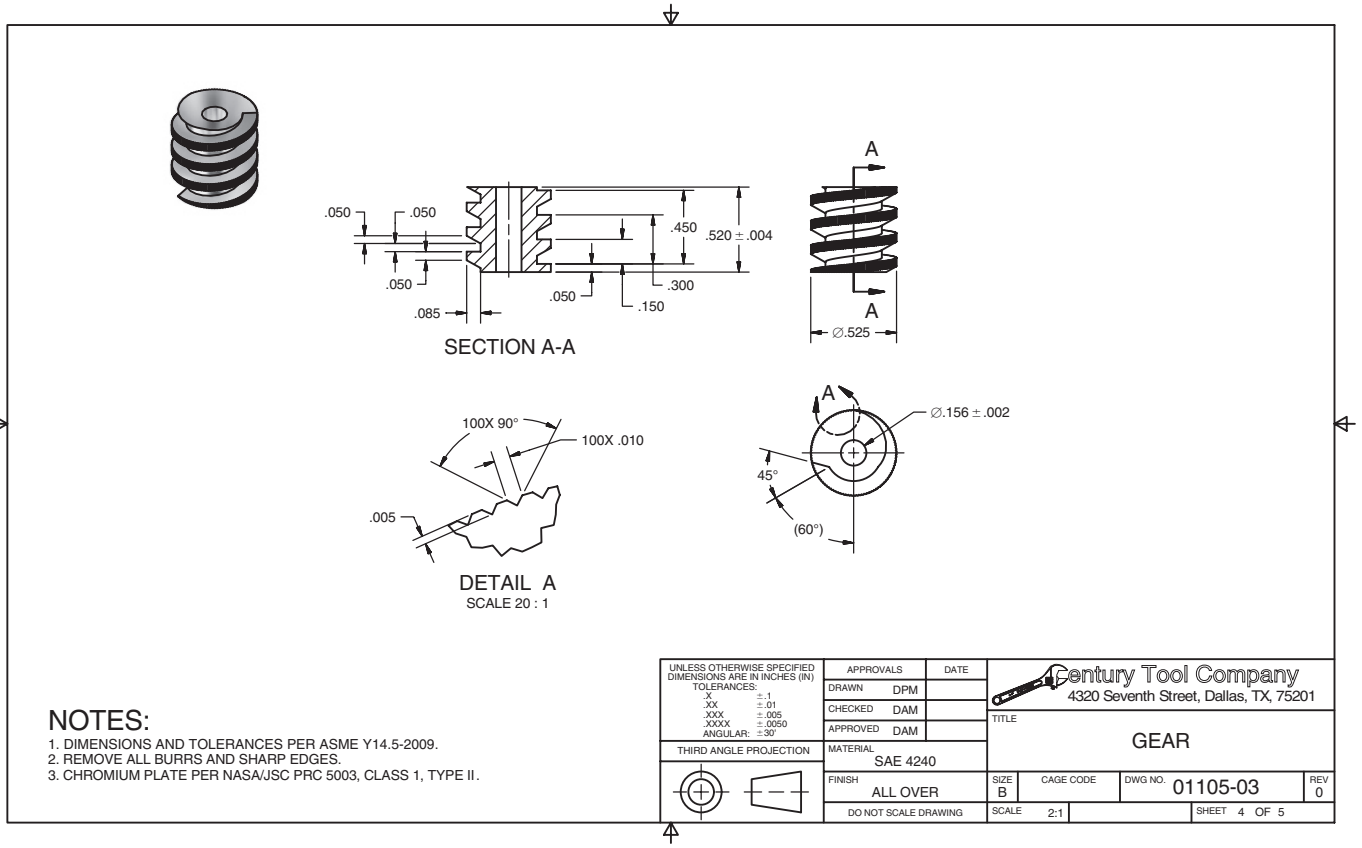
(b)

FIGURE 1.4 (b) Detail drawing of the new wrench BODY part. (*Continued*)

Continued



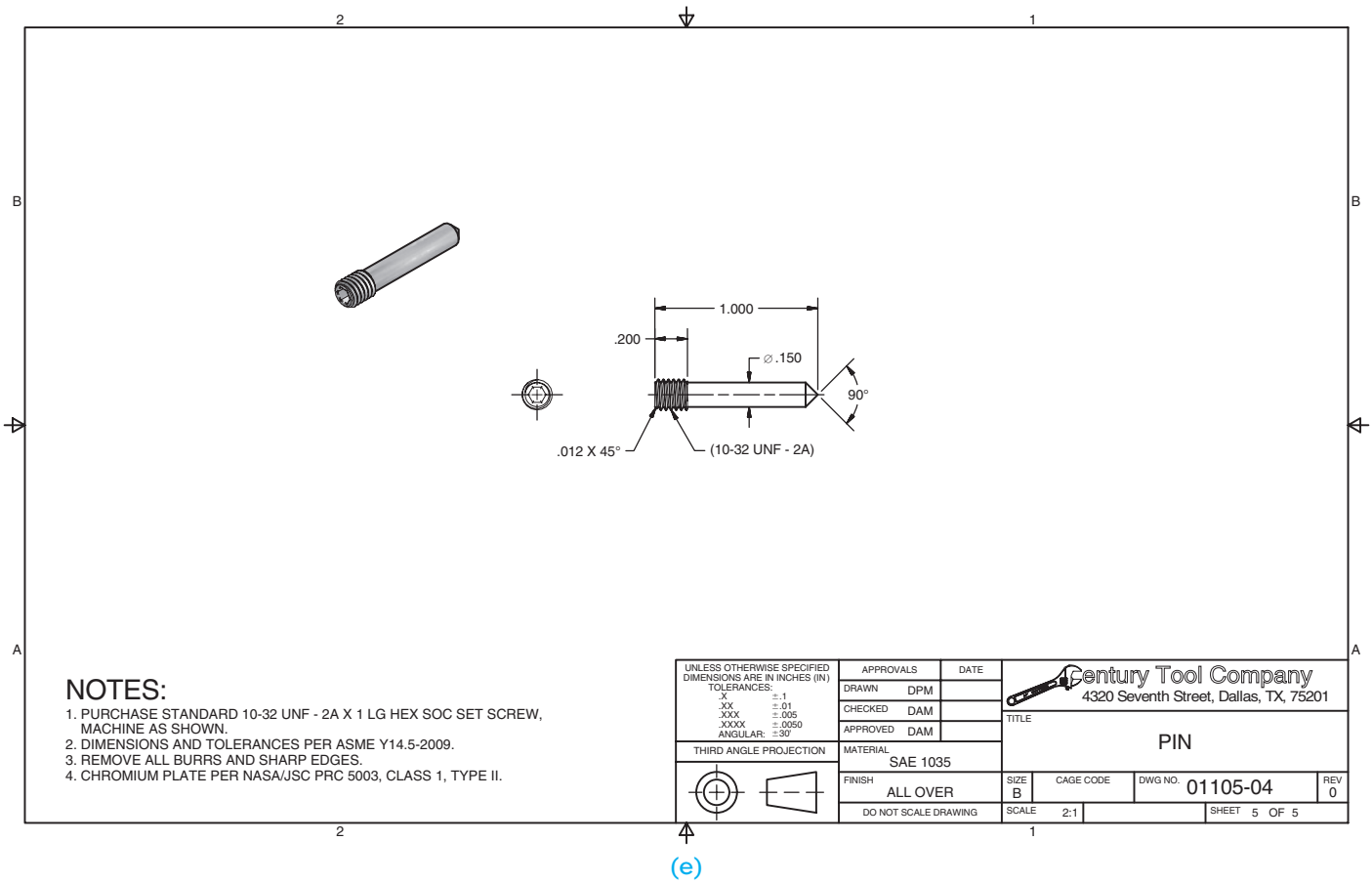
(c)



(d)

FIGURE 1.4 (c) Detail drawing of the new wrench JAW part. (d) Detail drawing of the new wrench GEAR part. (*Continued*)

Continued



(e)

FIGURE 1.4 (e) Detail drawing of the new wrench PIN part.

Courtesy of Century Tool Company

FIGURE 1.5 The drafter in this small company is responsible for creating catalog art and copy for marketing the new product.

FIGURE 1.6 The new wrench design in a finished product, ready to sell.

INTRODUCTION

Engineering drawing is the common language of engineering and describes the process of creating drawings for any engineering or architectural application. Engineering drawings, produced according to accepted standards and format, provide an effective and efficient way to communicate specific information about design intent. Engineering drawings are typically not open to interpretation like other drawings, such as decorative drawings and artistic paintings. A successful engineering drawing describes a specific item in a way that the viewer of the drawing understands completely and without misinterpretation.

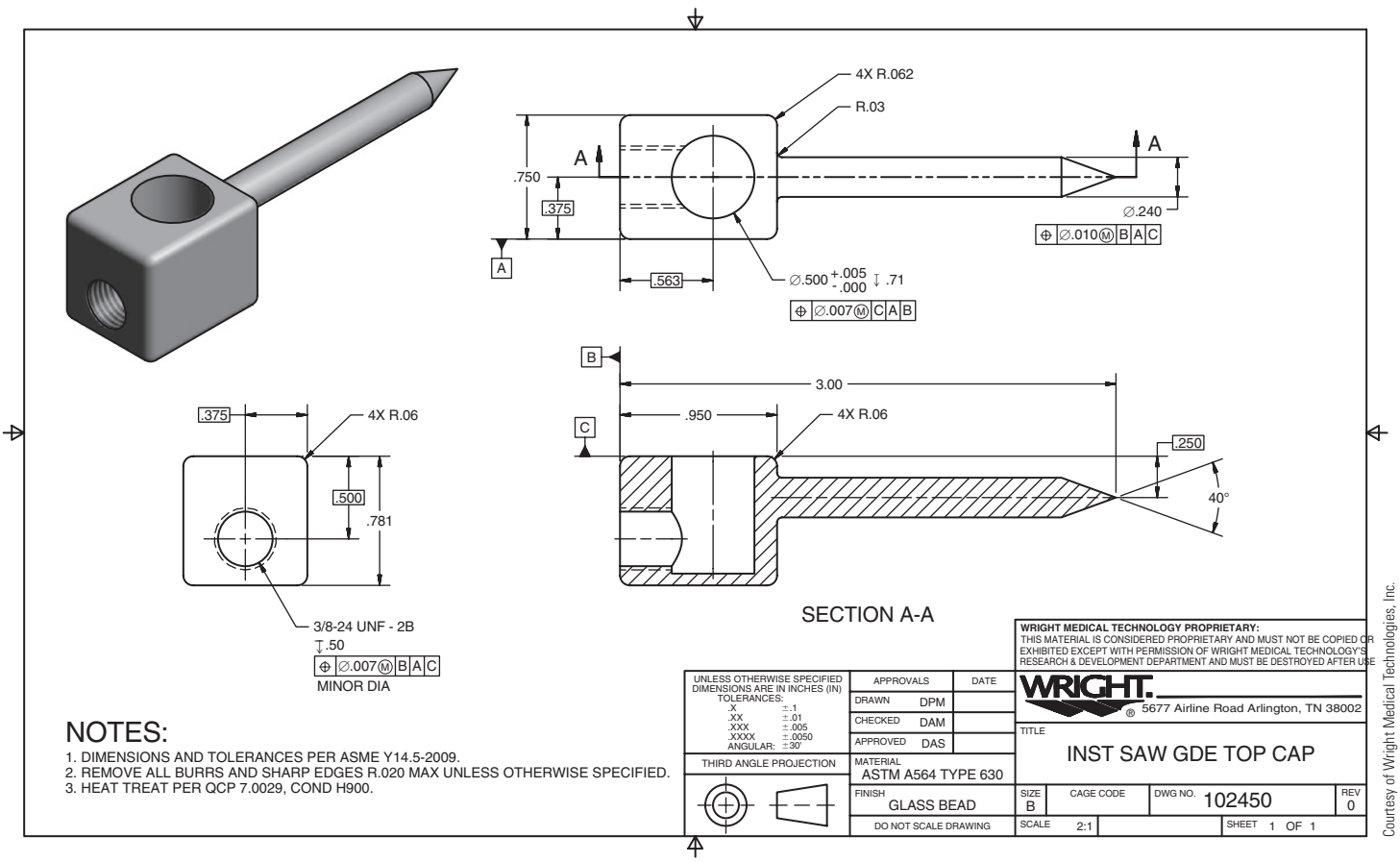
The term **engineering drawing** is also known as **drafting**, **engineering drafting**, **mechanical drawing**, **mechanical drafting**, **technical drawing**, and **technical drafting**. **Drafting** is a graphic language using lines, symbols, and notes to describe objects for manufacture or construction. Most technical disciplines use drafting, including architecture, civil and electrical engineering, electronics, piping, manufacturing, and structural engineering. The term **mechanical drafting** has alternate meanings. The manufacturing industry uses **mechanical drafting**, with its name derived from mechanisms. The construction industry also uses **mechanical drafting**, but the term refers to drafting heating, ventilating, and air-conditioning (HVAC) systems, which is the mechanical portion of an architectural project. You will learn about drafting common to other disciplines later in this chapter and throughout this textbook.

Manual drafting is a term that describes traditional drafting practice using pencil or ink on a medium such as paper or polyester film, with the support of drafting instruments and equipment. **Computer-aided drafting (CAD)** has taken the place of manual drafting. CAD uses computers for drafting. CAD also refers to **computer-aided design** when computers are used for design. The term **computer-aided design and drafting (CADD)** is introduced and described later in this section.

Engineering drawings communicate a variety of concepts, such as engineering requirements, instructions, and proposals, to a variety of people, such as the many different individuals and groups involved with a project. An engineering drawing or a complete **set of engineering drawings** provides all of the data required to manufacture or construct an item or product, such as a machine part, consumer product, or structure.

Study the drawing of the medical instrument part in Figure 1.7. The drawing completely and unmistakably describes the size and location of all geometric features, and it identifies other characteristics of the part, such as material and manufacturing precision and processes. The medical instrument company uses the drawing to share and document design intent and to manufacture the part. Consider how difficult it would be to explain the part without the engineering drawing.

Figure 1.8 shows another example of an engineering drawing, an architectural drawing for a home-remodeling project.



Courtesy of Wright Medical Technologies, Inc.

FIGURE 1.7 This drawing of a medical instrument part completely and unmistakably describes the size and location of all geometric features, and identifies other characteristics of the part.

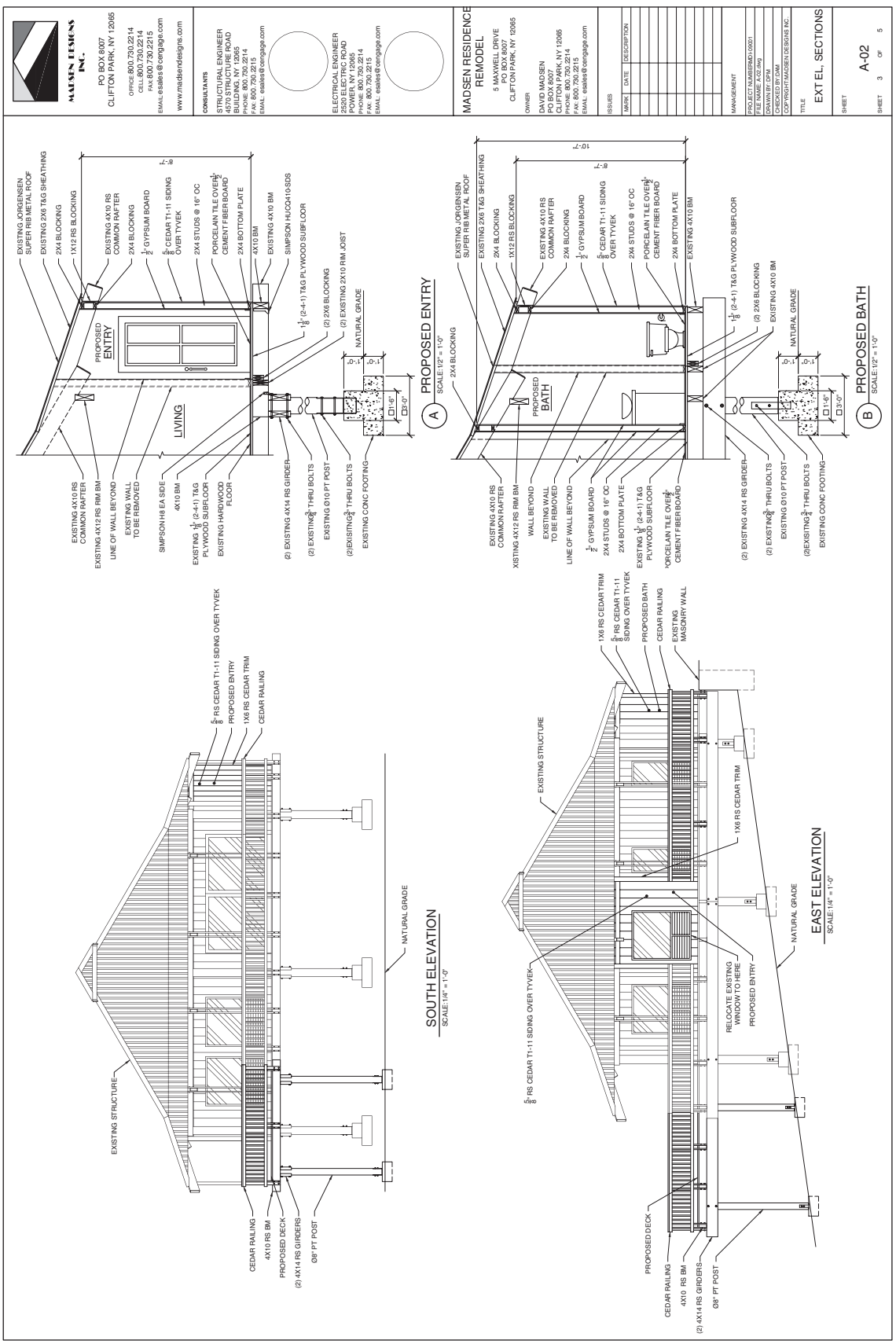


FIGURE 1.8 This engineering drawing is an architectural drawing for a home remodeling project. The drawing is one sheet in a set of drawings that communicates architectural style, the size and location of building features, and construction methods and materials.