TECHNICAL DRAWING *with* Engineering Graphics

15th Edition

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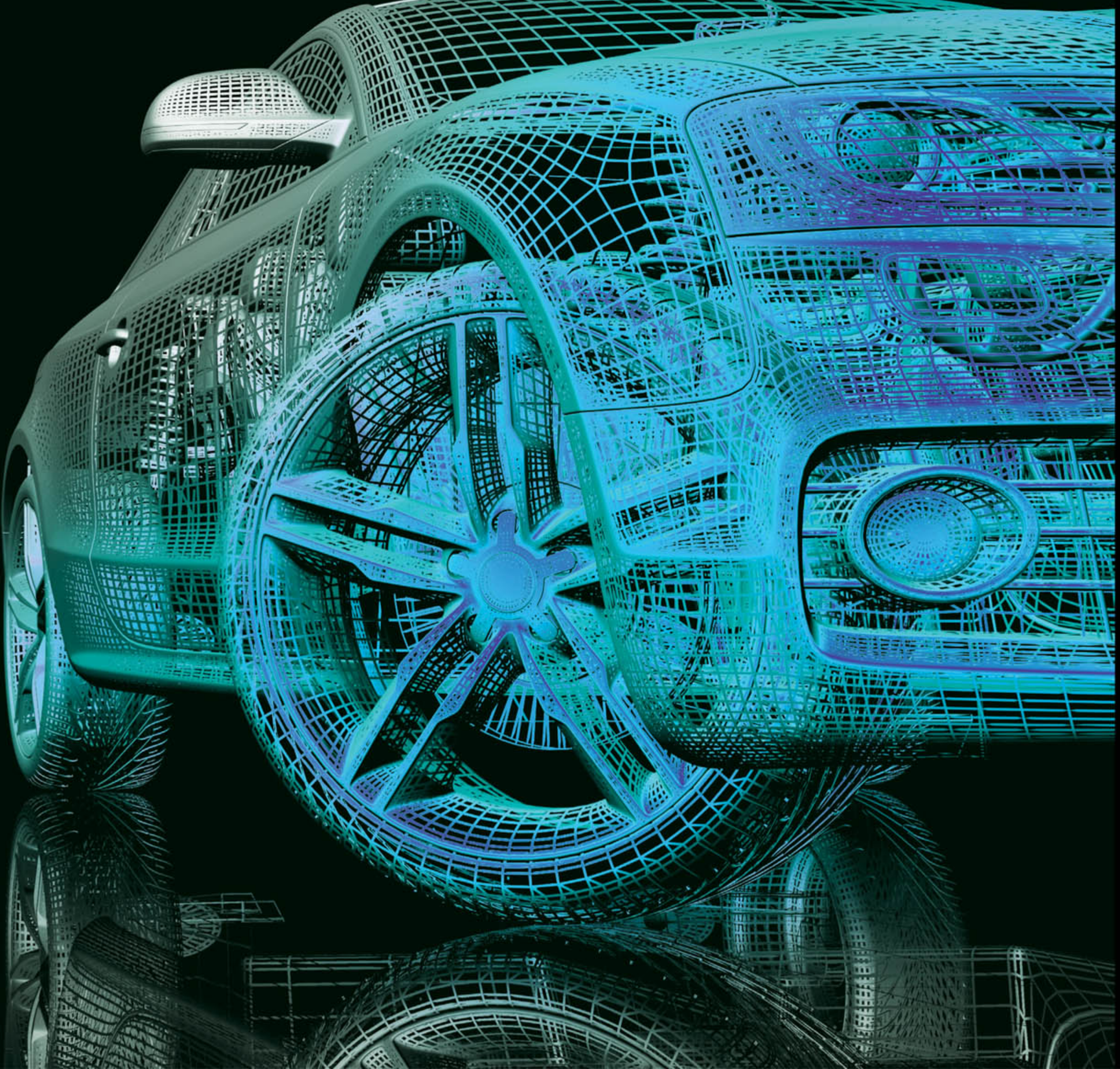

FIFTEENTH EDITION

TECHNICAL DRAWING WITH ENGINEERING GRAPHICS

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FIFTEENTH EDITION

TECHNICAL DRAWING WITH ENGINEERING GRAPHICS

ABOUT THIS BOOK

The fifteenth edition of Giesecke's *Technical Drawing with Engineering Graphics* is a comprehensive introduction and detailed reference for creating 3D models and 2D documentation drawings.

Continuing its reputation as a trusted reference, this edition expands on the role that the 3D CAD database plays in design and documentation. It provides excellent integration of its hallmark illustrations with text and contemporary examples, and consistent navigational features make it easy to find important information.

This edition illustrates the application of both 3D and 2D modeling and technical drawing skills to real-world work practice and integrates drawing and CAD skills in a variety of disciplines.

Updated Content

- Expanded coverage of 3D design and modeling techniques
- CAD coverage focusing on issues that arise in modeling and documenting designs
- Updated introduction illustrates design documentation with an industry case study
- New coverage of geometry useful for 3D modeling
- Updated for current ASME standards
- More examples of plastic and sheet metal parts
- Updated software examples
- Thoroughly checked for accuracy

Teaching/Learning Features

Visually oriented students and busy professionals will quickly locate content by navigating these consistent chapter features.

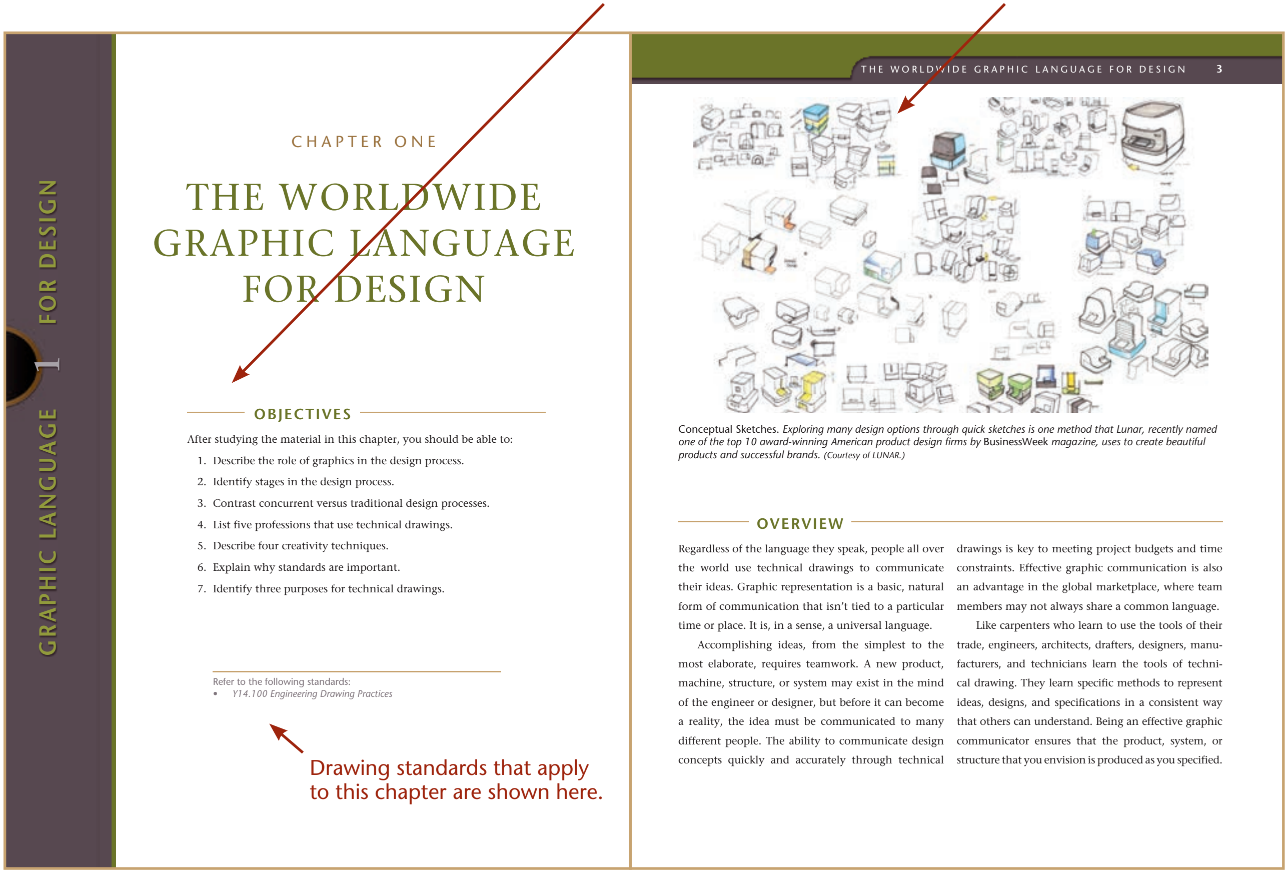
- ***Splash Spread*** An attention-getting chapter opener interests readers and provides context for chapter content.
- ***References and Web Links*** Applicable references to standards and links to handy websites are at the beginning of each chapter.
- ***Foundations Section*** An introductory section, set off by a topic heading tab at the top of the page for easy navigation, covers the topic's usage and importance, visualization tips, and theory related to the drawing techniques.
- ***Detail Section*** This is the "brass tacks" part of the book, where detailed explanations of drawing and modeling techniques, variations, and examples are organized into quick-read sections, each numbered for quick reference in the detailed table of contents.
- ***CAD at Work*** This breakout page includes tips related to using the 2D or 3D CAD model to generate drawings.
- ***Industry Case*** 3D modeling practitioners share their best practices for modeling and documenting design.
- ***Portfolio*** Examples of finished drawings wrap up the chapter by showing real-world application of topics presented.
- ***Key Words*** Set in bold italics on first reference, key words are summarized at the end of the chapter.
- ***Chapter Summary***
- ***Review Questions***
- ***Chapter Exercises*** The excellent Giesecke problem sets feature updated exercises, including plastic and sheet metal parts, modeling exercises, assembly drawings from CAD models, and sketching problems.

The following features were designed to provide easy navigation and quick reference for students and professionals who look to Giesecke both as a helpfully-organized teaching text and a lasting reference.

CHAPTER OPENER

Topics that you can expect to learn about in this chapter are listed here.

A large illustration and an interesting overview give you a real-world context for what this chapter is about.



GRAPHIC LANGUAGE 1 FOR DESIGN

CHAPTER ONE

THE WORLDWIDE GRAPHIC LANGUAGE FOR DESIGN

OBJECTIVES

After studying the material in this chapter, you should be able to:

1. Describe the role of graphics in the design process.
2. Identify stages in the design process.
3. Contrast concurrent versus traditional design processes.
4. List five professions that use technical drawings.
5. Describe four creativity techniques.
6. Explain why standards are important.
7. Identify three purposes for technical drawings.

Refer to the following standards:
- *Y14.100 Engineering Drawing Practices*

Drawing standards that apply to this chapter are shown here.

THE WORLDWIDE GRAPHIC LANGUAGE FOR DESIGN 3

Conceptual Sketches. *Exploring many design options through quick sketches is one method that Lunar, recently named one of the top 10 award-winning American product design firms by* BusinessWeek *magazine, uses to create beautiful products and successful brands.* *(Courtesy of LUNAR.)*

OVERVIEW

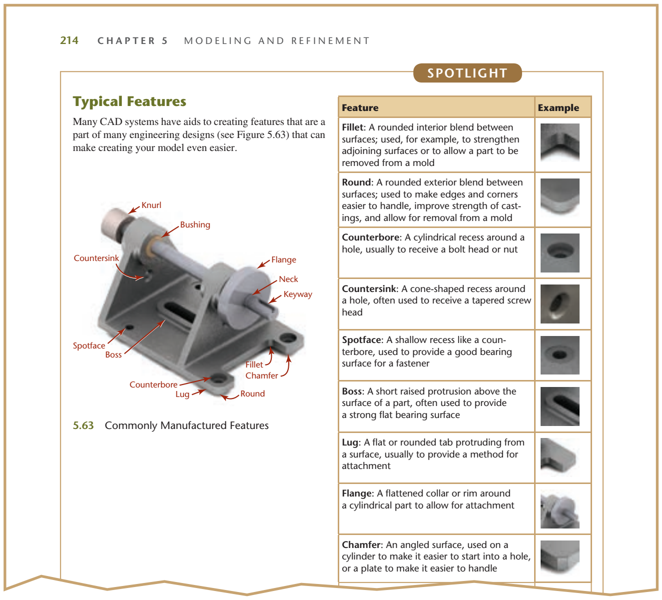
Regardless of the language they speak, people all over the world use technical drawings to communicate their ideas. Graphic representation is a basic, natural form of communication that isn't tied to a particular time or place. It is, in a sense, a universal language.

Accomplishing ideas, from the simplest to the most elaborate, requires teamwork. A new product, machine, structure, or system may exist in the mind of the engineer or designer, but before it can become a reality, the idea must be communicated to many different people. The ability to communicate design concepts quickly and accurately through technical drawings is key to meeting project budgets and time constraints. Effective graphic communication is also an advantage in the global marketplace, where team members may not always share a common language.

Like carpenters who learn to use the tools of their trade, engineers, architects, drafters, designers, manufacturers, and technicians learn the tools of technical drawing. They learn specific methods to represent ideas, designs, and specifications in a consistent way that others can understand. Being an effective graphic communicator ensures that the product, system, or structure that you envision is produced as you specified.

"SPOTLIGHT" SECTIONS

These sections add background information for key topics.



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SPOTLIGHT

Typical Features

Many CAD systems have aids to creating features that are a part of many engineering designs (see Figure 5.63) that can make creating your model even easier.

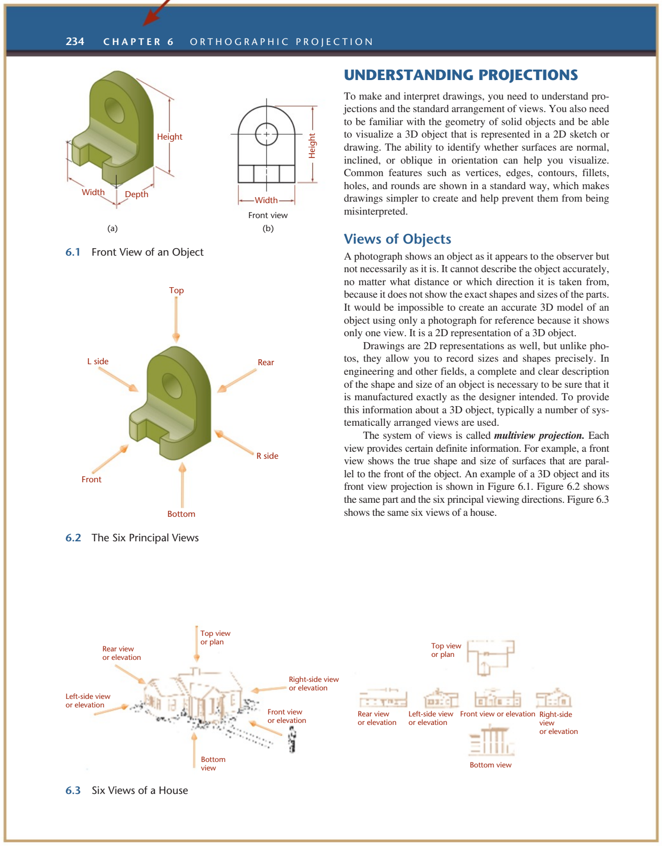
5.63 Commonly Manufactured Features

Feature	Example
Fillet: A rounded interior blend between surfaces; used, for example, to strengthen adjoining surfaces or to allow a part to be removed from a mold	
Round: A rounded exterior blend between surfaces; used to make edges and corners easier to handle, improve strength of castings, and allow for removal from a mold	
Counterbore: A cylindrical recess around a hole, usually to receive a bolt head or nut	
Countersink: A cone-shaped recess around a hole, often used to receive a tapered screw head	
Spotface: A shallow recess like a counterbore, used to provide a good bearing surface for a fastener	
Boss: A short raised protrusion above the surface of a part, often used to provide a strong flat bearing surface	
Lug: A flat or rounded tab protruding from a surface, usually to provide a method for attachment	
Flange: A flattened collar or rim around a cylindrical part to allow for attachment	
Chamfer: An angled surface, used on a cylinder to make it easier to start into a hole, or a plate to make it easier to handle	

"FOUNDATIONS" SECTION

This introductory section covers the chapter topic's usage and importance, visualization tips, and theory related to the drawing and modeling techniques.

Color at the top of the page makes it easy to flip to the "Foundations" section.



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UNDERSTANDING PROJECTIONS

To make and interpret drawings, you need to understand projections and the standard arrangement of views. You also need to be familiar with the geometry of solid objects and be able to visualize a 3D object that is represented in a 2D sketch or drawing. The ability to identify whether surfaces are normal, inclined, or oblique in orientation can help you visualize. Common features such as vertices, edges, contours, fillets, holes, and rounds are shown in a standard way, which makes drawings simpler to create and help prevent them from being misinterpreted.

Views of Objects

A photograph shows an object as it appears to the observer but not necessarily as it is. It cannot describe the object accurately, no matter what distance or which direction it is taken from, because it does not show the exact shapes and sizes of the parts. It would be impossible to create an accurate 3D model of an object using only a photograph for reference because it shows only one view. It is a 2D representation of a 3D object.

Drawings are 2D representations as well, but unlike photos, they allow you to record sizes and shapes precisely. In engineering and other fields, a complete and clear description of the shape and size of an object is necessary to be sure that it is manufactured exactly as the designer intended. To provide this information about a 3D object, typically a number of systematically arranged views are used.

The system of views is called ***multiview projection.*** Each view provides certain definite information. For example, a front view shows the true shape and size of surfaces that are parallel to the front of the object. An example of a 3D object and its front view projection is shown in Figure 6.1. Figure 6.2 shows the same part and the six principal viewing directions. Figure 6.3 shows the same six views of a house.

6.1 Front View of an Object

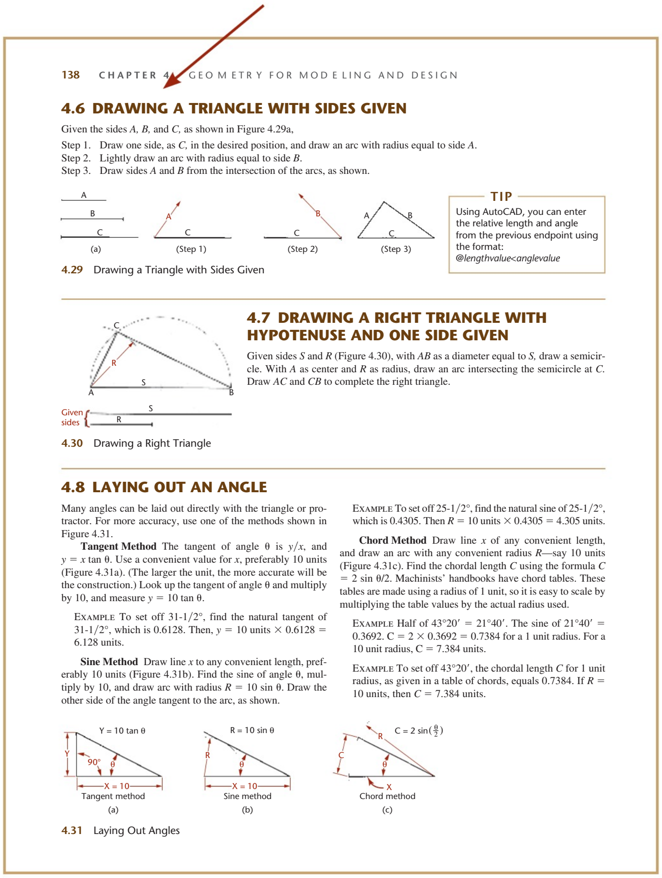
6.2 The Six Principal Views

6.3 Six Views of a House

"DETAIL" SECTION

This is the "brass tacks" of the book, where detailed techniques, variations, and examples are organized into quick-read sections, numbered for easy reference.

Content is broken into individual, numbered sections.



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4.6 DRAWING A TRIANGLE WITH SIDES GIVEN

Given the sides *A, B,* and *C,* as shown in Figure 4.29a,

Step 1. Draw one side, as *C,* in the desired position, and draw an arc with radius equal to side *A*.
Step 2. Lightly draw an arc with radius equal to side *B*.
Step 3. Draw sides *A* and *B* from the intersection of the arcs, as shown.

4.29 Drawing a Triangle with Sides Given

TIP

Using AutoCAD, you can enter the relative length and angle from the previous endpoint using the format: *@lengthvalue<anglevalue*

4.7 DRAWING A RIGHT TRIANGLE WITH HYPOTENUSE AND ONE SIDE GIVEN

Given sides *S* and *R* (Figure 4.30), with *AB* as a diameter equal to *S,* draw a semicircle. With *A* as center and *R* as radius, draw an arc intersecting the semicircle at *C.* Draw *AC* and *CB* to complete the right triangle.

4.30 Drawing a Right Triangle

4.8 LAYING OUT AN ANGLE

Many angles can be laid out directly with the triangle or protractor. For more accuracy, use one of the methods shown in Figure 4.31.

Tangent Method The tangent of angle θ is y/x, and $y = x \tan \theta$. Use a convenient value for *x*, preferably 10 units (Figure 4.31a). (The larger the unit, the more accurate will be the construction.) Look up the tangent of angle θ and multiply by 10, and measure $y = 10 \tan \theta$.

EXAMPLE To set off 31-1/2°, find the natural tangent of 31-1/2°, which is 0.6128. Then, $y = 10$ units $\times$ 0.6128 = 6.128 units.

Sine Method Draw line *x* to any convenient length, preferably 10 units (Figure 4.31b). Find the sine of angle θ, multiply by 10, and draw arc with radius $R = 10 \sin \theta$. Draw the other side of the angle tangent to the arc, as shown.

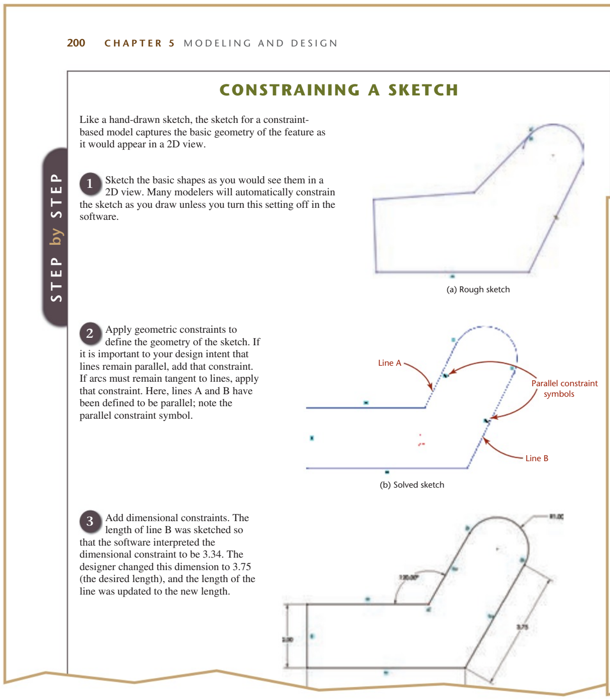
EXAMPLE To set off 25-1/2°, find the natural sine of 25-1/2°, which is 0.4305. Then $R = 10$ units $\times$ 0.4305 = 4.305 units.

Chord Method Draw line *x* of any convenient length, and draw an arc with any convenient radius *R*—say 10 units (Figure 4.31c). Find the chordal length *C* using the formula $C = 2 \sin \theta/2$. Machinists' handbooks have chord tables. These tables are made using a radius of 1 unit, so it is easy to scale by multiplying the table values by the actual radius used.

EXAMPLE Half of 43°20′ = 21°40′. The sine of 21°40′ = 0.3692. C = 2 × 0.3692 = 0.7384 for a 1 unit radius. For a 10 unit radius, C = 7.384 units.

EXAMPLE To set off 43°20′, the chordal length *C* for 1 unit radius, as given in a table of chords, equals 0.7384. If $R = 10$ units, then $C = 7.384$ units.

4.31 Laying Out Angles



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STEP by STEP

CONSTRAINING A SKETCH

Like a hand-drawn sketch, the sketch for a constraint-based model captures the basic geometry of the feature as it would appear in a 2D view.

1 Sketch the basic shapes as you would see them in a 2D view. Many modelers will automatically constrain the sketch as you draw unless you turn this setting off in the software.

(a) Rough sketch

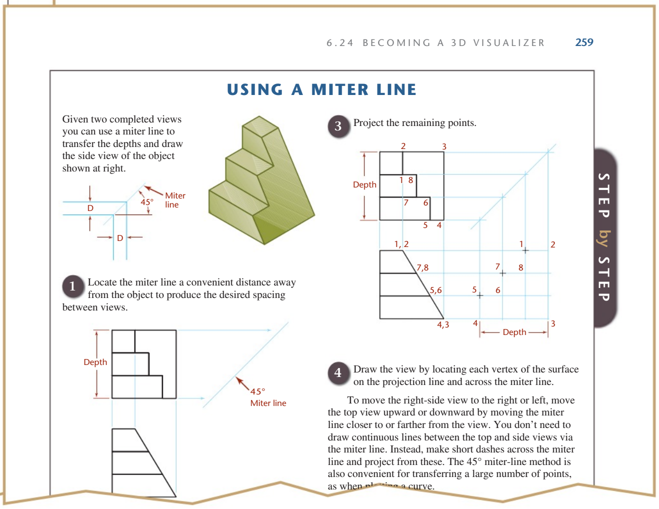
2 Apply geometric constraints to define the geometry of the sketch. If it is important to your design intent that lines remain parallel, add that constraint. If arcs must remain tangent to lines, apply that constraint. Here, lines A and B have been defined to be parallel; note the parallel constraint symbol.

(b) Solved sketch

3 Add dimensional constraints. The length of line B was sketched so that the software interpreted the dimensional constraint to be 3.34. The designer changed this dimension to 3.75 (the desired length), and the length of the line was updated to the new length.

"STEP BY STEP" ACTIVITIES

Complicated processes are shown as step-by-step activities with each illustration right next to the text that explains it.



6.24 BECOMING A 3D VISUALIZER 259

STEP by STEP

USING A MITER LINE

Given two completed views you can use a miter line to transfer the depths and draw the side view of the object shown at right.

1 Locate the miter line a convenient distance away from the object to produce the desired spacing between views.

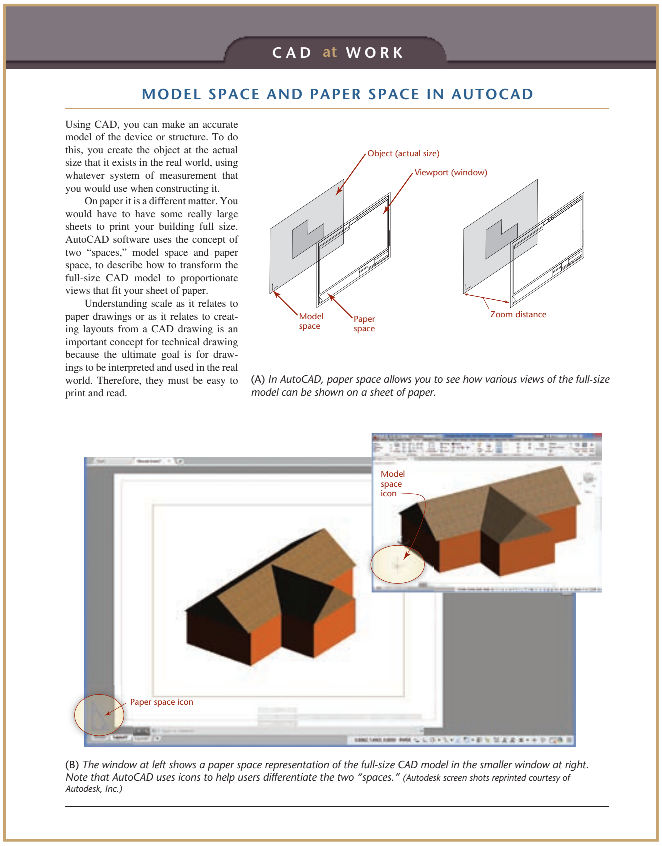
3 Project the remaining points.

4 Draw the view by locating each vertex of the surface on the projection line and across the miter line.

To move the right-side view to the right or left, move the top view upward or downward by moving the miter line closer to or farther from the view. You don't need to draw continuous lines between the top and side views via the miter line. Instead, make short dashes across the miter line and project from these. The 45° miter-line method is also convenient for transferring a large number of points, as when [illegible] a curve.

"CAD AT WORK"

CAD at Work sections break out examples related to using the 2D or 3D CAD model to generate drawings.



CAD at WORK

MODEL SPACE AND PAPER SPACE IN AUTOCAD

Using CAD, you can make an accurate model of the device or structure. To do this, you create the object at the actual size that it exists in the real world, using whatever system of measurement that you would use when constructing it.

On paper it is a different matter. You would have to have some really large sheets to print your building full size. AutoCAD software uses the concept of two "spaces," model space and paper space, to describe how to transform the full-size CAD model to proportionate views that fit your sheet of paper.

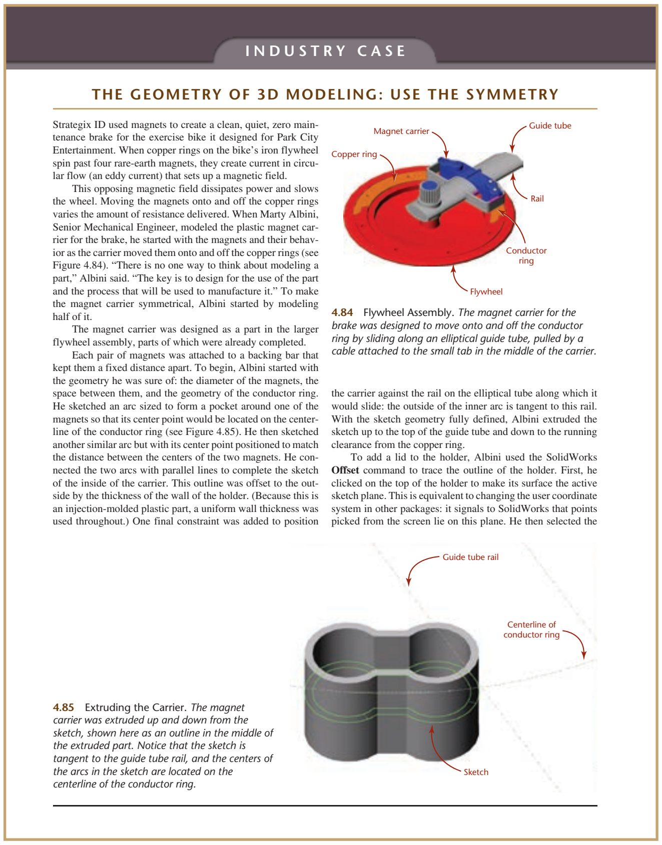
Understanding scale as it relates to paper drawings or as it relates to creating layouts from a CAD drawing is an important concept for technical drawing because the ultimate goal is for drawings to be interpreted and used in the real world. Therefore, they must be easy to print and read.

(A) *In AutoCAD, paper space allows you to see how various views of the full-size model can be shown on a sheet of paper.*

(B) *The window at left shows a paper space representation of the full-size CAD model in the smaller window at right. Note that AutoCAD uses icons to help users differentiate the two "spaces."* *(Autodesk screen shots reprinted courtesy of Autodesk, Inc.)*

"INDUSTRY CASE"

Several industry practitioners share their approaches to modeling and documenting design.



INDUSTRY CASE

THE GEOMETRY OF 3D MODELING: USE THE SYMMETRY

Strategix ID used magnets to create a clean, quiet, zero maintenance brake for the exercise bike it designed for Park City Entertainment. When copper rings on the bike's iron flywheel spin past four rare-earth magnets, they create current in circular flow (an eddy current) that sets up a magnetic field.

This opposing magnetic field dissipates power and slows the wheel. Moving the magnets onto and off the copper rings varies the amount of resistance delivered. When Marty Albini, Senior Mechanical Engineer, modeled the plastic magnet carrier for the brake, he started with the magnets and their behavior as the carrier moved them onto and off the copper rings (see Figure 4.84). "There is no one way to think about modeling a part," Albini said. "The key is to design for the use of the part and the process that will be used to manufacture it." To make the magnet carrier symmetrical, Albini started by modeling half of it.

The magnet carrier was designed as a part in the larger flywheel assembly, parts of which were already completed.

Each pair of magnets was attached to a backing bar that kept them a fixed distance apart. To begin, Albini started with the geometry he was sure of: the diameter of the magnets, the space between them, and the geometry of the conductor ring. He sketched an arc sized to form a pocket around one of the magnets so that its center point would be located on the centerline of the conductor ring (see Figure 4.85). He then sketched another similar arc but with its center point positioned to match the distance between the centers of the two magnets. He connected the two arcs with parallel lines to complete the sketch of the inside of the carrier. This outline was offset to the outside by the thickness of the wall of the holder. (Because this is an injection-molded plastic part, a uniform wall thickness was used throughout.) One final constraint was added to position the carrier against the rail on the elliptical tube along which it would slide: the outside of the inner arc is tangent to this rail. With the sketch geometry fully defined, Albini extruded the sketch up to the top of the guide tube and down to the running clearance from the copper ring.

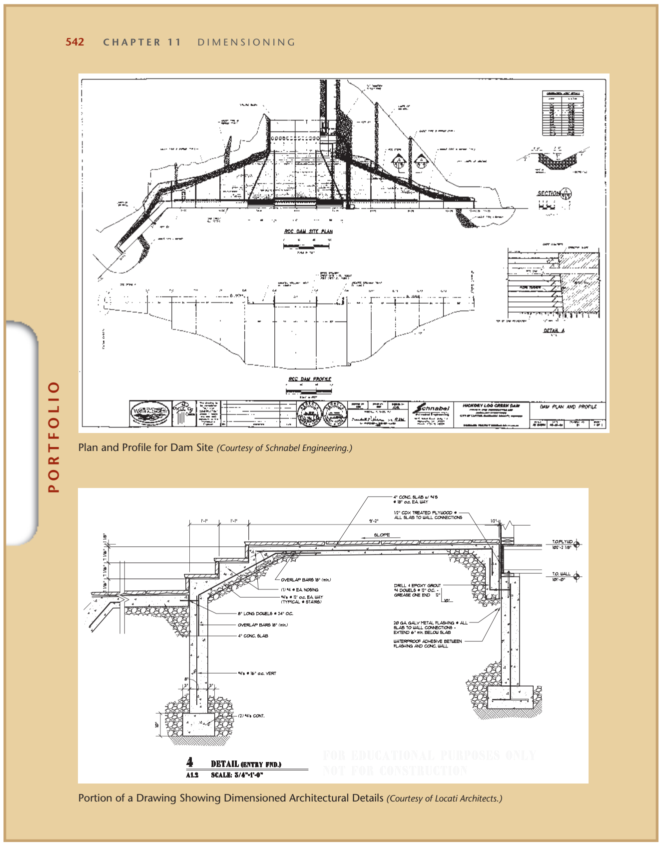
To add a lid to the holder, Albini used the SolidWorks **Offset** command to trace the outline of the holder. First, he clicked on the top of the holder to make its surface the active sketch plane. This is equivalent to changing the user coordinate system in other packages: it signals to SolidWorks that points picked from the screen lie on this plane. He then selected the

4.84 Flywheel Assembly. *The magnet carrier for the brake was designed to move onto and off the conductor ring by sliding along an elliptical guide tube, pulled by a cable attached to the small tab in the middle of the carrier.*

4.85 Extruding the Carrier. *The magnet carrier was extruded up and down from the sketch, shown here as an outline in the middle of the extruded part. Notice that the sketch is tangent to the guide tube rail, and the centers of the arcs in the sketch are located on the centerline of the conductor ring.*

"PORTFOLIO"

These pages offer examples of finished drawings showing real-world application of topics presented.



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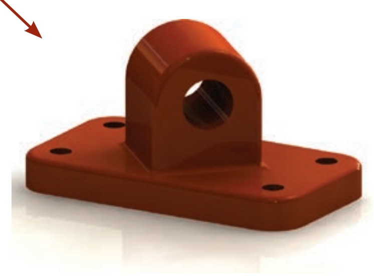
PORTFOLIO

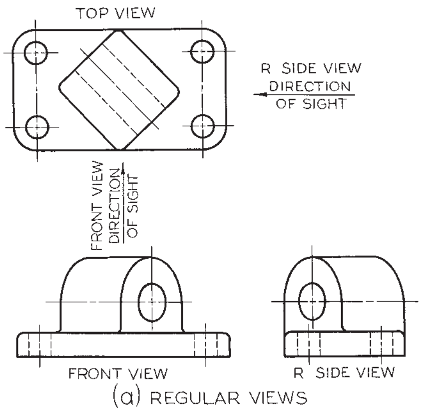
Plan and Profile for Dam Site *(Courtesy of Schnabel Engineering.)*

Portion of a Drawing Showing Dimensioned Architectural Details *(Courtesy of Locati Architects.)*

SOLID MODEL VISUALIZATION ART

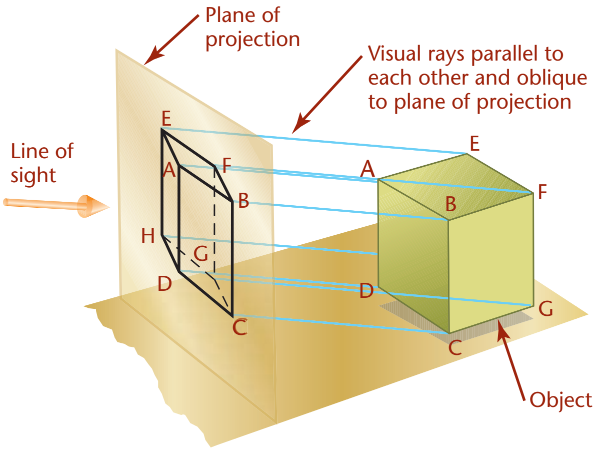
Solid models bring views to life on the page to help you visualize the drawing.





ILLUSTRATIONS

Colored callouts differentiate explanatory text from annotations in technical drawings. Consistent use of color helps differentiate the meaning of projection lines, fold lines, and other drawing elements. A color key is provided for easy reference.


Plane of projection

Visual rays parallel to each other and oblique to plane of projection

Line of sight

Object

Color Key for Instructional Art

Item	In instructional art	In a technical drawing
Callout arrow	→	*
Dimension line	↔	↔ a thin (0.3mm) black line
Projection line	—	— a lightly sketched line
Folding line	— – – — – – —	— – – — used in descriptive geometry
Picture plane on edge	—	*
Plane of projection	▨	*
Cutting plane on edge	— – – — – – —	↑_ _ _↑ (see Chapter 6)
Cutting plane	▨	*
Reference plane on edge	—	— – – — used in descriptive geometry
Reference plane	🟩	*
Viewing direction arrow	→	↑_ _ _↑
Horizon + ground line	—	—
Rotation arrow	↶	30° ↶

* Not a typical feature of technical drawings. (Shown in this book for instructional purposes.)

CHAPTER REVIEW

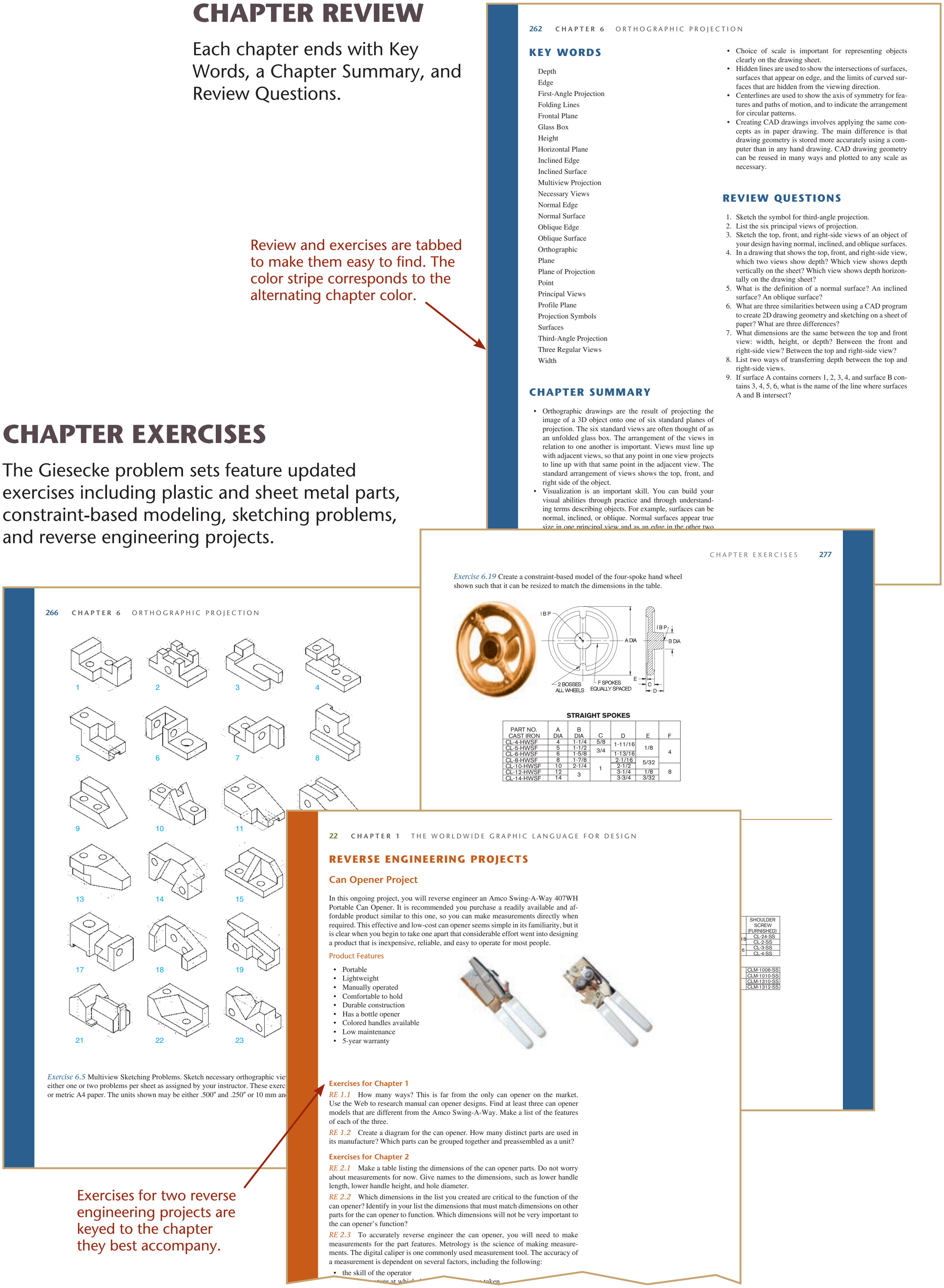
Each chapter ends with Key Words, a Chapter Summary, and Review Questions.

Review and exercises are tabbed to make them easy to find. The color stripe corresponds to the alternating chapter color.

CHAPTER EXERCISES

The Giesecke problem sets feature updated exercises including plastic and sheet metal parts, constraint-based modeling, sketching problems, and reverse engineering projects.

Exercises for two reverse engineering projects are keyed to the chapter they best accompany.



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KEY WORDS

- Depth
- Edge
- First-Angle Projection
- Folding Lines
- Frontal Plane
- Glass Box
- Height
- Horizontal Plane
- Inclined Edge
- Inclined Surface
- Multiview Projection
- Necessary Views
- Normal Edge
- Normal Surface
- Oblique Edge
- Oblique Surface
- Orthographic
- Plane
- Plane of Projection
- Point
- Principal Views
- Profile Plane
- Projection Symbols
- Surfaces
- Third-Angle Projection
- Three Regular Views
- Width

CHAPTER SUMMARY

- Orthographic drawings are the result of projecting the image of a 3D object onto one of six standard planes of projection. The six standard views are often thought of as an unfolded glass box. The arrangement of the views in relation to one another is important. Views must line up with adjacent views, so that any point in one view projects to line up with that same point in the adjacent view. The standard arrangement of views shows the top, front, and right side of the object.
- Visualization is an important skill. You can build your visual abilities through practice and through understanding terms describing objects. For example, surfaces can be normal, inclined, or oblique. Normal surfaces appear true size in one principal view and as an edge in the other two
- Choice of scale is important for representing objects clearly on the drawing sheet.
- Hidden lines are used to show the intersections of surfaces, surfaces that appear on edge, and the limits of curved surfaces that are hidden from the viewing direction.
- Centerlines are used to show the axis of symmetry for features and paths of motion, and to indicate the arrangement for circular patterns.
- Creating CAD drawings involves applying the same concepts as in paper drawing. The main difference is that drawing geometry is stored more accurately using a computer than in any hand drawing. CAD drawing geometry can be reused in many ways and plotted to any scale as necessary.

REVIEW QUESTIONS

1. Sketch the symbol for third-angle projection.
2. List the six principal views of projection.
3. Sketch the top, front, and right-side views of an object of your design having normal, inclined, and oblique surfaces.
4. In a drawing that shows the top, front, and right-side view, which two views show depth? Which view shows depth vertically on the sheet? Which view shows depth horizontally on the drawing sheet?
5. What is the definition of a normal surface? An inclined surface? An oblique surface?
6. What are three similarities between using a CAD program to create 2D drawing geometry and sketching on a sheet of paper? What are three differences?
7. What dimensions are the same between the top and front view: width, height, or depth? Between the front and right-side view? Between the top and right-side view?
8. List two ways of transferring depth between the top and right-side views.
9. If surface A contains corners 1, 2, 3, 4, and surface B contains 3, 4, 5, 6, what is the name of the line where surfaces A and B intersect?

CHAPTER EXERCISES 277

Exercise 6.19 Create a constraint-based model of the four-spoke hand wheel shown such that it can be resized to match the dimensions in the table.

STRAIGHT SPOKES

PART NO. CAST IRON	A DIA	B DIA	C	D	E	F
CL-4-HWSF	4	1-1/4	5/8	1-11/16	1/8	4
CL-5-HWSF	5	1-1/2	3/4			
CL-6-HWSF	6	1-5/8		1-13/16		
CL-8-HWSF	8	1-7/8	1	2-1/16	5/32	
CL-10-HWSF	10	2-1/4		2-1/2		8
CL-12-HWSF	12	3		3-1/4	1/8	
CL-14-HWSF	14			3-3/4	3/32	

SHOULDER SCREW (FURNISHED)
CL-24-SS
CL-2-SS
CL-3-SS
CL-4-SS

CLM-1006-SS
CLM-1010-SS
CLM-1310-SS
CLM-1312-SS

266 CHAPTER 6 ORTHOGRAPHIC PROJECTION

Exercise 6.5 Multiview Sketching Problems. Sketch necessary orthographic vie
either one or two problems per sheet as assigned by your instructor. These exerc
or metric A4 paper. The units shown may be either .500″ or .250″ or 10 mm an

22 CHAPTER 1 THE WORLDWIDE GRAPHIC LANGUAGE FOR DESIGN

REVERSE ENGINEERING PROJECTS

Can Opener Project

In this ongoing project, you will reverse engineer an Amco Swing-A-Way 407WH Portable Can Opener. It is recommended you purchase a readily available and affordable product similar to this one, so you can make measurements directly when required. This effective and low-cost can opener seems simple in its familiarity, but it is clear when you begin to take one apart that considerable effort went into designing a product that is inexpensive, reliable, and easy to operate for most people.

Product Features

- Portable
- Lightweight
- Manually operated
- Comfortable to hold
- Durable construction
- Has a bottle opener
- Colored handles available
- Low maintenance
- 5-year warranty

Exercises for Chapter 1

RE 1.1 How many ways? This is far from the only can opener on the market. Use the Web to research manual can opener designs. Find at least three can opener models that are different from the Amco Swing-A-Way. Make a list of the features of each of the three.

RE 1.2 Create a diagram for the can opener. How many distinct parts are used in its manufacture? Which parts can be grouped together and preassembled as a unit?

Exercises for Chapter 2

RE 2.1 Make a table listing the dimensions of the can opener parts. Do not worry about nomenclature for now. Give names to the dimensions, such as lower handle length, lower handle height, and hole diameter.

RE 2.2 Which dimensions in the list you created are critical to the function of the can opener? Identify in your list the dimensions that must match dimensions on other parts for the can opener to function. Which dimensions will not be very important to the can opener's function?

RE 2.3 To accurately reverse engineer the can opener, you will need to make measurements for the part features. Metrology is the science of making measurements. The digital caliper is one commonly used measurement tool. The accuracy of a measurement is dependent on several factors, including the following:

- the skill of the operator

PREFACE

For many decades, *Technical Drawing with Engineering Graphics* has been recognized as an authority on the theories and techniques of graphics communication. Generations of instructors and students have used and retained this book as a professional reference. The long-standing success of *Technical Drawing with Engineering Graphics* can be attributed to its clear and engaging explanation of principles, and to its drawings, which are unsurpassed in detail and accuracy.

Although not a departure from its original authoritative nature and hallmark features, the book is thoroughly revised and updated to the latest technologies and practices in the field. With the addition of topics related to the role of the 3D CAD database in design and documentation, this fifteenth edition of *Technical Drawing with Engineering Graphics* will prepare students to enter the marketplace of the twenty-first century and continue to serve as a lasting reference.

Shawna Lockhart, author of the fourteenth edition, first used Giesecke's *Technical Drawing* when teaching engineering graphics at Montana State University. Throughout her 15 years as an award-winning professor, she selected this text because, in her words, "It was the most thorough and well-presented text with the best graphic references and exercises on the market."

The quality of the illustrations and drawing examples was established by the original author, Frederick E. Giesecke, who created the majority of the illustrations in the first edition of *Technical Drawing*, published in 1933.

Giesecke, founder of the first formal architectural education program in Texas at what is today Texas A&M University, has been described as "a wunderkind of the first magnitude." He joined the A&M faculty at the age of 17, after graduating in 1886 with a B.S. in Mechanical Engineering, and by the age of 19, was appointed head of A&M's Department of Mechanical Drawing.

Having studied architectural drawing and design at Cornell University and the Massachusetts Institute of Technology, Giesecke also served as head of the Department of Architecture and the official college architect at Texas A&M, designing many campus buildings that are still standing today.

A long-time admirer of Giesecke's legacy, Lockhart was honored to carry on the commitment to clear, engaging, thorough, and well-organized presentation that began with the original author.

Lockhart is known as an early adopter and authority on CAD technologies. She is an instructor noted for outstanding dedication to students and for encouraging a broad spectrum of individuals, particularly women and minorities, to follow careers in engineering-related fields. Lockhart now works fulltime to ensure that the Giesecke graphics series continually applies to an evolving variety of technical disciplines.

THE FIFTEENTH EDITION

The fifteenth edition of *Technical Drawing with Engineering Graphics* continues its long history as an introduction to technical drawing and an easy-to-use reference for techniques and practices. Reviewers advised us on how to make *Technical Drawing with Engineering Graphics* a superb guide and resource for today's students. New content includes:

- Expanded coverage of 3D design and modeling techniques
- Updated introduction that illustrates the design documentation process with an industry case study
- Additional sketching content, including sketching assemblies and case study on sketching for ideation
- New coverage of geometry useful for 3D modeling
- All new chapter on modeling tools and techniques
- More examples of plastic and sheet metal parts
- Updated coverage of modeling for manufacture with all new sections on using the model for simulation and analysis
- Web chapters available for axonometric projection and perspective drawing

ONLINE RESOURCES

An Instructor's Manual (9780134308241) and Lecture Slides in PowerPoint format (9780134308258) are available on the companion site for this book at www.pearsonhighered.com/program/Giesecke-Technical-Drawing-with-Engineering-Graphics-15th-Edition/PGM281463.html.

Web chapters on axonometric projection and perspective drawing may be downloaded from peachpit.com. To access and download the bonus chapters:

1. Visit peachpit.com/register.
2. Log in with your Peachpit account, or if you don't have one, create an account.
3. Register using this book's ISBN, 9780134306414, then click the Access Bonus Content link next to this book on your account's Registered Products page.

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FIFTEENTH EDITION

TECHNICAL DRAWING WITH ENGINEERING GRAPHICS

CHAPTER ONE

THE WORLDWIDE GRAPHIC LANGUAGE FOR DESIGN

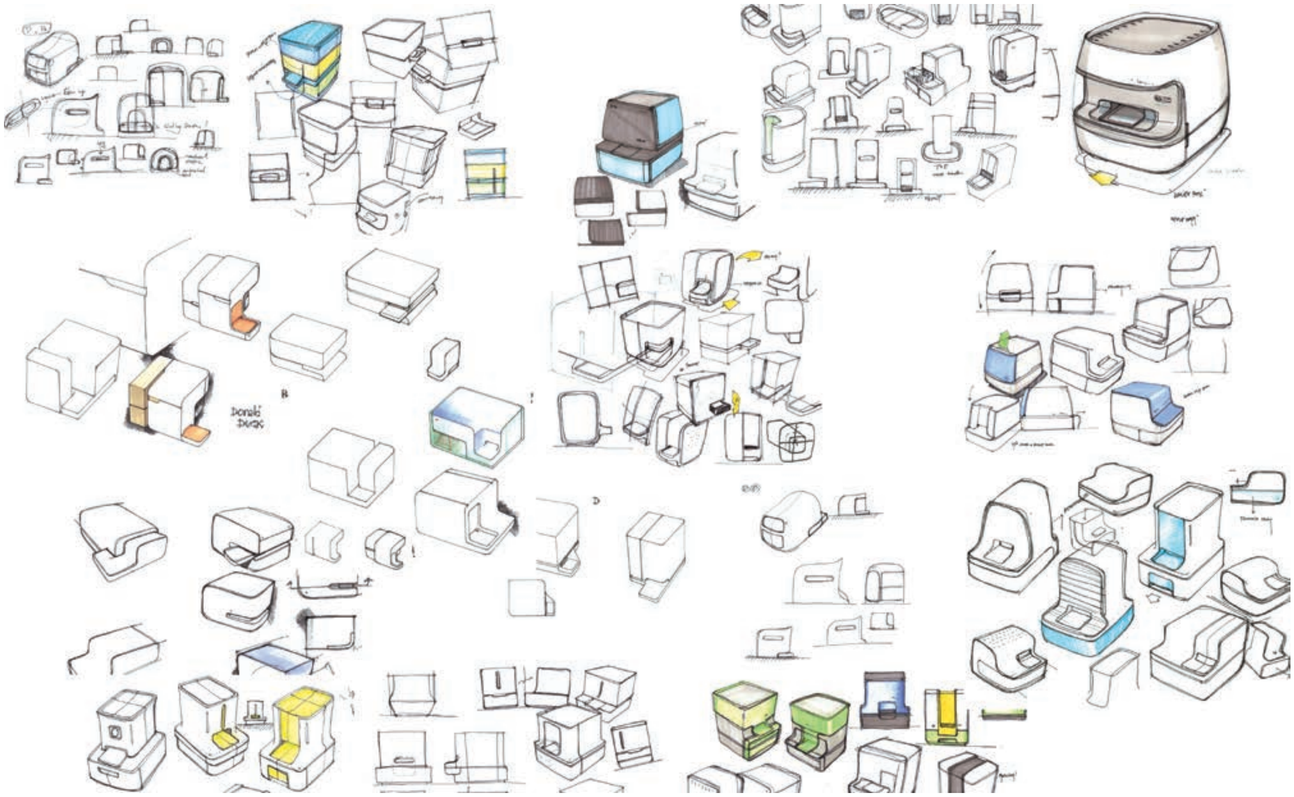
OBJECTIVES

After studying the material in this chapter, you should be able to:

1. Describe the role of graphics in the design process.
2. Identify stages in the design process.
3. Contrast concurrent versus traditional design processes.
4. List five professions that use technical drawings.
5. Describe four creativity techniques.
6. Explain why standards are important.
7. Identify three purposes for technical drawings.

Refer to the following standard:

- *ANSI/ASME Y14.100 Engineering Drawing Practices*



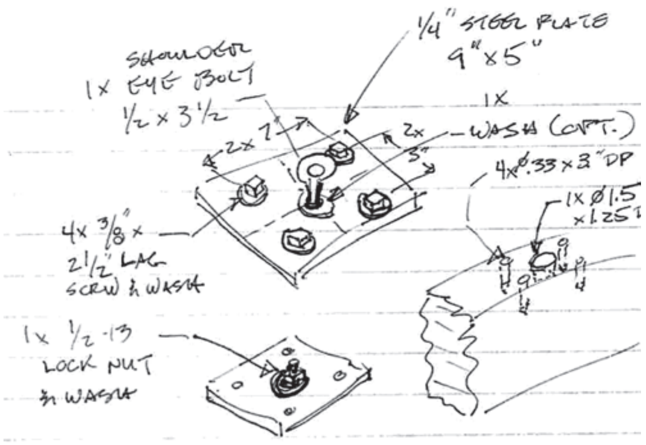
Conceptual Sketches. *Exploring many design options through quick sketches is one method that Lunar, recently named one of the top 10 award-winning American product design firms by* BusinessWeek *magazine, uses to create beautiful products and successful brands. (Images courtesy of LUNAR.)*

OVERVIEW

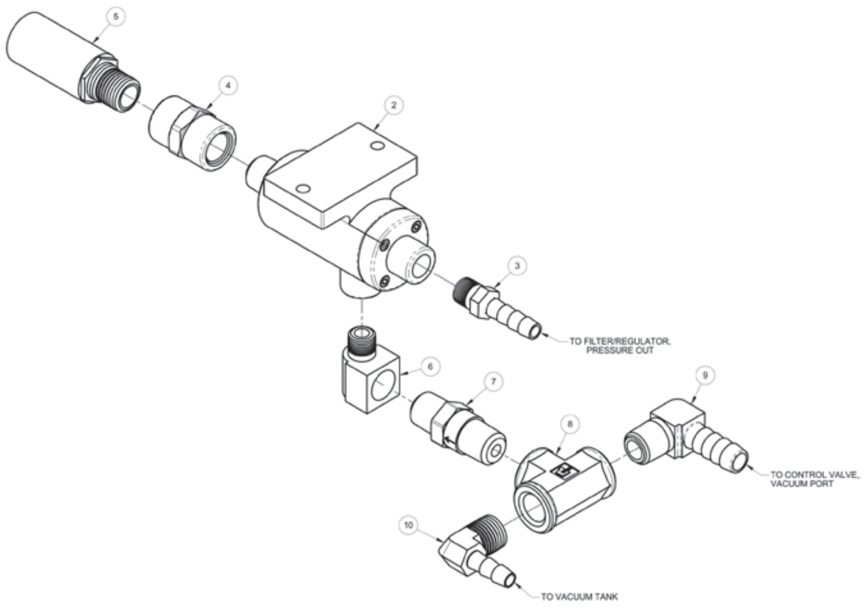
Regardless of the language they speak, people all over the world use technical drawings to communicate their ideas. Graphic representation is a basic, natural form of communication that isn't tied to a particular time or place. It is, in a sense, a universal language.

Accomplishing ideas, from the simplest to the most elaborate, requires teamwork. A new product, machine, structure, or system may exist in the mind of the engineer or designer, but before it can become a reality, the idea must be communicated to many different people. The ability to communicate design concepts quickly and accurately through technical drawings is key to meeting project budgets and time constraints. Effective graphic communication is also an advantage in the global marketplace, where team members may not always share a common language.

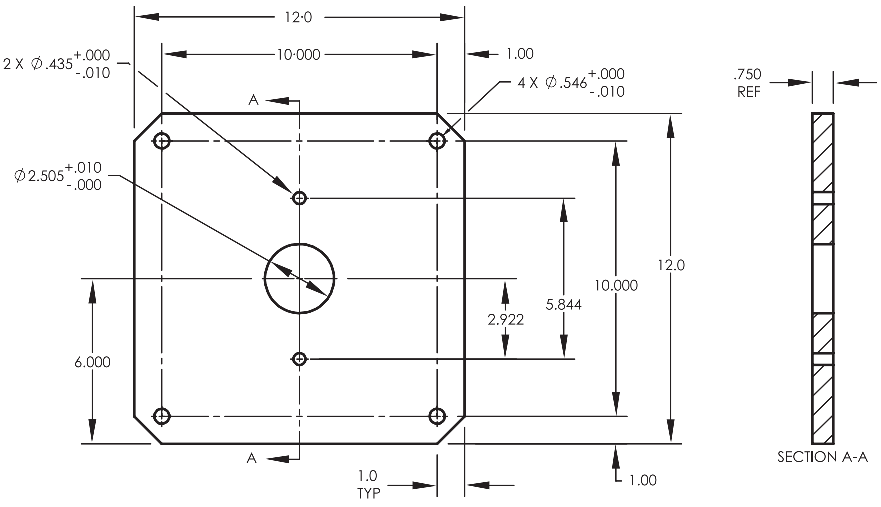
Like carpenters who learn to use the tools of their trade, engineers, architects, drafters, designers, manufacturers, and technicians learn the tools of technical drawing. They learn specific methods to represent ideas, designs, and specifications in a consistent way that others can understand. Being an effective graphic communicator ensures that the product, system, or structure that you envision is produced as you specified.



1.1 Computation Sketch Detail *(Courtesy of Jeffrey J. Zerr.)*



1.2 Excerpt from an Assembly Drawing *(Courtesy of Woods Power-Grip Co., Inc.)*



1.3 A Part Drawing *(Courtesy of Dynojet Research, Inc.)*

UNDERSTANDING THE ROLE OF TECHNICAL DRAWINGS

Drawings and specifications control the many details of product manufacture, assembly, and maintenance. Both ease in freehand sketching and the ability to use computers to produce CAD models and technical drawings are valued skills in the global marketplace. Conveying information graphically requires knowledge of the standards that allow drawings to concisely communicate designs around the world.

Technical drawings can take many forms: idea or concept sketches (such as the sketches on the previous page), computation sketches, design sketches, layout drawings, part drawings, working or construction drawings, electrical drawings, installation drawings, and assembly drawings are all examples. Sketches, 2D CAD drawings, and 3D CAD models are all forms of technical drawing. Some of these types of technical drawings are shown in Figures 1.1 through 1.3. Each of these types of drawings and others have a place in the process of designing and building a product, system, or structure. In general, technical drawings serve one of three purposes:

- ***Visualization***
- ***Communication***
- ***Documentation***

A wide variety of professions use technical drawings to communicate and document designs. Some examples are civil engineering, mechanical engineering, electrical engineering, architecture, bio-resource engineering, landscape design, landscape architecture, industrial design, construction engineering, construction technology, pattern making, project management, fabrication, and manufacturing. There are many others.

Whether you are designing a bridge, installing underground power lines in a subdivision, or designing a plastic housing for a new toaster, understanding and using technical drawing is a key skill you will need.

1.4 *These drills all perform similar functions, but a consumer's choice of one over another may depend on the product's styling and aesthetics as well as function.* *(©Shutterstock/Vereshchagin Dmitry.)*

1.5 *A project engineer in a hard hat examines a blueprint.* *(Courtesy of Dennis MacDonald/Photo Edit, Inc.)*

The Design Process

The organized and orderly approach to solving problems is known as the ***design process.*** The engineering design process addresses society's needs, desires, and problems by applying scientific principles, experience, and creativity.

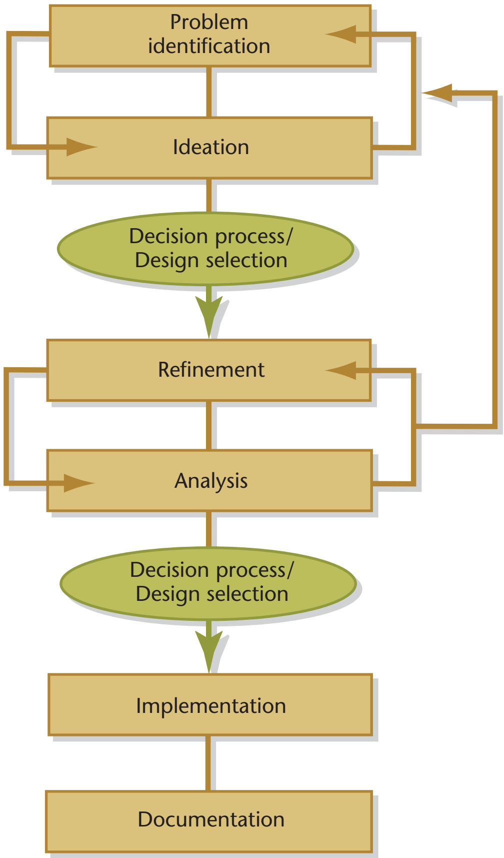
Different types of technical drawings have a specific function in the engineering design process. For example, freehand sketches capture and document the ideation process. Later in the process, CAD models and drawings capture the design and specify the details necessary for manufacture.

The design process for any product requires a clear understanding of the functions and the performance expected of that product. The steel beam construction shown in Figure 1.5 is very different from the styling and functional requirements of the products shown in Figure 1.4, but the stages in the design process are similar for both.

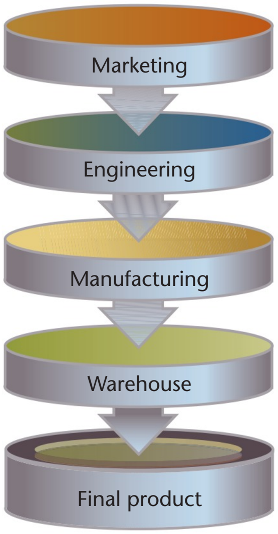
It has been estimated that 70% to 80% of the cost of product development and manufacture is determined during the initial design stages. Although many industrial groups may identify them in their own way, one procedure for designing a new or improved product follows the stages shown in Figure 1.6:

1. ***Problem identification***: First, a clear statement of the need for and objectives for the design must be written.
2. ***Ideation***: Technical sketches are often used to convey concepts to multidisciplinary teams.
3. ***Refinement/analysis***: Designs may be rethought, based on engineering analysis. CAD models and sketches are useful during the analysis and compromise stage. Accurate 2D or 3D CAD models and drawings are created to refine the design.
4. ***Implementation/documentation***: Production and/or working drawings providing the details of manufacture and assembly are finalized and approved.

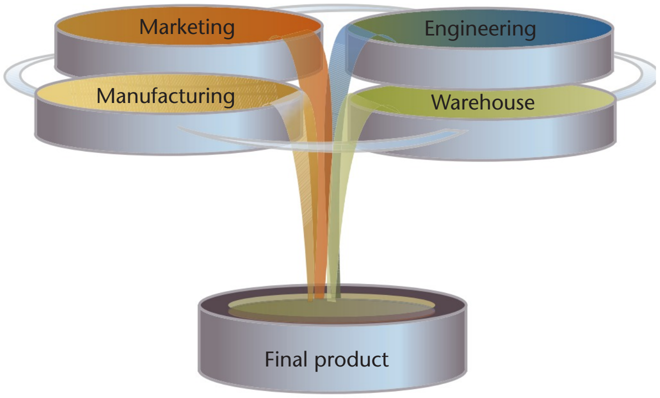
Ideally, the design moves through these stages, but as new information becomes available, it may be necessary to return to



1.6 The Stages of the Design Process

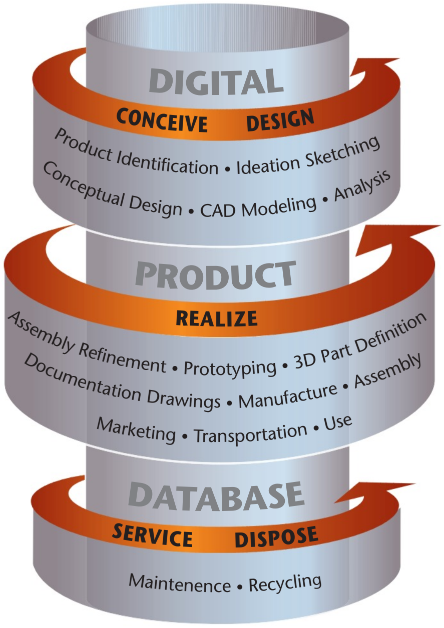


(a) Sequential Process



(b) Concurrent Process

1.7 A Model of the Concurrent Design Process



1.8 The Life Cycle of a Product

a previous stage and repeat the process. For example, based on engineering analysis, the familiar phrase "back to the drawing board" might come into play at the refinement/analysis stage.

Concurrent Engineering

Traditionally, design and manufacturing activities have taken place in sequential order rather than concurrently (simultaneously). Designers would spend considerable effort and time analyzing components and preparing detailed part drawings, and then forward them to other departments. For example, the materials department would use the drawing to identify the particular alloys and source vendors to use. The manufacturing department would then identify the processes needed for efficient production. This step-by-step approach seems logical, but in practice it has been found to be wasteful.

For example, if a manufacturing engineer wanted to taper the flange on a part to make it easier to cast in metal, or to choose a different alloy, the design analysis stage would have to be repeated to ensure that the product would still function effectively. These iterations, illustrated in Figure 1.7a, may be necessary, but they waste resources, and more importantly, time. Time is important because early product introduction makes possible a greater market percentage (and hence greater profits) and a longer life before the product becomes obsolete (clearly a concern with products such as consumer electronics).

Concurrent engineering is a systematic approach that integrates the design and manufacture of products with the goal of optimizing all elements involved in the life cycle of the product. Figure 1.7b illustrates the concurrent design process.

Life cycle design means that all aspects of a product (such as design, development, production, distribution, use, and its ultimate disposal and recycling) are considered simultaneously. Figure 1.8 depicts the life cycle of a product from conception to disposal.

The basic goals of concurrent engineering are to minimize product design and engineering changes and to reduce the time and cost involved in taking a product from concept through production and ultimately to the marketplace. In concurrent engineering, all disciplines are involved in the early design stages, so that natural iterations result in less wasted effort and lost time.

Communication between and within disciplines is especially important in a concurrent design process. Effective interaction among engineering, marketing, and service functions, as well as among engineering subdisciplines, is recognized as crucial to this type of process. Cross-disciplinary communication also helps provide a fertile environment for innovative approaches that can lead to savings in material and production costs.

Computer-Aided Design and Product Development

For both large and small companies, product design often involves preparing analytical and physical models of the product that can be used to study factors such as forces, stresses, deflections, and optimal part shape. The necessity for these types of models depends on how complex the product is. Today, the process of constructing and studying analytical models is simplified by using ***computer-aided design*** (CAD), ***computer-aided engineering*** (CAE), and ***computer-aided manufacturing*** (CAM) techniques. These systems allow rapid design analysis for simple objects as well as complex structures.

CAD allows for a range of activities, from modeling 2D and 3D geometry to creating drawings that document the design for manufacturing and legal considerations.

CAM provides computerized control for manufacturing processes. Examples include using a computer interface to control a lathe, or generating the path for milling machine tools directly from the CAD model. In more sophisticated systems, CAM can be used in materials handling, assembly, and inspection.

CAE allows users to simulate and analyze structures that will be subject to various temperatures, static loads, or fluctuating loads. Kinematic analysis studies moving parts. Some of these functions are integrated with CAD software, and other packages import data from a CAD system. Using these tools, engineers can simulate, analyze, and test designs efficiently, accurately, and quickly.

Designing Quality into Products

Companies use a number of systematic ways to try to design "quality" into their products as well as to measure performance and make decisions based on data. Designers may feel that their creative approach to problem solving is stifled when these systems are poorly implemented in the workplace; but when these systems are well implemented, organizations can show quality improvement.

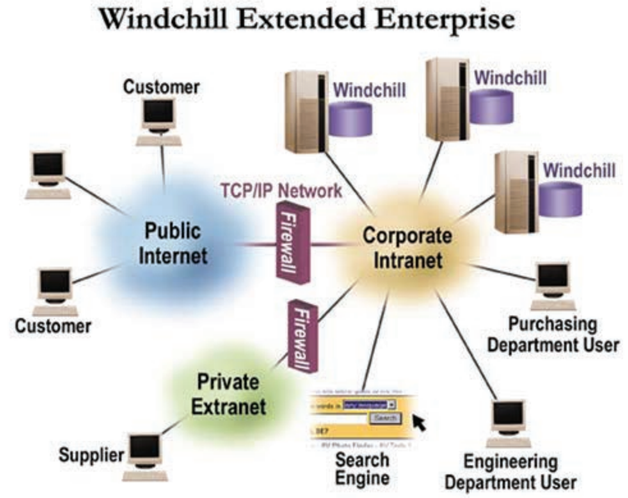
DFSS ***Design for Six Sigma*** is an approach that uses engineering and statistical tools to design products in a way that predicts and minimizes customer and manufacturing problems.

Six Sigma is a process originated at Motorola to improve quality by reducing or eliminating defects.

DMAIC ***Define, Measure, Analyze, Improve, and Control*** are steps defined in a continuous improvement process that attempts to define and ensure critical to function (CTF) characteristics.

QFD ***Quality Function Deployment*** is a tool for decision making that helps companies focus on a customer-driven approach and set of product characteristics.

A Structural Designer Working with CAD. (Courtesy of Kryczka/iStockphoto.com.)



1.9 Product Data Management. *PTC's Windchill is an enterprise-wide product data management system designed to be extended to serve data over the internal network (or intranet). Data from the database are provided to external users via a secure, password-protected site (to share nonpublic information with suppliers and other partners in remote locations).* (Courtesy of Parametric Technology Corporation.)

The Digital Database

Computer use continues to change the way products are produced. All the information to manage, design, analyze, simulate, package, market, and manufacture a product can be shared with a diverse (and perhaps geographically distant) group of users through a single complex digital database.

Product data management (PDM) systems or ***enterprise data management*** (EDM) systems electronically store the various types of data associated with designing and manufacturing a product. An effective PDM system allows all the product data to be quickly stored, retrieved, displayed, printed, managed, and transferred to anywhere in the organization. This allows for designs to be optimized or directly modified at any time. Costs, product revisions, and ***engineering change orders*** (ECOs) can be analyzed, tracked, and implemented quickly. Managing enterprise data requires commitment and planning, but companies who implement PDM effectively can capture product data once and utilize it many ways to achieve a competitive advantage (Figure 1.9).

1.1 GRAPHICS TOOLS IN ACTION

Designers and engineers use graphics for visualization, communication, and documentation throughout the design process. A case study from Santa Cruz Bicycles will illustrate the tools used in the redesign of its V10 model, a downhill racing mountain bike, shown in Figure 1.10.

1.10 *The V10 is a generation of downhill racing bikes first sold in 2002 and continually improved based on race team results and rider feedback. The 3D model of the new design is shown here.* (Courtesy of Santa Cruz Bicycles.)

Design Phase: Problem Identification

The impetus for the V10, as for most racing bikes, was higher performance. In 2000, Santa Cruz Bicycles (SCB) purchased three patents for suspension systems that had never been developed. Most bikes have suspension on the front wheel; these patents showed how rear suspension could be manipulated to improve performance and control.

The bicycle's suspension has two roles: absorbing bumps and translating the pulsing motion coming from the human pedaler into forward movement. The balance between how far the wheel can move up and down and maximal forward motion determines bike performance.

The first V10 was ridden in 2002. Its rear suspension allowed the wheel to travel vertically 10 inches. At that time, 8–8.5 inches of travel was common among competitors.

When SCB set out to update the V10 design, better performance was a key criterion. The design team included the product manager (who interfaced with marketing), two design engineers, and racers who rode the V10. The team members had plenty of information for defining the problem: they were familiar with the design drawings, performance specifications, and manufacturing costs of the V10 already being produced. Racing teams provided feedback about how the current design handled and where they envisioned improvement. Racers and engineers viewed race videos to see how the bike performed on courses with more or less rugged terrain. Marketing provided information about competitors' bikes and how the V10 measured up against them.

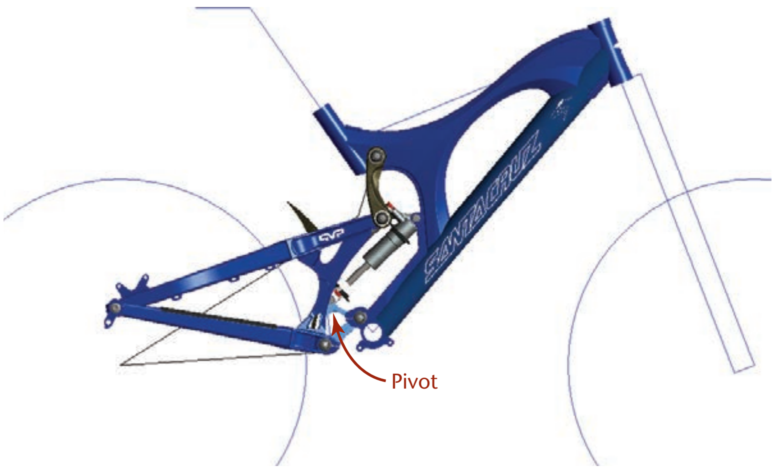
At the problem identification stage, the team worked to enlarge the criteria for judging the solution. The team identified three primary goals for the redesign:

- Get maximum forward movement from a suspension that also absorbs bumps.
- Improve the handling to give the rider better control.
- Minimize the weight to make a lighter bike.

SPOTLIGHT

Santa Cruz Bicycles

The team at Santa Cruz Bicycles believes that to build a good bike, you have to first really love riding bikes. They all ride daily—from the owner to the engineers to the salespeople. This creates a very strong relationship between the design team and their customers—each model is constantly being refined and improved based on feedback from riders who want to—and do—win races with a Santa Cruz bike. Their engineers are proficient 3D modelers who use the many features of Pro/ENGINEER to visualize, analyze, and test designs before they are built. More important, the 3D model supports the continual improvement that is built into the Santa Cruz culture. They can quickly modify parts, see how the new part affects the movement of the bike, assess the stresses on the new part, and send it to be prototyped for the ultimate test: riding on unpredictable terrain.



1.11 *The V10's rear wheel attaches to a triangular swingarm that connects to the front part of the frame with a pivot. This allows the rear wheel to travel up and down.* *(Courtesy of Santa Cruz Bicycles.)*

Design Phase: Ideation

The design team focused first on the geometry of how the parts of the bike are arranged. Unlike the frame of a conventional bicycle, the V10's frame is in two parts. The back wheel connects to a triangular "swingarm" that attaches to the front frame with a pivot (see Figure 1.11). The length of the parts, the angles between them, and their movement determine how the bike handles. In the ideation phase, the team captured and evaluated different combinations of handlebar placements, seat, crank, pivots to the wheels and shock absorbers, and more. How much the shock absorbers allow the wheel to travel vertically, the pivot locations, and link sizes all affect how the bike will perform.

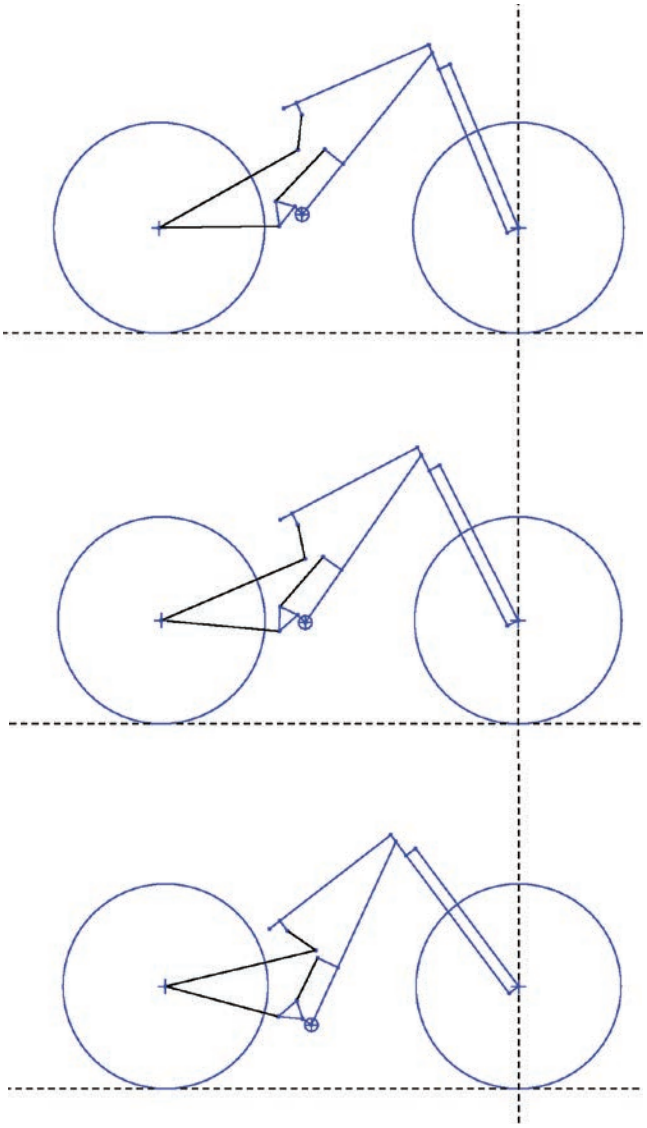
At the ideation stage, being able to draw a readable freehand sketch is vital to "selling" your idea to your design team colleagues. This stage is called ***universal possibilities*** because the group seeks to consider every possible solution and not limit the design by preconceived notions of what will be best.

For each subsystem of the bike, the team generated and evaluated many concepts. For example, they brainstormed all the ways a pivot assembly might be made. They also employed a kind of "contest" to spur creativity and generate options. One engineer would be given 1.5 days to come up with a combination of parts and materials to make a subsystem, such as a link mechanism. Then, the design tasks would be shuffled and a different engineer would have 1.5 days to define an alternative approach to the link mechanism. Using a whiteboard, the team would then list the pros and cons of each subsystem design.

Design Phase: Decision Process/Design Selection

The design selection process varies by company and by the design challenge. It may be informal and conducted by a single individual, or it may be a highly formal process in which different teams compete for development dollars for new products. In all cases, design selection narrows the field of options for the final design.

SCB's team needed to evaluate how the parts would *move*. They created 3D skeleton models in CAD. A skeleton model is a simplified representation of the centerlines and other shapes that capture the design geometry. These skeleton models are useful for kinematic analysis (Figure 1.12).



1.12 *Skeleton models were used for kinematic analysis of different combinations of the swingarm geometry. The model shows how much the swingarm can pivot.* *(Courtesy of Santa Cruz Bicycles.)*