TECHNICAL GRAPHICS COMMUNICATION

FOURTH EDITION

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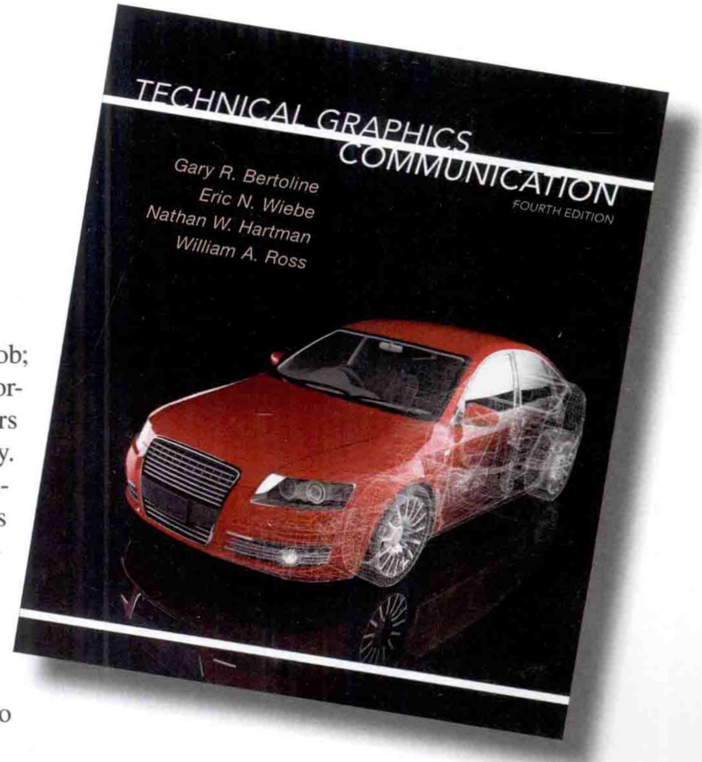
Preface



To the authors of this text, teaching graphics is not a job; it is a "life mission." We feel that teaching is an important profession and that the education of our engineers and technologists is critical to the future of our country. Further, we believe that technical graphics is an essential, fundamental part of an engineer and technologist's education. We also believe that many topics in technical graphics and the visualization process can be very difficult for some students to understand and learn. For these and other reasons, we have developed this text, which addresses both traditional and modern elements of technical graphics, using what we believe to be an interesting and straightforward approach.

Engineering and technical graphics have gone through significant changes as a direct result of the use of computers and CAD software. Although these changes are important to the subject of technical graphics, there is much about the curriculum that has not changed. Engineers and technologists still find it necessary to communicate and interpret designs, using graphics methods such as drawings or computer models. As powerful as today's computers and CAD software have become, they are of little use to engineers and technologists who do not fully understand fundamental graphics principles and 3-D modeling strategies or do not possess high-level visualization skills.

This graphics text is therefore based on the premise that there must be some fundamental changes in the content and process of graphics instruction. Although many graphics concepts remain the same, the fields of engineering and technical graphics are in a transition phase from hand tools to the computer, and the emphasis of instruction is changing from drafter to 3-D geometric modeler, using computers instead of paper and pencil.

Goals of the Text

This text was written to help the engineering and technology student learn the techniques and standard practices of technical graphics so that design ideas can be adequately communicated and produced. The text concentrates on the concepts and skills necessary to use both hand tools and 2-D or 3-D CAD. The primary goals of the text are to show how to

1. Clearly represent mental images.
2. Graphically represent technical designs, using accepted standard practices.
3. Use plane and solid geometric forms to create and communicate design solutions.
4. Analyze graphics models, using descriptive and spatial geometry.
5. Solve technical design problems, using traditional tools or CAD.
6. Communicate graphically, using sketches, traditional tools, and CAD.
7. Apply technical graphics principles to many engineering disciplines.

The authors of this text have gone to great lengths to truly integrate traditional and modern engineering design graphics theory and practice into a single text.

Features of the Fourth Edition

Much thought has gone into designing a complete instructional approach to teaching and learning of technical graphics. The instructor is provided with a number of tools to assist in the instruction aspects, and the student is provided with tools to assist in the learning process.

This text was specifically written using techniques that will prepare students to use technical graphics concepts, practices, and modern tools, to solve design problems and communicate graphically. One goal was to provide to the students a textbook that was clear, interesting, relevant, and contemporary.

Some of the distinguishing features of this text include the following:

1. *New Feature—Supplemental Solid Modeling Exercises*—A series of new problems focusing on 3-D solid modeling for parts and assemblies have been developed and are included in a special section at the ends of Chapter 10 Multiview Drawing, Chapter 13 Auxiliary Views, Chapter 16 Section Views, and Chapter 20 Working and Assembly Drawings. Visual examples for each part and assembly have been created with various solid modeling software packages and are included with engineering sketches to aid students in visualizing part geometry and the modeling process. In addition to supplementing traditional subjects in each of the chapters, these problems also provide a logical extension to the chapter on 3D Modeling by furnishing students a new series of software-independent solid modeling exercises that may be modeled with any of the popular parametric based solid modeling software packages currently in use. In addition to 3-D solid modeling experience, it is also intended that these problems may serve as a basis for students to; 1) explore basic property analysis of solid models, 2) develop variable parametric models based on design intent, 3) generate detail and working assembly documentation drawings, 4) create intelligent spread sheet driven bills of material for managing the product development process and 5) explore methods of relational bottom up and top down assembly modeling.
2. *Design Problems*—The new design problems in Chapter 3 were developed to provide students an opportunity to exercise the various stages of the design process outlined in this chapter. They provide an ideation stage, a decision-making stage, design creation stage, and a documentation stage. Each problem includes provisions for sketching, 3D modeling, and documentation of the student's final solution to the problem. In addition, the problems were deliberately designed in an open-ended fashion to promote creativity in the solution process, and to provide a context in which the student can work to develop a 3D model that addresses the required criteria.
3. *Integration of CAD*—CAD concepts and practices have been integrated through all the chapters when they are relevant to the topic. They are not simply "tacked onto" the end of a chapter.
4. *Visualization chapter* (chapter 5)—This *unique* chapter, devoted exclusively to visualization, assists the student in understanding the concepts and importance of visualization and offers techniques for reading and visualizing engineering drawings.
5. *3-D modeling chapter* (chapter 9)—This *unique* chapter is devoted exclusively to the theory and practice of 3-D modeling with an emphasis in constraint-based CAD.
6. *Modern topics*—The book is filled with modern examples, illustrations, and industry examples so students can relate to the material being presented and get excited about the subject.
7. *Integration of design*—Design concepts are integrated through the text to give relevance and understanding of the relationship of design to technical graphics. This is visually reinforced throughout the text through the use of an icon located in the margin of the text whenever a design concept is covered. The icon is a smaller version of the Concurrent Engineering Design Process figure first introduced in Chapter 2. Figure 2.8 breaks design into three major components: ideation, refinement, and implementation. Whenever one of these topics is discussed in the text, a smaller version of Figure 2.8 is placed in the margin with ideation, refinement, or implementation highlighted. This lets the student know that the topic being covered is relevant to the engineering design process and constantly reinforces design as the underlying theme for engineering and technical graphics.


Ideation


Refinement


Implementation

Coverage of Modern Topics

One of the primary reasons we wrote the text is that many modern topics are either not found or not covered in sufficient detail in traditional texts. Examples of contemporary topics covered in this book include:

Computer simulation
Human factors
Product data management (PDM)
Virtual reality (VR)
NURBS
Data exchange standards
3-D modeling problems
3-D modeling concepts and practices

Extensive Coverage of Traditional Topics

Even though we firmly believe our coverage results in the most modern text available, we have been very careful to include all the traditional topics normally found in a technical drawing textbook. The authors fully understand that students must learn the fundamentals whether using hand tools or CAD to communicate graphically. Therefore, coverage of traditional topics is comprehensive and in many cases includes step-by-step procedures and enhanced color illustrations to facilitate teaching and learning. The text includes the latest ANSI standard practices used in industry.

Chapter Overviews and Features

Every chapter has been carefully planned and written with a consistent writing, illustration, design style, and pedagogy. The book was written as a part of a more global instructional approach to engineering and technical graphics and will serve as a starting point for instructor and student.

To accomplish these goals, the text is divided into 4 parts and 25 chapters. Each part has a brief introduction with a listing of chapters in the part so the instructor and student understand the logical sequencing of topics and chapters. Each chapter has a logical sequence and organization that is easily navigated. Each chapter contains these features:

Relevant Quotes Each chapter opens with a quote that is relevant to the chapter material being covered or the topic of graphics in general. These quotes, many by famous historical figures, reinforce the importance of graphics in industry and society.

Objectives Each chapter has a list of measurable objectives that can be used as a guide when studying the material presented in the text. Instructors can also use the objectives as a guide when writing tests and quizzes.

Introduction A brief overview of the chapter contents prepares the student for the material to be presented. The introduction sets the stage for the relevancy and importance of the material to be covered for the engineer or technologist. The introduction includes a rationale explaining why it is important to learn the material in the chapter.

Color Is Important in a Modern Engineering and Technical Graphics Textbook This was the first technical graphics textbook to use four-color illustrations throughout to better present the material and improve learning. The selection and use of color in the text is consistent to enhance learning and teaching. *Many of the color illustrations are also available to the instructor in the image library found in the Instructor Resources to supplement lectures, as explained in detail later in this Preface.*

The use of color in the text was done specifically to enhance teaching, learning, and visualization. Workplanes are represented as a light pink (Figure 9.30). Projection and picture planes are a light purple color (Figure 10.10).

Important information in a figure is shown in red to highlight the feature and draw the attention of the reader (Figure 8.6). Color shading is often used on pictorial illus-

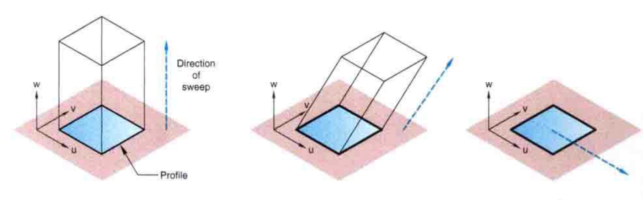


Figure 9.30

Types of linear sweeping operations
In some systems, linear sweeps are restricted to being perpendicular to the workplane.

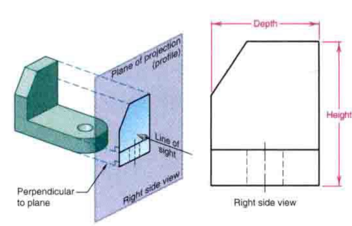


Figure 10.10

Profile view
A right side view of the object is created by projecting onto the profile plane of projection.

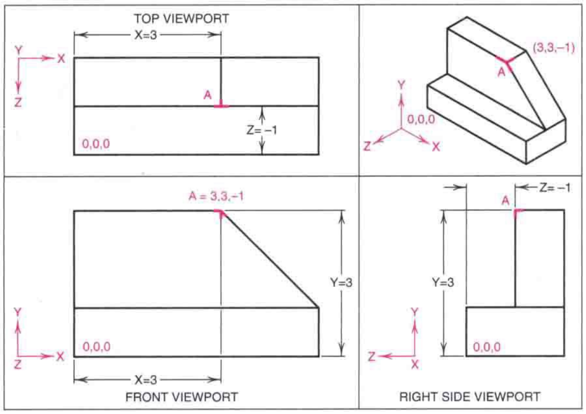


Figure 8.6

Display of coordinate axes in a multiview CAD drawing
Only two of the three coordinates can be seen in each view.

trations so the user can better visualize the 3-dimensional form of the object (Figure 10.43). This is especially important for most students who are being asked to use their visual mode to think and create. Color shading highlights important features, more clearly shows different sides of objects, and adds more realism to the object being viewed.

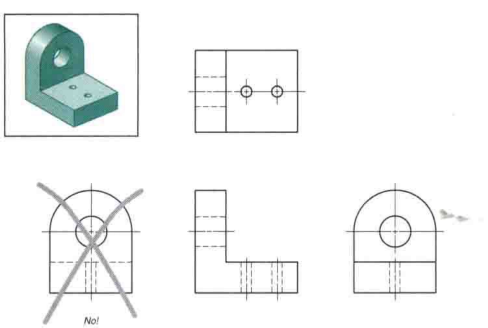


Figure 10.43

Most descriptive views
Select those views which are the most descriptive and have the fewest hidden lines. In this example, the right side view has fewer hidden lines than the left side view.

Frequently, different shades of color are used on objects to highlight various features, improve visualization of objects, and better describe them (Figure 8.48). Different shades of color are also used on a single object to highlight surface features, which is useful especially when trying to draw attention to certain features, such as holes, oblique planes, and surfaces to be projected onto a picture plane. **Some texts use two colors, which are adequate for some illustrations, but our research with students clearly**

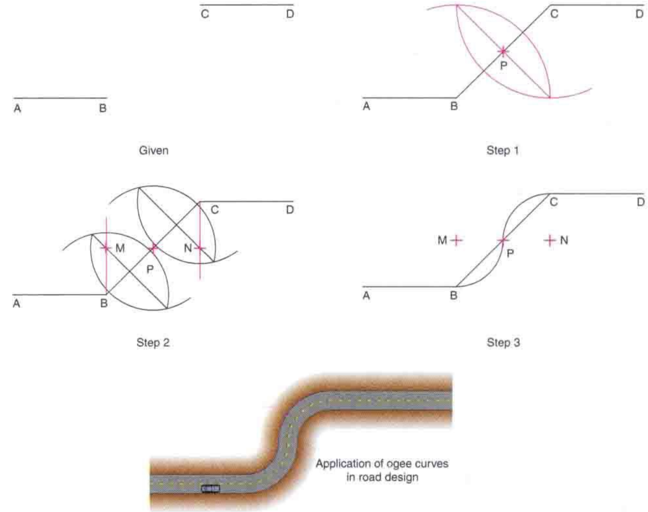


Figure 8.48

Constructing an ogee curve between two parallel lines

demonstrates that having the ability to display objects and text illustrations in many different colors provides a considerable advantage when teaching engineering and technical graphics. Effective use of color improves the pedagogy and can greatly enhance an instructor's lecture and ability to teach complicated or hard to understand concepts. Being limited to one or two colors as in other texts is an unnecessary obstacle to effective teaching and learning.

Photographs and screen captures are much more interesting and show much more detail when in color (Figure 3.40). In some aspects of engineering design, such as

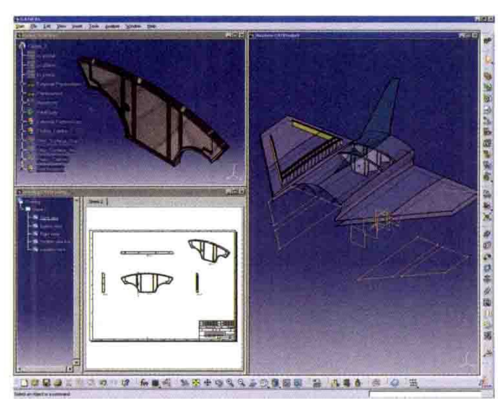


Figure 3.40

Production drawing
A production drawing showing views of a welded body part.
(Courtesy of Dassault Systemes.)

finite element analysis, color is the method used to communicate or highlight areas of stress or temperature. Showing a black and white illustration to explain finite element analysis is just short of being useless. CAD systems are capable of displaying millions of colors and can create photographic realistic models of designs and assemblies. Full-color illustrations in engineering and technical graphics are prerequisite for a modern text.

Practice Exercises A unique feature of the text is the use of practice exercises, which cause the student to pause and actively engage in some activity that immediately reinforces their learning. For example, Practice Exercise 7.1 in Chapter 7, "Sketching and Text," asks the student to find a few familiar objects and begin making isometric sketches.

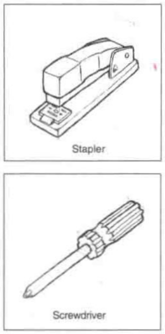


Figure 7.36

Isometric sketches of common objects

Step-by-Step Illustrated Procedures Most chapters include many drawing examples that use step-by-step procedures with illustrations to demonstrate how to create graphics elements or to solve problems. These step-by-step procedures show the student in simple terms how a drawing is produced. Most of the illustrations accompanying the step-by-step procedures are in multiple parts so the student can see how the drawing is created. In many cases the color red is used in each step of the illustration to show what is being added or created.

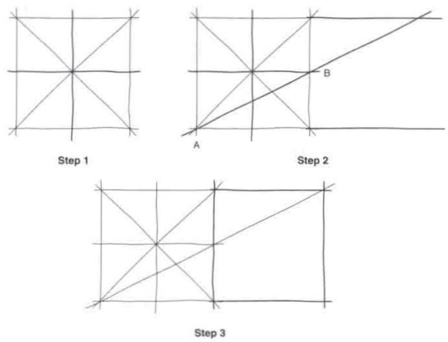


Figure 7.21

Sketching identically proportioned squares

An identically proportioned square is created by extending both top and bottom horizontal lines and constructing diagonals across the existing box.

Integration of CAD Every chapter includes specific references to CAD rather than simply adding them to the end of the chapter. By integrating the references in the text, the student learns how CAD is used in the context of the topic being explained. In some cases whole sections or chapters deal with CAD topics. For example, Chapter 9, "Three-Dimensional Modeling," covers the use of CAD to create 3-D models. Students begin to understand that CAD is another tool used by the engineer and technologist to communicate. Traditional topics and CAD topics are seamlessly integrated because the text was written that way from the outset. CAD is not an add-on or afterthought. It is fully integrated and embraced as a means of creating graphics for engineers and technologists (Figure 10.35).

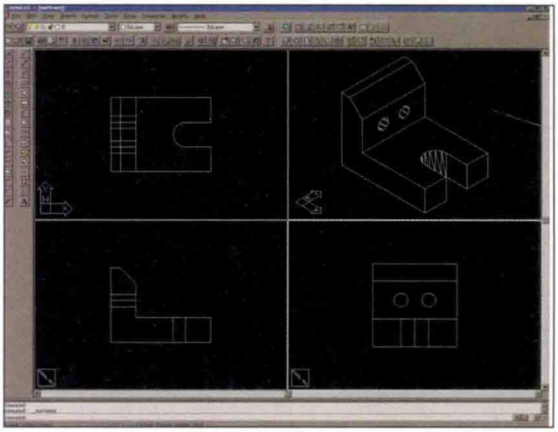


Figure 10.35

Predefined multiviews on a CAD system

Historical Highlights Many of the chapters include information about important events and people in the history of graphics. This is an extension of the history of graphics first introduced to the students in Chapter 1. Historical Highlights are presented as a special boxed feature that contains an overview of the person or event along with photographs and drawings. They are used as a means of giving the student an historical context to graphics.

Dream High Tech Jobs This feature is included in many chapters and describes interesting jobs that are available to engineers and technologists who have mastered technical communications.


456 PART 2 Fundamentals of Technical Graphics

Dream **High Tech** Job

Designing Snowboards

The engineering design process is used in many types of jobs from the design of consumer product packaging to the design of snowboards and related equipment. An understanding of the design process and 3-D solid modeling—along with formal education in a field of engineering—can lead to exciting job opportunities, such as the one described here of an engineer who worked on the design of snowboards.

Snow Sports

"When I was a kid, we called my grandfather 'Fix-it Grandpa.' He could fix anything, and I often followed him around asking questions about everything. I was always fascinated when he took everything apart; only, if I did it, I couldn't always get it back together. Neither of my parents were mechanically inclined, so, when I needed something fixed, I either had to call Grandpa or fix it myself.

"When I was graduating from high school, I wanted to go to college at University of California, Santa Barbara. My dad and I were looking through the college catalog and ran across a picture of a Human Powered Vehicle under the mechanical engineering section. We both agreed that it looked interesting, and I felt confident that I could study mechanical engineering because I enjoyed math, science, and physics.

"Because of my engineering education, I feel that I can solve any problem and can do whatever I want with my life. The education gave me a set of tools to have a successful life.

"To make extra money, I worked for Joyride Snowboards as a college sales rep. I had been an avid snowboarder for the last 12 years so it seemed like a good fit to use my engineering skills to further the sport of snowboarding.

"My employment at K2 started as an internship after graduation and eventually became a full-time gig. At K2, I designed snowboard footprints, profiles, and constructions with an emphasis on women's boards. I also organized and led on-snow tests on Mt. Hood for prototype testing. My design, the K2 Mix, is still in production and was ranked in the Top 5 Women's boards in the 2002 Transworld Buyers Guide. In fact, Gretchen Bleiler, the winner of the Women's Super-pipe in the 2003 X-Games and the Women's U.S. Open Half-pipe Championships, rides my board!"

Skis and Snowboards

Engineers who love to ski and snowboard naturally gravitate toward work in the snow sports industry. Traditionally, when an idea for a new ski or snowboard design came along, engineers would build a prototype, perform laboratory tests for stiffness, and test it on the slopes. Based on the test experience, engineers would make design changes and retest the equipment. This method of design resulted in a slow and tedious process. In addition, the perfectly crafted ski or snowboard is not perfect for everyone. The needs of a 5'2" female snowboarder are much different than the needs of a 6'0" male snowboarder. The snowboard's height, weight, and skill level, as well as the snow conditions and the angle of the slope, all need to be taken into consideration when trying to fit the perfect board to the enthusiast.

Snowboards are made out of several layers of materials, along with glue and paint. Snowboarders believe that the edge design, or effective edge, is the most important part of the design. Edge design determines how the snowboard will turn. The more surface area the edge has, the more control and, hence, the sharper the turns that can be made. Structural strength of the snowboard is also very important. Engineers determine the strength by figuring out the acceleration of the rider.

To accommodate these various conditions, engineers from manufacturers such as K2 and Head are designing intelligent technology that will enable skiers and snowboarders to go faster and have more control.

STACIE GLASS
Former Snowboard Design Engineer, K2 Snowboards
(Courtesy of Stacie Shannon Glass.)

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Design in Industry Most chapters includes a special feature covering some aspect of design as practiced in industry. This Design in Industry feature covers design in many types of industries so that students with varied engineering interests can see how design is used to solve problems. Many feature quotes from engineers working in industry explaining how they solved problems or used CAD tools to enhance the design process. All the Design in Industry items include figures to supplement the information presented.

Highlighting Key Terms Important terms are highlighted in each chapter with bold or italicized text. All boldfaced terms are included in the extensive glossary found at the end of the text for easy reference. Italicized text draws the attention of the reader to highlighted important terms or phrases.

Summary Each chapter ends with a summary as a means to pull everything covered in the chapter together for the student. The summary is a brief overview of the most important topics covered in the chapter. In some cases, the summary also includes important information listed in tables or bulleted lists.

Questions for Review Each chapter includes an extensive list of questions for review. Included are questions meant to measure whether students learned the objective listed at the start of each chapter. Other questions are used to reinforce the most important information presented in the chapter. The types of questions used require students to answer through writing or through sketching and drawing.

Further Reading Many of the chapters include a list of books or articles from periodicals relevant to the content covered in the text. The Further Reading list can be useful for the instructor to find additional information about a topic.

Problems Every chapter in the text includes an extensive number and variety of problem assignments. Most chapters include text-based problems that describe a problem to solve or drawing to create. Most chapters include problems with figures that students are to solve or replicate using traditional tools and CAD. The figure-based problems are very extensive and range from the very simple to complex. This arrangement allows the instructor to carefully increase the complexity of the problems as students learn and progress. The most complex drawings can be used to supplement assignments given to the most talented students or for group-based projects.

Most of the problems are of real parts made of plastic or light metals, materials commonly found in industry today. There are many examples of *unique* problems that

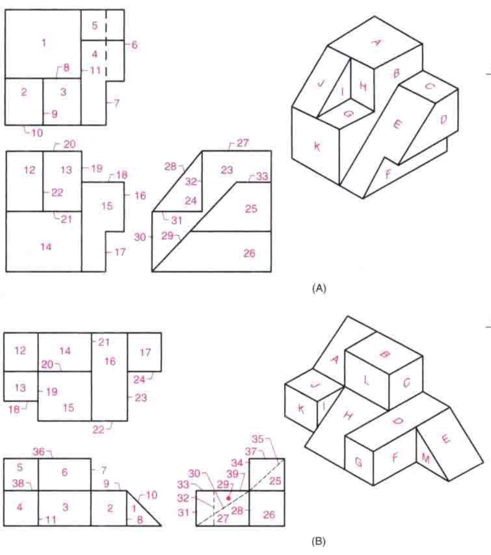

Figure 5.55

are not found in other textbooks. For example, many of the problems in Chapters 5 and 9 are not found in other engineering and technical graphics texts. These problems reinforce student learning and give them experience that will be of great value in industry.

The wide range and numerous problems allow the instructor to frequently change assignments so that fresh problems are used from semester to semester. Additional problems are available on the website and through our workbooks.

Classic Problems Many chapters include Classic Problems, which are additional problems that can be assigned. They have been taken from the seminal technical graphics textbooks by Thomas E. French, published by McGraw-Hill. Many of the problems are castings with machined surfaces giving the student experience with additional materials and machining processes.

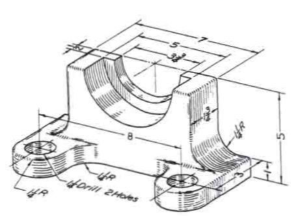

Figure 10.156
Bearing rest

Part 1
Global Implementation for Technical Graphics

This section contains four chapters that introduce the student to engineering design graphics. It includes an explanation of the importance of graphics instruction for engineers and technologists, has a brief overview of the engineering design process, explains the tools used to communicate graphically, and shows how to create simple sketches.

- Chapter 1, "Introduction to Graphics Communications," explains the role and importance of graphics communications in engineering design. The concept of visualization is first introduced to the student so they can begin to relate its importance to design graphics. There is a strong emphasis on communications so students begin to understand that graphics is a powerful form of human communications. One *unique* feature of the chapter is Practice Exercise 1.1, which shows through a simple exercise why graphics communication is the only useful method of describing design and the power of graphics over the written or spoken word.
- Chapter 2, "The Engineering Design Process," was significantly changed for the 3rd and 4th editions. Much of the original content was moved to a new Chapter 3, and new material was added. Chapter 2 is a brief introduction to traditional and modern technical design methodologies with more emphasis on concurrent engineering and product lifecycle management. One *unique* aspect of this chapter is the explanation of the modern practices used in engineering design, in which engineers interact and communicate with other professionals in the company.
- Chapter 3, "Design in Industry," is an in-depth overview of modern engineering design practice in industry. Before the 4th edition this was chapter 4. It was moved adjacent to Chapter 2 to provide a more comprehensive view of the processes and artifacts of the technical graphics processes as utilized in industry. Engineering design is explained in context with 3-D CAD modeling and the sharing of design information across the enterprise. The design process is covered in detail and includes important topics, such as ideation, the designer's notebook, computer simulation, design analysis, and design review meetings.
- Chapter 4, "The Role of Technical Graphics in Production Automation and Manufacturing Processes," is an introduction to modern manufacturing and production processes. The chapter explains in contemporary terms the general manufacturing and production process and its relationship to technical design and drawing, including 3-D models. In addition, quality management, automation, and design for manufacturability (DFM) are explained.

Part 2
Fundamentals of Technical Graphics

This part explains visualization in the context of engineering design and shows students how to construct 2-D and 3-D geometry and create multiview and pictorial technical drawings.

- Chapter 5, "Design Visualization," is a *unique* chapter aimed at helping students improve their visualization abilities, which are fundamental to understanding and creating technical graphics. This chapter is unlike anything found in other technical graphics texts. The chapter briefly explains the human visual systems so students understand the complexity and power of human visualization.

The chapter quickly moves into the very basics of visualization as it related to engineering design graphics. The nomenclature and techniques used to describe objects are explained in detail so students understand the language of engineering and technical graphics. This leads into extensive coverage of the visualization techniques employed for technical drawings, such as image planes and orientation. Students get their first introduction into inclined, normal, and oblique lines and planes.

Integrated into the chapter is information about data visualization and the use of graphs and charts to describe and visualize engineering data. Another *unique* feature of this chapter is the extensive coverage of VR in Section 5.8, "Virtual Reality and Visualization."

- Chapter 6, "Technical Drawing Tools," is an introduction to the traditional and modern tools used to create sketches, drawings, and computer models. Traditional tools are described, with step-by-step instructions on how to use them. The instructions also cover how CAD is used to supplement traditional tools. This is the first chapter employing one of the major features of this text: step-by-step instructions.
- Chapter 7, "Sketching and Text," is an introduction to the creation of sketches and their use to support the design process. Traditional sketching tools are described, along with important sketching techniques. Step-by-step procedures guide the student through simple sketching activities.

  The additional sketching techniques are similar to those found in the classic text, *Drawing on the Right Side of the Brain* by Betty Edwards, and includes contour sketching, negative space sketching, and upside-down sketching. All of these techniques can dramatically improve a person's ability to make sketches.
- In Chapter 8, "Engineering Geometry and Construction," the student is shown how to create and edit 2-D geometry, using both traditional tools and CAD. More advanced technical geometry that can be created with 3-D CAD is also introduced. This chapter includes an extensive explanation of coordinate space which is especially useful for 3-D CAD. Another *unique* aspect of this chapter is the extensive coverage of geometric principles, such as parallelism, intersections, tangencies, and comprehensive coverage of 2-D and 2-D geometry.
- Chapter 9, "Three-Dimensional Modeling," is an extensive coverage of 3-D modeling theory, techniques, and applications. The chapter shows how computers are used to create all types of 3-D models, using various construction techniques. Coverage includes wireframe, surface, and solid modeling, constraint modeling, constructive solid geometry modeling CSG, and boundary representation modeling. Feature analysis is explained so students begin to understand design intent which is so important when concerned with modern engineering design. A section on feature definition explains how to build models using various features defined by the user. Virtually every method and technique used to create 3-D models with CAD is covered in the chapter, giving the student the understanding necessary to use any 3-D modeling system. Chapter 9 has more modern topic coverage, including more material on constraint-based modeling.
- Chapter 10, "Multiview Drawings," introduces standard multiview drawings for technical design and production. The chapter begins by explaining projection theory in general and multiview projections in particular. Standards and conventional practices for multiview drawings are then introduced. Integrated into the chapter are explanations and the use of illustration to assist the learner in visualizing the principles of orthographic projection. These visualization techniques provide a solid foundation and understanding of orthographic projection and how it relates to creating multiview drawings.
- Chapter 11, "Axonometric and Oblique Drawings," is an introduction to such drawings and contains an in-depth discussion of pictorial projections and drawings, building on the material covered in Chapter 7, "Sketching and Text." Through step-by-step instructions, the student is shown how to create pictorial drawings, using traditional instruments or CAD. This chapter also goes to great lengths to explain the theory and technique of axonometric and oblique drawings so students understand at a very fundamental level how these projection techniques are created.
- Chapter 12, "Perspective Drawings," is an introduction to perspective projection and drawings. This chapter again builds on the information presented in Chapter 7, "Sketching and Text." Step-by-step instructions describe how to create one- and two-point perspective drawings. Extensive background material is provided so students understand the concepts underlying perspective projections.
- Chapter 13, "Auxiliary Views," introduces the theory of auxiliary views and the techniques for drawing them. The fold-line and reference plane methods are explained using step-by-step instructions. Auxiliary view techniques are then applied to the solutions of problems concerning reverse construction, views in a spec-

ified direction, dihedral angles, and the true size of an oblique plane.

Part 3
Descriptive Geometry

Part 3 is a basic introduction to the theory and practice of descriptive geometry, intersections and developments.

- Chapter 14, "Fundamentals of Descriptive Geometry," is an introduction to the application of descriptive geometry to the solution of spatial problems. There is extensive coverage of the underlying concepts and projection theory related to auxiliary views. One *unique* feature of this chapter is the five principles of descriptive geometry, which summarize the important concepts in the solution of spatial geometry problems. Another feature is the list of tips and axioms useful in solving such problems.
- Chapter 15, "Intersections and Developments," introduces two concepts: (1) the intersections between geometric forms and (2) 3-D geometric developments. The chapter presents the standards and techniques for drawing these important elements through detailed step-by-step illustrated procedures. One *unique* aspect of the illustrations used in the step-by-step procedures includes 3-D pictorial color illustrations of the intersecting objects, making it easier for the student to visualize the problem being solved.

Part 4
Standard Technical Graphics Practices

Part 4 includes ten chapters which describe the standard practices commonly used to create technical drawings to support the engineering design process. In this part students learn how to create section views, dimension and tolerance a drawing, and represent fasteners on drawings. Modern manufacturing practices are covered as well as working drawings.

- Chapter 16, "Section Views," is an introduction to the techniques and standards used to create all types of section views. One important concept is section view visualization, which is explained early in the chapter. Each section view type is examined in terms of its visualization, the applicable standards practices, and the techniques useful in its construction. A Summary of Important Practices is included at the end of this chapter to assist the student in making section views.
- Chapter 17, "Dimensioning and Tolerancing Practices," introduces the techniques and standards for adding dimensions to technical drawings. There is extensive coverage of standard practices used for nearly any feature found on drawings, and they are explained using illustrations which sometimes include color rendered pictorial views useful in visualizing the dimensioning or tolerancing concept being explained. The need for tolerancing is discussed in great detail so that the student will understand and appreciate the importance of tolerancing in technical design. The summary includes two tables that condense important dimensioning and tolerancing information useful for students in developing their own technical drawings.
- Chapter 18, "Geometric Dimensioning and Tolerancing Basics," introduces the standards, techniques, and practices associated with ASME Y14.5M-1994 standard geometric dimensioning and tolerancing. The chapter explains each type of geometric dimension, how it is measured, and how its associated symbols are used in technical drawings. There is extensive use of illustrations with rendered pictorial views of the principle being explained.
- Chapter 19, "Fastening Devices and Methods," introduces the student to various types of fasteners and their representation on technical drawings. Step-by-step procedures demonstrate how to read a thread table, create simplified and schematic internal and external thread forms, and draw bolts and springs. One *unique* feature of this chapter is the many references to the *Machinery Handbook* to familiarize students with this important guide to information on fasteners. Another is the very detailed explanation of how to read an ANSI standard thread table.
- Chapter 20, "Working Drawings," describes how to create a standard set of drawings that specify the manufacture and assembly of a product based on its design. All of the important features of a set of working drawings are described and illustrated, along with engineering change orders (ECO) and reprographic practices, including digital technologies.
- Chapter 21, "Technical Data Presentation," describes how to create technical illustrations and represent data using both traditional techniques and computers. The chapter covers such modern illustration techniques as color theory, lighting, animation, and multimedia. Students learn the basic concepts used to represent data graphically followed by examples of charts and graphs produced from data. One *unique* feature of this chapter is the representation of 3-D graphs and charts to represent data.

- Chapter 22, "Mechanisms: Gears, Cams, Bearings, and Linkages," is an introduction to the standard technical drawings for gears, cams, bearings, and linkages. In this chapter students learn the theory and practice used to represent mechanisms. Included in this chapter are a number of step-by-step procedures used to read mechanism catalogs and draw the mechanism using standard practices.
- Chapter 23, "Electronic Drawings," is an introduction to the symbols and applications of electronic drawings in industry.
- Chapter 24, "Piping Drawings," explains the fundamentals of piping, as well as the symbols used to create standard piping drawings.
- Chapter 25, "Welding Drawings," is an introduction to welding processes and the symbols used to represent welded assemblies in technical drawings.

Glossary, Appendixes, and Index

At the end of the text is an extensive glossary containing the definitions of all key terms shown in bold in the text. This glossary contains over 600 terms related to engineering and technical drawing, engineering design, CAD, and manufacturing.

The appendixes contain supplementary information useful to the student, such as an extensive listing of abbreviations commonly used in technical graphics; geometric dimensioning and tolerancing information; materials properties, useful when creating a materials library for CAD solid modelers; properties of geometric forms, useful for 3-D modeling; ANSI standard tolerancing tables; and standard fastener tables for drawing and specifying various fasteners, keys, washers, and pins.

An extensive index is included at the end of the text to assist the reader in finding topics quickly. This index is carefully cross-referenced so related terms can easily be found by the user.

Supplements

A number of supplements have been developed to assist in the instruction of technical graphics.

Instructor's Manual

This supplement is available on the instructor's web site and it contains

Chapter objectives
Chapter outlines
Chapter summaries
Key terms
Questions for review with answers
True-false questions with answers
Multiple-choice questions with answers
Teaching tips and suggestions

Solutions Manual

This solutions manual contains answers to the end-of-chapter word problems, as well as many of the end-of-chapter drawing problems. Solutions are available on the instructor's web site.

Workbooks

A workbook with additional drawing problems is available. *Graphics Drawing Workbook* contains many of the problems found in the text in workbook form. This workbook has many traditional and nontraditional types of problems that are useful for visualization exercises and 3-D modeling.

Online Learning Center (OLC)

The OLC website follows the textbook chapter by chapter. As students study, they can refer to the OLC website for learning objectives, a chapter summary, flashcards, animations, and more. Before taking an exam, students will know if they're ready thanks to interactive exercises and taking self-grading quizzes.

A secured Instructor Center stores your essential course materials to save you prep time before class. The Instructor's Manual and presentation materials are now just a couple of clicks away. You will also find additional problem material and exercises (some are Internet-specific).

OLC Supplements

Many supplements for each chapter are found on the online learning center, including the following;

Learning Objectives   A listing of all learning objectives for each chapter in the text.

Chapter Outline   An extensive outline of each chapter.

Multiple-Choice Quiz   An interactive online quiz covering important topics in the chapter. Answers are submitted for automatic and immediate grading for review by the student.

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Illustrators

A text of this type would be useless without good, accurate graphics. We have had the good fortune to have some of the best young illustrators in the country work on this text. Joe Mack and James Mohler led a team of illustrators that worked many months on the illustrations. The authors are indebted to these two individuals, both of whom have enormous talent. Joe Mack has since moved on to a very successful career in multimedia software development, and James Mohler has started his own multimedia company. In addition, the authors would like to thank the other illustrators on the team: Rob Cumberland, Jonathan Combs, Doug Acheson, Doug Bailen, Aaron Cox, Brad Johnson, Steve Adduci, Clark Cory, Trent Mohr, Keith Huggins, Dale Jackson, Jonathan Humphries, Sue Miller, Andy Mikesell, Travis Fuerst, Jason Bube, and Kevin Bertoline.

Other Contributors

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Finally, we would like to know if this book fulfills your needs. We have assembled a "team" of authors and curriculum specialists to develop graphics instructional material. As a user of this textbook, you are a part of this "team," and we value your comments and suggestions. Please let us know if there are any misstatements, which we can then correct, or if you have any ideas for improving the material presented. Write in care of the publisher, McGraw-Hill, or E-mail Gary R. Bertoline at bertoline@purdue.edu.

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"If I have seen further . . . it is by standing upon the shoulders of Giants." Isaac Newton

This book is dedicated to the pioneers in graphics, and our teachers, colleagues, family, and students from whom we have learned so much and to whom owe our gratitude.

Questions for Review The questions include a hint button if a student cannot answer the question. The hint button refers the student to the chapter page where the material relevant to answering the question can be found.

True or False Questions An interactive online true and false test covering important topics in the chapter. Answers are submitted for automatic and immediate grading for review by the student.

Flashcards Interactive exercises to assist students in learning important terms from each chapter of the text.

Web Site Links Many chapters include numerous web site links that can be used by students and faculty to supplement the textbook material.

Animations Many chapters include animations that can be downloaded and played on a computer showing how to visualize and understand concepts.

Related Readings A listing of additional books that can be used as references or further reading on topics covered in the chapter.

Image Library The image library, available to instructors, contains all the images in each chapter that can be viewed, printed, or saved.

AutoCAD Problems Some chapters contain additional mechanical, civil, and architectural AutoCAD problems in PDF format for viewing and printing hard copies. These problems include step-by-step procedures useful in drawing the problem using AutoCAD software.

Stapler 3-D Modeling Project The 3-D stapler modeling project was removed from the 4th edition, but it can be found on the Online Learning Center. The purpose of the integrated 3-D modeling project is to further assist and motivate students to learn engineering and technical graphics concepts through a real project. The 3-D modeling project uses a real product, a stapler made by Swingline. The stapler is a fairly simple device with some challenging surfaces. The range of complexity allows students to begin with simple parts and move on to increasingly sophisticated graphics and models as they become more knowledgeable and experienced in using computer graphics.

Old Drawing Problems Many of the drawing problems that were in the 3rd edition but not replaced with new problems in the 4th edition can be found on the Online Learning Center.

Geometric Forms Patterns of simple geometric forms are patterns that can be cut out by the student and formed into their 3-D shape. Instructors can use them to supplement their lectures, as visualization aids, and for additional problem assignments.

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Glossary

A

absolute coordinates (n) Coordinates associated with an origin that never changes location and thus gives a stable method of locating geometry in space. The absolute coordinate system is also called the *world* or *global* coordinate system.

absolute scale (n) A data scale that has both a defined zero point and units. The Kelvin temperature scale is an example of an absolute scale.

actual size (n) A tolerancing measure used to describe the size of a finished part after machining.

additive (adj. or v) A process or state whereby elements combine together, such as two primitive shapes combining to form a larger, more complex one. Additive is the opposite of subtractive.

additive primaries (n) The three primary colors: red, green, and blue. Color systems use these primaries in differing amounts, working on the principle of *adding* spectral wavelengths to the light energy to create new colors. This system is used in lighting and computer display graphics. The complementary colors are the subtractive primaries: cyan, magenta, and yellow.

adjacent areas (n) Surfaces that are separated on a multiview drawing by lines that represent a change of planes. No two adjacent areas can lie in the same plane.

adjacent view (n) Orthographic views that are aligned to each other, allowing dimensional information to be shared. Examples are the front and top views or the front and right side views.

aerial perspective (n) A perceptual cue where objects farther away appear bluer and hazier. The cue is based on the effect of particles in the atmosphere blocking the passage of light.

aerospace engineering (n) A field of engineering concerned with the design and operation of aircraft, missiles, and space vehicles.

aesthetics (n) The artistic qualities or aspects that elicit an emotional response to an object.

agricultural engineering (n) A field of engineering concerned with production agriculture and its natural resource base and the processing and chemistry of biological materials for food and industrial products.

aligned dimensions (n) A style of dimensioning in which text is placed parallel to the dimension line, with vertical dimensions read from the right of the drawing sheet. The *aligned method* of dimensioning is not approved by the current ANSI standards but may be seen on older drawings.

aligned section (n) A section view created by bending the cutting plane line to pass through an angled feature. The resulting section does not show the section in true projection, yet it gives the clearest possible representation of the features.

allowance (n) A tolerancing measure used to describe the minimum clearance or maximum interference between parts. Allowance is the tightest fit between two mating parts.

alphabet of lines (n) The standard linestyles established by ANSI to be used for technical drawing. The standards specify both the *thickness* and the *design* (i.e., dashed, solid, etc.) of the lines.

alternate four-center ellipse method (n) A method of creating an approximate ellipse. The method is used for cavalier oblique drawings.

ambient light source (n) A light source defined by its lack of orientation or location. Fluorescent lighting in an office is an example of ambient lighting. In renderings, an ambient light source is sometimes used as a default light source to give a baseline level of lighting to the model.

analogous (adj.) A concept meaning *similar* or *comparable* in some respects. The concept is used to describe the extent to which a graphic representation compares with a real object.

analytic geometry (n) The analysis of geometric structures and properties, principally using algebraic operations and position coordinates. The term also refers to a particular geometric method for describing 3-D solid models.

angle (n) The relative orientation of two linear elements with respect to each other. The angle is usually measured relative to the point of intersection or termination of the two lines.

angularity (n) An orientation control for geometric dimensioning and tolerancing. Angularity is a condition of a surface, center plane, or axis at an angle other than a right angle to a datum plane or datum axis.

animation (n) A technique or technology used to represent change over time through stroboscopic motion. A sequence of images are generated where change between any two images are small, but the rapid display of numerous images in sequence creates the appearance of motion and change.

apparent motion (n) The sense of motion induced by rapidly displaying a series of images of an object to make the object appear to change location or shape. Animation techniques take advantage of this perceptual effect.

archiving (v) A term used to describe the storing and retrieval process for engineering documentation. Although originally involving paper documents, the term increasingly refers to the storage of computer-generated information on magnetic or optical media.

area rendering (n) A data visualization technique in which the pixels in a 2-D area are each assigned a value. A color lookup table maps a specific color to each data value to create a rendered region.

array (n, v) Either the process of or resulting geometry of a single feature being duplicated in a regular fashion in a model. An array is procedural, in that instructions are given as to how a feature(s) is to be duplicated rather than having the user define the final location of each duplicate. Arrays are defined as being either linear or radial, depending on how the duplication is defined. Typically, the operator will indicate the direction (in one or two dimensions) of the duplication, spacing between each duplicate feature, and how many duplicates to create.

arrow plot (n) A visualization technique in which the dependent variable is a vector rather than a scalar and is represented by line or arrow marks. Because there are typically a large number of arrow marks in a small region, pattern (texture) perception can be used to evaluate trends in the data.

artistic drawing (n) A type of drawing used to express aesthetic, philosophical, and abstract ideas. These types of drawings are not intended to communicate clear, concise information pertaining to a design.

artwork drawing (n) *See* fabrication drawing.

assembly drawing (n) A drawing showing how each part of a design is put together. An assembly drawing normally consists of all the parts drawn in their operating positions and a parts list or bill of materials.

assembly section (n) A section view of multiple parts in an assembly. Differing section line designs differentiate between different materials, or between similar materials belonging to different parts.

associativity (n) Describing the relationship between software components which share data. For example, bi-directional associativity between a modeler and a drawing module means that changes to the geometry in the modeler will be reflected in the drawing and vice versa.

asymptote (n) Convergence of two curves (or a curve and a straight line) whose distance tends to zero, but may or may not eventually intersect.

authoring (v) The process of using computer programming tools to assemble different media into an interactive presentation.

automation (n) The use of machinery in place of human labor.

autorouting (v) A specialized software process that suggests routing connections between components on a circuit board. Autorouting is usually part of a suite of CAD electronics software functions that also include automated component placement, programming of CNC board drilling, and component insertion equipment.

auxiliary section (n) A section view derived from an auxiliary view. The term distinguishes from section views derived from standard orthographic views.

auxiliary view (n) A view derived from any image plane other than the frontal, horizontal, or profile planes. Auxiliary views are usually termed *primary* or *secondary,* depending on whether or not they are perpendicular to one of the above-mentioned primary projection planes. Primary auxiliary views are termed depth, height, or width auxiliaries, depending on the dimension transferred from the measuring view.

average (n) *See* mean.

axis (n) The line or vector representing a center of rotation, such as the longitudinal center line that passes through a screw thread cylinder. Also, a vector indicating a dimension in model space or in a visualization such as a graph.

axonometric axes (n) The axes used to define the orientation of the primary dimensions in an axonometric pictorial projection. The relative angle of the axes to each other determines the type of axonometric projection.

axonometric projection (n) A parallel projection technique used to create pictorial drawings of objects by rotating the object on an axis relative to a projection plane.

B

B-spline curve (n) A parametrically defined freeform curve that approximates a curve to a set of control points and provides for local control. Multiple 2-D curves are often combined to create 3-D surface patches.

backface culling (n) In rendering, a preprocessing step that removes all faces of the model that will be completely hidden from view.

balloon (n) A symbol, usually a circle, which contains the part number or other identifying code for a part or feature in a technical drawing. The balloon usually refers to the feature or part with a leader.

bar graph (n) A graph (usually 2-D) in which one dimension represents the independent variable and the other represents the dependent variable. The magnitude of the dependent variable is represented by a line or area of uniform width (a bar).

base feature (n) The first feature created when defining a solid model. The base feature creates the initial geometry of the model from which additional geometry can be added or subtracted.

basic dimension (n) A tolerancing measure used to describe the theoretically *exact* size of a feature.

basic size (n) A tolerancing measure used to describe the theoretical size used as a *starting point* for the application of tolerances.

bearing (n) A mechanical device designed to transfer radial or axial loads from a shaft while minimizing energy loss due to friction from the rotating shaft. Bearings are usually divided into two general categories: plain and rolling contact.

Bezier curve (n) A special case of the B-spline curve. Unlike a standard B-spline curve, the Bezier does *not* provide for local control, meaning that changing one control point affects the entire curve.

bicubic surface patch (n) A 3-D freeform surface bounded by a set of curves described by third degree (cubic) functions. The bounding curves, often B-spline or Bezier curves, and their associated control points are used to manipulate the shape of the surface.

bilateral (adj) Relating to, or affecting both sides. A *bilateral tolerance* varies in both directions from the basic size of a part (e.g., both larger and smaller).

bilateral tolerance (n) The dimensional variation of a part that varies in both directions from the basic size.

bill of materials (n) A listing of parts or materials used in an assembled object. The listing is usually included as part of the working drawing of the full assembly.

binary tree (n) A hierarchical, logical structure used to organize related elements. Each node on the tree is linked to exactly *two* leaves on the next level down. Binary trees are used to describe the relationship of geometric elements in a CSG solid modeler.

bird's eye view (n) In a perspective pictorial, a viewpoint looking *down* from above the object. From this viewpoint, the ground line is below the horizon line of the object.

blind hole (n) A hole that does not go completely through the material. Blind holes can be created by any cutting device (such as a twist drill bit) that is capable of plunging into the material.

block diagram (n) A relatively simple diagram that quickly identifies the relationships between systems, groups, people, or other physical or abstract entities. (*See also* flow diagrams.)

blueprint (n or v) The photographic process used to duplicate documents. It also refers to the document produced by this process. Though blueprint originally referred to a particular reproduction technology (which produced white lines on a blue background), it is now commonly used to refer to any type of copying process for large engineering documents or the document resulting from this process.

boldface (adj.) A style of text in which the lines that make up the letters are thicker than normal. This technique is used to make words or letters stand out visually from the rest of the text.

bolt (n) A mechanical fastening device with a head on one end of an externally threaded shaft. A nut is placed on the threaded shaft and rotated to clamp the material between the head and nut.

bonding (v) A process in which a material (usually, a hardening liquid) is added to an assembly to hold parts together. Bonding is a *permanent* fastening method, using processes such as welding, soldering, brazing, and gluing.