CHAPTER 1 Introduction to Graphics Communication and Sketching

OBJECTIVES

After completing this chapter, you will be able to:

1. Describe why the use of graphics is an effective means of communicating when designing.
2. Define standards and conventions as applied to technical drawings.
3. Describe the design process.
4. Identify the important parts of a CAD system used to create technical drawings.
5. Identify the important traditional tools used to create technical drawings.
6. Use sketching and CAD to draw lines, circles, arcs, and curves.
7. Read and use scales.
9. Identify the types and thicknesses of the various lines in the alphabet of lines.
10. Create a design sketch using pencil or computer.
11. Identify and use sketching tools.
12. Follow good hand-lettering practice.

INTRODUCTION

Chapter 1 is an introduction to the graphic language and tools of the engineer and technologist. The chapter explains why technical drawing is an effective way to communicate engineering concepts, relating past developments to modern practices, and examines current industry trends, showing why engineers and technologists today have an even greater need to master graphics communications. Concepts and terms important to understanding technical drawing are explained and defined, and an overview of the tools, underlying principles, standards, and conventions of engineering graphics is included. In addition, this chapter introduces you to sketching and the use of sketching for lettering. These techniques are expanded on in later chapters.

Technical drawings are created using a variety of instruments, ranging from traditional tools, such as pencils, compass, and triangles, to the computer. Drawing tools are used to make accurate and legible drawings and models. Traditional drawing instruments are still important, especially for sketching; today, however, the computer can be used for most drawing and modeling requirements. This chapter is an introduction to: computer-aided design/drafting (CAD) systems, including the related hardware, software, and peripheral devices; and the traditional equipment normally used by engineers and technologists to create technical drawing models.

1.1 In engineering, 92 percent of the design process is graphically based. The other 8 percent is divided between mathematics, and written and verbal communications. Why? Because graphics serves as the primary means of communication for the design process.
1.2 Drafting and documentation, along with design modeling, comprise over 50 percent of the engineer's time and are purely visual and graphical activities. Engineering analysis depends largely on reading engineering graphics, and manufacturing engineering and functional design also require the production and reading of graphics.

1.3 Engineering graphics can also communicate solutions to technical problems. Such engineering graphics are produced according to certain standards and conventions so they can be read and accurately interpreted by anyone who has learned those standards and conventions.

1.4 A designer has to think about the many features of an object that cannot be communicated with verbal descriptions. Technical drawings are a nonverbal method of communicating information.

1.5 **Engineers** are creative people who use technical means to solve problems. They design products, systems, devices, and structures to improve our living conditions. **Technologists** assist engineers and are concerned with the practical aspects of engineering in planning and production. Both engineers and technologists are finding that sharing technical information through graphical means is becoming more important as more nontechnical people become involved in the design/manufacturing process.

THE IMPORTANCE OF ENGINEERING GRAPHICS

Engineering graphics is a real and complete language used in the design process for:

1. Communicating
2. Solving problems
3. Quickly and accurately visualizing objects.
4. Conducting analyses.

1.6-7 A drawing is a graphical representation of objects and structures and is done using freehand, mechanical, or computer methods. Drawings may be abstract, such as the multiview drawings shown in, or more concrete, such as the very sophisticated computer model shown in.

1.8 Technical drawing is used to represent complex technical ideas with sufficient precision for the product to be mass-produced and the parts to be easily interchanged.

THE DESIGN PROCESS

1.11 A engineering drawing is used for documentation. These types of drawings are used in manufacture, for planning, fabrication, and assembly.

1.12 The traditional design process involves organizing the creative and analytical processes used to satisfy a need or solve a problem. It is a sequential process that can be grouped into six major activities, beginning with identification of the problem and ending with documentation of the design.

1.13 This finite element model of a crane hook is used in the analysis of a part to determine where maximum stress and strain occurs when a part is placed under various load conditions.
CHANGES IN THE ENGINEERING DESIGN PROCESS

1.14 The design process in U.S. industry is shifting from a linear, segmented activity to a team activity, involving all areas of business and using computers as the prominent tool. This new way of designing, with its integrated team approach, is called concurrent engineering. Concurrent engineering involves coordination of the technical and nontechnical functions of design and manufacturing within a business. Engineers must be able to work in teams. They must be able to design, analyze, and communicate using powerful CAD systems, and they must possess a well-developed ability to visualize, as well as the ability to communicate those visions to nontechnical personnel.

1.15 Geometric modeling is the process of creating computer graphics to communicate, document, analyze, and visualize the design process. There are various applications for a CAD database in the production of a product, using concurrent engineering practices.

STANDARDS AND CONVENTIONS

1.16 Conventions are commonly accepted practices, rules, or methods used in technical drawing.

1.17 Standards are sets of rules that govern how technical drawings are represented. Standards allow for the clear communication of technical ideas. In the United States, the American National Standards Institute (ANSI) is the governing body that sets the standards used for engineering and technical drawings. Other professional organizations, such as the American Society for Mechanical Engineering (ASM), assist ANSI in developing technical graphics standards.

ALPHABET OF LINES

1.18 The alphabet of lines is a set of standard linetypes established by the American National Standards Institute (ANSI) for technical drawing. The alphabet of lines, and the approximate dimensions used to create different linetypes, which are referred to as linestyles when used with CAD. Listed below are the standard linetypes and their applications in technical drawings:

Center lines are used to represent symmetry and paths of motion, and to mark the centers of circles and the axes of symmetrical parts, such as cylinders and bolts.

Break lines are freehand lines used to show where an object is broken to reveal interior features.

Dimension and extension lines are used to indicate the sizes of features on a drawing.

Section lines are used in section views to represent surfaces of an object cut by a cutting plane.

Cutting plane lines are used in section drawings to show the location of a cutting plane.

Visible lines are used to represent features that can be seen in the current view.

Hidden lines are used to represent features that cannot be seen in the current view.

Phantom lines are used to represent a moveable feature in its different positions.

1.19 CAD software provides different linestyles for creating standard technical drawings.
SPECIALISTS AND TECHNICAL DRAWINGS

Over the years, specialized technical and engineering fields have developed to meet the needs of different industries and professions. Many of these specialized areas have also developed their own types of technical drawings.
TRADITIONAL TOOLS

1.20 Traditional mechanical drawing tools are still used in some places for the creation of traditional working drawings, but more often for sketching and informal drawing purposes. Traditional equipment includes:

1. Wood and mechanical pencils.
2. Instrument set, including compass and dividers.
3. 45- and 30/60-degree triangles.
4. Scales.
5. Irregular curves.
6. Protractors.
7. Erasers and erasing shields.
8. Drawing paper.
10. Isometric templates.

1.21 Mechanical pencils used for engineering drawings come in different lead sizes for drawing the different thicknesses of lines required on technical drawings.

1.22 Line weight refers to the relative darkness of the line. Uniform thickness means that the line should not vary.

Media are the surfaces upon which an engineer or technologist communicates graphical information. The media used for technical drawings are different types or grades of paper such as tracing paper, vellum, and polyester film.

1.23 Pencils are graded by lead hardness, from 9H to 7B: 9H is the hardest, and 7B is the softest.

1.24 Preprinted standard borders and title blocks on drafting paper are commonly used in industry.

Scales are used to measure distances on technical drawings. They are used to translate the size of real objects to dimensions that can comfortably fit on a sheet of paper.

1.25-7 The civil engineer’s scale is a decimal scale divided into multiple units of 10 and is called a fully divided scale.

1.28 A combination scale is one that has engineering, metric, and architectural components on a single scale.

1.29-33 The mechanical engineer’s scale is used to draw mechanical parts and is either fractionally divided into 1/16 or 1/32, or decimally divided into 0.1 or 0.02.

1.34 The lead in a compass is sharpened to a bevel using sandpaper.

1.35 The compass is used to draw circles and arcs of varying diameters.

1.36 A circle is drawn with a compass by first locating the center point, placing the needle at this point, and then leaning the compass in the direction you draw the circle.
1.37 A **divider** is used to transfer measurements. Unlike a compass, it has needles on both ends.

1.38-9 **Templates** are devices used to assist in the drawing of repetitive features, such as circles, ellipses, threaded fasteners, and architectural symbols.

**TECHNICAL AND COMPUTER-AIDED DRAWING TOOLS**

1.40-1 A **CAD system** consists of hardware devices used in combination with specific software. The hardware for a CAD system consists of the physical devices used to support the CAD software.

**FUTURE TRENDS**

1.42-3 Future trends in technical and engineering graphics include the use of increased realism in graphic images through the use of high resolution displays, animation and simulation, 3-D stereo, holographic, and other virtual reality techniques.

A general discussion can be had about the uses of visualization techniques in other areas. Many of your students may have had experience with computer/video/arcade games which make use of stereoscopic displays or other virtual reality (VR) techniques. Emphasize that advanced visualization techniques are important in a wide range of technical and scientific fields.

An important concept to get across to students is that 3-D models created on the computer are meant to be **virtual models** of real world objects. **Virtual reality** is simply technology which strives to make this model and its surrounding environment as realistic as possible. The two main factors in the success of this experience is the **fidelity** and **responsiveness** of the virtual environment. Together, these two factors create a sense of **immersion**.

For most VR systems, immersiveness is achieved with the following features:
- Displays
- Tracking
- Tactile/audio feedback
- Response time

A distinction should be drawn between telepresence and VR. Typically, the VR system is uses an environment which is by and large synthetic. That is, it is created completely on the computer. Telepresence uses remote video equipment under the user's control to allow someone to experience a real environment which is in a remote location.

**TECHNICAL SKETCHING**

1.44-52 It is important to emphasize to the students the role that sketching plays in the engineering design process and how **technical sketching** differs from other types of sketching, such as those used in the fine arts. Many students have the mistaken impression that since sketching is less precise than manual drafting or CAD, it is less important. They don't realize that good sketching is an acquired skill and just because sketching is less precise doesn't mean that it should be sloppy or confusing. It may be worth noting that in many
applications, technical sketches are required to follow the same graphics conventions that are imposed on formal drafted or CAD-produced drawings.

FREEHAND SKETCHING TOOLS

1.53 Note that though sketches can be created with any kind of drawing instrument on most any kind of paper, a good quality pencil and paper will help a beginning student. The instructor will have to decide their policy on the use of grid paper. Some feel it is a great way to support orthogonal and isometric line sketching in beginning (or advanced) students, but others feel it becomes a crutch which prevents them from becoming proficient on plain paper. The same decision goes for the use of tracing paper.

Another important issue is the use of straight edges. Students feel a tremendous need to produce that 'perfect' line. It is the opinion of this author that when you start using a straight edge, it is not longer a true sketch and you have lost much of the speed and flexibility advantage of sketching.

SKETCHING TECHNIQUE

1.54-7 Students will come to your class with a truly diverse abilities to mentally create and manipulate graphic imagery (visualization). Either through their life experiences or through innate ability, some students are simply better at visualization than others. This does not mean that those who don't come to your class with strong skills can't be taught many of the skills presented in the text. What it does mean is that it will be worth your while to try to informally assess your student's visualization abilities; either through exercises presented in this chapter, direct observation, or other methods. The ability level of your students may influence the level of instruction needed to get students to an appropriate level of proficiency.

It is important to emphasize the dynamic qualities of the visualization process. Not only can this dynamic process be taking place solely in one head, but also between the mind, the eyes, and some physical stimulus such as a drawing or an object.

To apply these ideas in a more functional way, have your students experience this feedback loop. If you have already done some sketching exercises, then ask them to sketch a simple object in pictorial form. Now verbally describe changes you want them to make in their object (e.g. drill a hole through it, chamfer a corner, etc.). Ask them to first mentally imagine this operation and then sketch it. They can also do this completely on their own; have them start with a simple shape and then transform it into a common household object over a series of four or five sketches.

1.58-9 One of the most fundamental techniques in sketching is contour sketching. This technique defines the edges and contours of the object. The lines also define the boundary between the object and the surrounding space.

1.60-1 Variations on contour sketching include negative space sketching and upside-down sketching.

1.62-5 Encourage students to explore with different paper positions and body postures for drawing their lines. Emphasize the need to develop an appropriate balance of speed and accuracy in their linework. Encourage them not to look right at where the pencil is but to where the pencil is going to. Intermediate points (especially for curved lines) can be of great help in creating lines which follow the marked path.
1.66-8 Get students comfortable with sketching out squares to guide circle and circular arc construction and rhomboids for elliptical curves. With the **guide boxes** in place, have students develop a feel for the proper curvature relative to the box. Trying to sketch without guide boxes is a common pitfall with beginning students and happens almost as often on small diameter circles as it does with large ones.

**PROPORTIONS AND CONSTRUCTION LINES**

1.69-75 A logical extension of the use of guide boxes for circles and ellipses is the use of bounding (guide) boxes for developing the **proportions** of the sketch. Emphasize the importance of their use since all but the most gifted students are unlikely to have the visualization skills necessary to control the sketch proportions 'on the fly'. Encourage them to not only make small hash marks to mark distances, but to draw complete construction lines. These lines subdivide regions of the sketch and help the student refine the object from a rough whole to a detailed sketch. This process goes hand in hand with developing a student's visualization skills of looking at objects at various levels of detail; from the overall shape of an object to the details of particular features to where these features are located on the overall object.

**LETTERING**

1.76-7 Lettering is certainly one area where CAD has definitively increased the speed and accuracy of engineering and technical drawing. On the other hand, sketching done by hand cannot take advantage of the computer. For that reason, lettering has been placed in the chapter on sketching. In addition, this section also introduces many of the text variables you have at your disposal when using a CAD system. If you have not introduced CAD yet in your course, you may want to come back and review portions of this section when you do.

1.78-9 In addition to the ANSI standards, you may have other rules of thumb to convey to the students. Good and bad examples of lettering are always helpful in illustrating these principles.

1.80 Again, if the emphasis on your course is on CAD, you may want to only briefly touch on this section. By having all the students do a small amount of practice lettering in class, you can identify those needing help and have them do some remedial work out of class. If your primary interest in lettering is for use on sketches, you may not want to discuss lettering guides, since they slow down sketching much in the same way straight edges do.

1.81 Emphasize that guidelines (construction lines) are just as important in lettering as they are in sketching and drafting. You may decide, however, that those students who don't seem to be having too much trouble keeping their lettering aligned vertically, can skip putting in their vertical guidelines.
1.82 Cover not only the design style of each of the letters but also the numbers. There especially is a tendency to use non-standard designs for numbers among beginning students. Proper spacing is also something important to cover. Emphasize that the idea is to have uniform volume between the letters, not necessarily uniform distances between the nearest elements of the letters.

Though different companies and industries may use different computer lettering styles, Single Stroke Gothic is still the ANSI standard. (In AutoCAD, the closest equivalent is Roman Simplex). There can be a tendency among students to go a bit wild with their font choices (if given the opportunity) on a CAD system.

1.83-7 Within the same font, there are quite a few ways of varying the lettering, including plain, bold, slant, aspect, alignment (justification), etc. Point out times where it is appropriate to use these options. Explain to your students that the object is always drawn full scale in the CAD system, but that lettering may have to drawn at something other than the ANSI standard 3mm to account for print/plot scaling; that is, the 3mm standard is for the size on the printed/plotted page.

**TEXT ON DRAWINGS**

1.88 Examples from Chapter 10 on production drawings might to helpful in explaining the different areas where text is used on a drawing. Note that lettering within the drawing area should almost always conform to the ANSI standard 3mm, but that different sized and style text is often incorporated in other areas such as the titleblock.

If you can, point out examples of graphics which would clarified with the addition of a small amount of text and text notes which would be clarified by the addition of some graphic elements.

**SUMMARY**

As a student of engineering graphics, you will study and learn to apply the tools used to create engineering drawings and models. Even more important, you will also learn the underlying principles and concepts of engineering graphics, such as descriptive geometry. You will also learn the standards and conventions that will enable you to create drawings and models that can be read and accurately interpreted by engineers or technologists anywhere.

The tools used for technical drawing include traditional ones, such as the triangle and the compass, and CAD. Traditional tools are used to make technical drawings by hand, and it takes practice and repetition to become proficient at their use. Although with CAD there is less emphasis on developing good technique, it still requires practice and repetition to attain proficiency.

The ability to draw is a powerful skill. It gives a person’s thoughts visible form. Engineering drawings can communicate complex ideas both efficiently and effectively, and it takes special training to be able to produce these complex images. If drawings are “windows to our imaginations,” then engineering drawings
are specialized windows that give expression to the most complex, technical visions our minds can imagine. Engineering drawing does more than communicate. Like any language, it can actually influence how we think. Knowing how to draw allows you to think of and deal with many problems that others may not. A knowledge of technical graphics helps you more easily envision technical problems, as well as their solutions. In short, engineering graphics is a necessity for every engineer and technologist.

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Sketching is an important tool for quickly and efficiently communicating design ideas. It is a particularly useful tool early in the design process, when several ideas are being explored. One of the appealing characteristics of sketches is the minimal amount of equipment needed for their creation. A pencil, eraser, and paper are the only tools really necessary for creating a sketch. Increasingly, software being developed to run on low-cost computer systems has many of the same attributes as hand sketching. This new software has the potential of allowing a more direct translation of sketched designs into final, refined models that can be used in manufacturing and construction.

Whether a sketch is created by hand or on the computer, there is a basic set of techniques that should be used. Sketches are meant to be quickly created approximations of geometric forms. Therefore, exact measurements are usually not used in sketching. Instead, construction line techniques are used to preserve the proportions of different features of the object.

The process of transferring the features of an object onto a sheet of paper is called projection. One way of defining the projection relates to whether the lines projecting the features of the object are all parallel to each other. The types of projection include isometric pictorial, oblique pictorial, and multiview. These projections constitute the most popular methods used in engineering and technical graphics. Another type of projection, perspective, more closely matches how you perceive objects in the real world. This type of projection is less commonly used, in part because of the difficulty in laying out the sketch, and also because of the distortions it creates in the features of the object drawn.

The graphical methods used in creating a sketch communicate considerable information. At times, however, words are more effective for providing information on a drawing. The use of a standard method of lettering ensures that text in a drawing will be clear and legible. Computers are used extensively for generating text. This is due in part to the flexibility with which text can be generated and modified to meet specialized needs. Later chapters in this book will go into more detail as to the proper use and placement of text in engineering and technical graphics.

The mind uses many visualization tools, working in concert, to interpret the world. The mind engages in constant problem solving in the interpretation process. Part of this problem-solving process is automatic. However, you can develop numerous sketching and modeling techniques that will help. With a better understanding of how the mind interprets what it receives, you can use conscious mental power to assist in this process. You can also learn to bring physical processes into play. For example, you may be able to pick up an object and rotate it, to gain a better understanding of the object. More importantly, you may be able to create a sketch which will help you in the visual problem-solving process.

**GOALS REVIEW**

1. Describe why the use of graphics is an effective means of communicating when designing. Section 1.2
2. Define standards and conventions as applied to technical drawings. Section 1.5
3. Describe the design process, Sections 1.3 and 1.4
4. Identify the important parts of a CAD system used to create technical drawings. Section 1.12
5. Identify the important traditional tools used to create technical drawings. Section 1.8 Use sketching and CAD to draw lines, circles, arcs, and curves. Section 1.13
6. Read and use scales. Section 1.8
8. Identify standard metric, U.S., and architectural drawing sheet sizes. Section 1.8.2
9. Identify the types and thicknesses of the various lines in the alphabet of lines. Section 1.6
10. Create a design sketch using pencil or computer, Section 1.12
11. Identify and use sketching tools. Section 1.13.1
12. Follow good hand-lettering practice. Section 1.16

QUESTIONS FOR REVIEW

1. Define the following terms: drawing, engineering drawing, and technical drawing. What are the distinctions among these terms?

2. What are ideation drawings used for?

3. What is the purpose of document drawings?

4. Why are technical drawings an important form of communication for engineers and technologists?

5. How might graphics be used in your area of study or work?

6. Define standards.

7. Define conventions.

8. List three examples of how graphics are used in engineering design.

9. Sketch and label the concurrent engineering model in Figure 1.14.

10. Define CAD.

11. List the typical hand tools used to create a drawing.

12. What are templates used for? Give an example of one.

13. Describe how pencils are graded.

14. List the standard paper sizes used for technical drawings.

15. How are metric drawings clearly identified on the drawing sheet?
16. Define and describe the uses for technical sketching.

17. Define an ideation sketch and explain how it differs from a document sketch.

18. List the two important uses for text on a drawing.

19. Define font.

20. Define text alignment and sketch an example.

21. Define text aspect ratio and give examples.

**TRUE AND FALSE QUESTIONS**

1. In engineering, 8% of the design process is graphically based.

2. Graphics is confined to only one part of the engineering design process.

3. Artistic applications are typically considered distinct from technical applications of graphics.

4. Part of the reason why technical graphics is so effective is that it does not have to conform to conventions and standards like writing and math does.

5. The American Society for Mechanical Engineers (ASME) assists the American National Standards Institute (ANSI) in defining standards.

6. Visualization of geometric information is an important use for technical graphics.

7. The use of technical graphics is restricted primarily to mechanical engineering.

8. A mouse input device can be either mechanical or optical.

9. A drawing using a metric scale is clearly labeled with the word METRIC on it.

10. In order to choose the appropriate scale, you must know the size of the paper you will be drawing on.

11. Templates are commonly used in place of scales.

12. Hidden lines are used exclusively for representing features on the interior of an object.

13. CAD stands for computer-automated design.

14. Technical sketching is only appropriate for fine detail work near the conclusion of the design process.

15. Technical sketching is only appropriate for capturing simplified conceptions of the design very early in the design process.
16. Ideation sketches are often done quickly in order to explore as many design ideas as possible.

17. Lettering is only used in the drawing area of a production drawing.

18. There is only one ANSI approved text style (font).

19. A text aspect ratio of 6 would create a very tall, narrow letter.

20. Virtual objects cannot be created in a regular 3-D CAD system.

MULTIPLE CHOICE QUESTIONS

1. Graphics is used in the engineering design process for:
   a. communicating
   b. conducting analyses
   c. solving problems
   d. all of the above

3. Which is not a geometry which is considered a foundation for technical graphics?
   a. Relative
   b. Descriptive
   c. Analytic
   d. Plane

4. _____________ are commonly accepted practices, rules, or methods.
   a. Standards
   b. Laws
   c. Conventions
   d. Habits

5. Which of the following input devices does not translate hand movements into instructions for the computer?
   a. Scanner
   b. Mouse
   c. Keyboard
   d. Tablet and puck

7. Which tool can be used to draw a 90 degree angle?
   a. 30/60 triangle
   b. protractor
   c. drafting machine
   d. all of the above

8. Which set of lead grades has a grade out of sequence?
   a. H, HB, B, 3B
   b. 7B, H, F, 3H
   c. 6B, B, H, 4H
d. 9H, HB, B, 2B

9. Which type of line is part of a dimension?
   a. break lines
   b. phantom lines
   c. extension lines
   d. cutting plane lines

10. Which type of line is particular to section drawings?
    a. break lines
    b. phantom lines
    c. extension lines
    d. cutting plane lines

11. Which angle cannot be made with either a 45 or 30/60 triangle or a combination of the two?
    a. 90
    b. 70
    c. 30
    d. 15

12. A drawing instrument set usually contains all of the following, except:
    a. bow compass
    b. scale
    c. dividers
    d. sextent

13. Which line type is thin and light?
    a. visible lines
    b. center lines
    c. construction lines
    d. all of the above

14. Which line type is thick and black?
    a. visible lines
    b. center lines
    c. construction lines
    d. all of the above

15. What type of sketch are typically used in the refinement stage of the design process?
    a. isometric
    b. document
    c. oblique
    d. ideation
16. Which type of line has precedence over all other types of lines?
   a. a hidden line
   b. a center line
   c. a visible line
   d. none of the above

17. Which statement(s) is true about the precedence of lines?
   a. a hidden line has precedence over a center line
   b. a center line has precedence over a visible line
   c. a visible line has precedence over a miter line
   d. all of the above

18. In a VR system, all of the following statements about immersiveness are true, except:
   a. response time is an important factor
   b. both display resolution and display size can affect it
   c. the visual sense is the only sense to affect it
   d. tracking body movement is an important factor