

# Drafting Equipment

## Section 3.1

Board-Drafting  
Equipment

## Section 3.2

Computer-Aided Drafting (CAD) Equipment

### Chapter Objectives

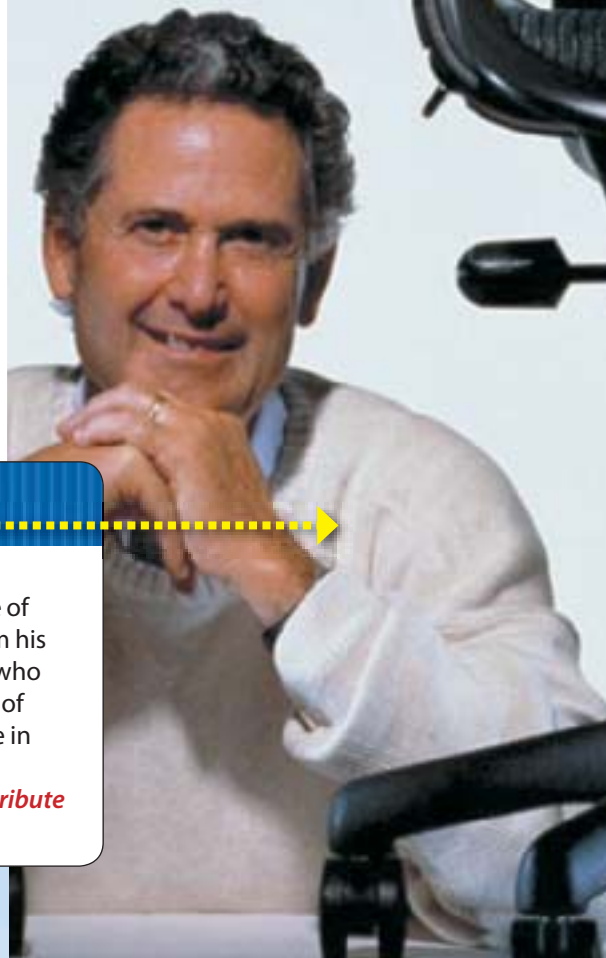
- **Identify** and describe basic board-drafting equipment.
- **Describe** types of drafting media.
- **Select** the appropriate scales for architectural, mechanical, and civil drafting.
- **Describe** the components of a CAD workstation.
- **Identify** the three main types of CAD software.
- **Describe** the characteristics of efficient CAD furniture.
- **Identify** CAD safety guidelines.

### Discuss The Photo

#### Applying Skill and Patience

Chadwick's love of furniture design comes from his cabinetmaker grandfather who taught him the importance of skill, precision, and patience in using the tools of the trade.

*How do these qualities contribute to good design?*





## DRAFTING CAREER *Success*

**Bill Stumpf and Don Chadwick,**  
*Product Designers*

### From Concept

"We designed the [Aeron] chair... as a metaphor of human form," says Bill Stumpf. He and Don Chadwick won the Design of the Decade (1990s) award for their ergonomic chair, which is in the Museum of Modern Art's permanent collection. "The only way to be sure a chair is comfortable is to actually sit in it..." Chadwick says.

### To Reality

Stumpf and Chadwick needed to develop a new material for the Aeron because foam, traditional chair padding, can cause skin temperatures to increase by as much as 20%. They solved the problem by designing *Pellicle*, a lattice-like material that promotes air circulation and helps evenly distribute weight.

### Academic Skills and Abilities

- Problem identification, formulation and solution
- Mathematics
- Reading/language arts
- Creative thinking
- Reasoning

### Career Pathways

Science clubs, Boys & Girls Clubs, and high school technology camps are among organizations that provide programs for high school students to participate in hands-on science projects.



Go to [glencoe.com](http://glencoe.com) for this book's OLC to learn more about Bill Stumpf and Don Chadwick.

# 3.1

# Board-Drafting Equipment

## READING GUIDE

### Before You Read

**Connect** As a beginning drafter, you will need to purchase your tools. Which tools do you think are important to include in your basic board drafting kit?

### Content Vocabulary

- drawing board
- T-square
- irregular curve
- vellum
- dividers
- true edge
- protractor
- template
- case instruments
- compass
- scales

### Academic Vocabulary

Learning these words while you read this section will also help you in your other subjects and tests.

- media
- minimal

### Graphic Organizer

Use a table like the one below to organize information on various types of board-drafting equipment discussed in this section.

Drafting Machine (functions)	Drafting Media (types)	Bow Instruments (functions)



Go to [glencoe.com](http://glencoe.com) for this book's OLC for a downloadable version of this graphic organizer.

### Academic Standards



#### English Language Arts

Conduct research and gather, evaluate, and synthesize data to communicate discoveries (NCTE)



#### Mathematics

**Measurement** Apply appropriate techniques, tools, and formulas to determine measurements (NCTM)

**NCTE** National Council of Teachers of English

**NCTM** National Council of Teachers of Mathematics

# Basic Board-Drafting Equipment

## What is a common purpose of all drafting tools?

While sketches can show a design idea in its initial development stages, final drawings communicate technical information to the people who design and manufacture the product. They are made with drafting instruments on drafting **media** or using a CAD system.

Drafting instruments and equipment, as well as computer-aided drafting (CAD) systems, constitute the “tools of the trade” in the engineering, design, and drafting office. Being able to identify them is the first step in the process of learning to use them.

## Drawing Tables and Desks

Drawing tables and desks come in many different sizes and types. **Figure 3-1** shows a typical drafting table. The table surface should be cleaned daily to avoid transferring pencil graphite smudges onto your drawings. Some drawing tables can be adjusted for either standing or sitting.

## Drawing Boards

The **drawing board** is a large, flat board on which you attach a drawing sheet to make a drawing. A drawing board can be the surface of a drafting table or a separate board



**Figure 3-1**  
A typical drafting table

that is placed on top of a desk or table. They are made so that they will not warp and so that the guiding edge, or **true edge**, will stay straight. The most basic boards usually measure 18" × 24" (460 × 600 mm). Professional boards are typically larger, however, and may be any size needed.

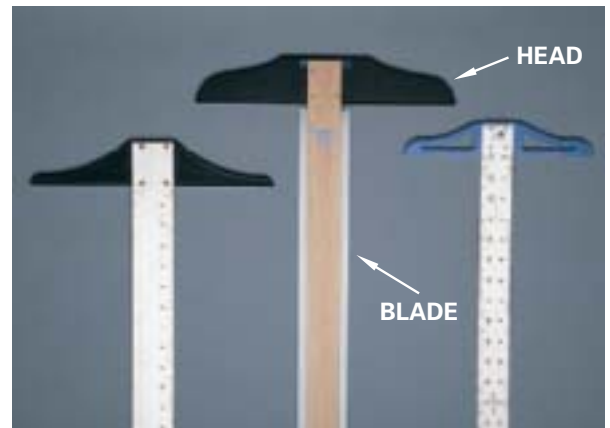
## T-Squares

A **T-square** is a drafting instrument made up of a head that lines up with the true edge of a drafting board and a blade, or straight-edge, that provides a true edge. **Figure 3-2** shows three types of T-squares. Most T-squares have plastic-edged wooden blades or clear plastic blades with heads made of wood or plastic. The most accurate ones use steel or aluminum blades with metal heads.

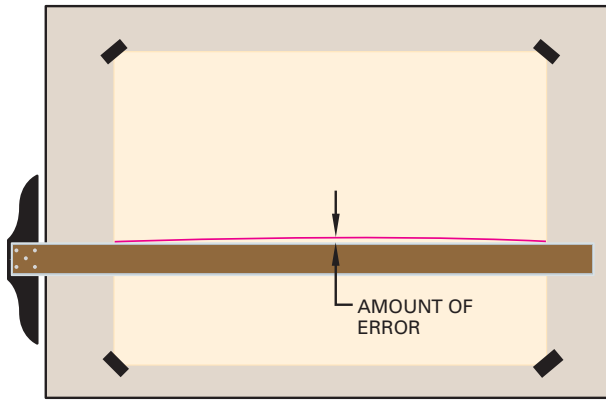
You can easily check the accuracy of your T-square (see **Figure 3-3** on page 66). First, on a clean sheet of paper, draw a line along the drawing edge of the T-square. Second, turn the drawing sheet upside down and line up the T-square’s drawing edge with the other side of the line. If the drawing edge and the line do not match, the T-square is not accurate and should be replaced.

### Reading Check

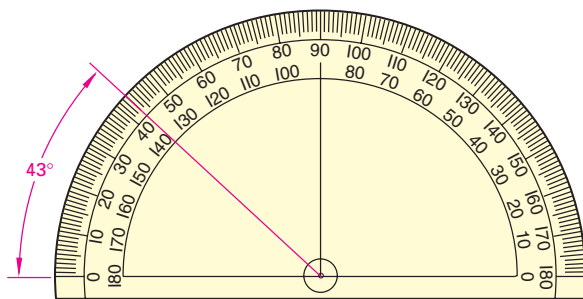
**Explain** What is the T-square tool used for in drafting?



**Figure 3-2**  
T-squares are available in various styles and materials.



**Figure 3-3**  
Check to see that the T-square is accurate.



**Figure 3-4**  
A protractor is used to measure or lay out angles.



**Figure 3-5**  
A parallel-ruling straightedge is a convenient instrument that can save time.



**Figure 3-6**  
An arm- or elbow-type drafting machine

## Parallel-Ruling Straightedges

Many drafters prefer to use a *parallel-ruling straightedge* (see **Figure 3-4**). This device works like the T-square but is attached to the drawing board and slides up or down the board in parallel positions. This provides a true edge anywhere in the drawing area.

## Triangles

Drafters use two types of *triangles* in combination with a T-square or parallel ruling straightedge to draw lines at various angles. The 45° triangle has one 90° angle and two 45° angles. The 30°-60° triangle has 30°, 60°, and 90° angles.

## Protractors

A **protractor** is an instrument that is used to measure or lay out angles. **Figure 3-5** shows a semicircular protractor measuring a 43° angle.

## Drafting Machines

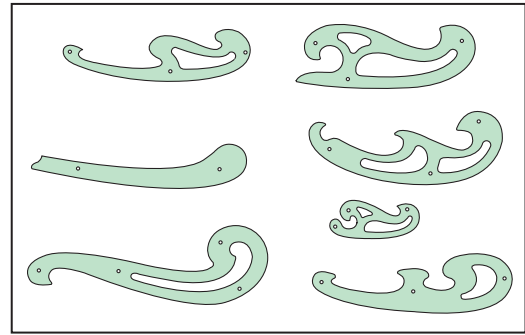
A *drafting machine* combines the functions of the T-square, triangles, **scales**, and protractor. Scales are used to lay off and measure distances. The drafting machine has arms that move these instruments in parallel positions to any location on the board. This lets you draw faster and more easily.

Two drafting machine types are currently used. The arm- or elbow-type (**Figure 3-6**) uses an anchor and two arms to hold the protractor and two scales. The scales are ordinarily at right angles to each other.

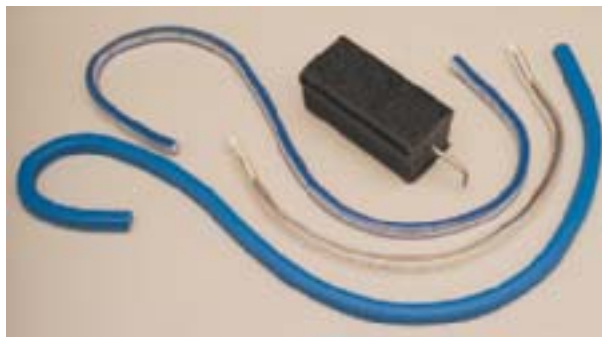
The track-type drafting machine (**Figure 3-7**) uses a horizontal guide rail at the top of the board and a moving arm rail at a right angle to the top rail. It is specially adapted for wide drawings, but can also be used for regular-sized drawings. The scales should be cleaned with a mild soap and warm water daily. Also, check scales regularly for accurate alignment and adjust when necessary.



**Figure 3-7**  
The track-type drafting machine



**Figure 3-8**  
Some examples of irregular, or French, curves



**Figure 3-9**  
Flexible curves for plotting smooth curves. Some drafters use “ducks” such as the one (the rectangular object) shown here, to position flexible curves accurately.



**Figure 3-10**  
Templates are made for many different uses and save a good deal of time.

## Other Basic Tools

In addition to the equipment described thus far, board drafters use a variety of other tools, instruments, and equipment. These make up an important part of a board drafter’s everyday tool kit.

## Irregular Curves

Drafters use a tool called an **irregular curve**, or French curve, to draw noncircular curves such as spirals and ellipses. These devices are made of sheet plastic and come in different shapes, some of which are shown in **Figure 3-8**.

Many drafters also use flexible curves such as those in **Figure 3-9**. Flexible curves can be

adjusted to complex curved paths that may be difficult to draw using other types of irregular curves.

## Templates

A **template** is a thin, plastic sheet with holes cut in the various shapes a drafter might need to draw. By tracing around the holes, the drafter can quickly and accurately draw the shape required. Templates are available with basic shapes, like circles, or for special uses, such as drawing bolt heads, nuts, and electrical, architectural, and plumbing symbols. See **Figure 3-10** for several different templates.

# Drafting Media

## What qualities are important for drafting media?

Technical drawings are made on many different kinds of drawing sheets, known as *drafting media*. Paper is one kind of drafting medium. Drawing paper may be white, cream, or pale green and comes in many sizes and qualities.

## Types of Drafting Media

Most drawings are made on paper, tracing paper, vellum, or polyester drafting film. **Vellum** is paper that has been treated to make it more transparent. This is important if you need to copy part of the drawing onto another sheet later. *Polyester drafting films* are widely used in industrial drafting rooms. They have a matte (dull, rough) surface, are transparent, durable, and suitable for both pencil and ink work.

## Sizes of Drafting Media

Trimmed sizes of drafting media follow standards set by two organizations: the American Society of Mechanical Engineers (ASME) and the International Standards Organization (ISO). See **Table 3-1** for the specifications used by both organizations.

ASME standard drawing sheet size A is based on the dimensions of 8.5" × 11" (letter-sized) paper. Standard-size sheets can be cut from rolls of film or paper 36" or 42" wide with **minimal** waste.

The ISO standard is developed from a base sheet with an area of about 1 square

meter (1 m<sup>2</sup>). Sheet sizes are based on a length-to-width ratio of 1 to the square root of 2 (1:2). Each smaller size has an area equal to half of the preceding size. Multiples of these sizes also are used for larger sheets.



### Reading Check

**Name** What two organizations set the standards for the trimmed sizes for drafting media?

# Drawing Instruments

## What types of instruments are included in a typical drafting kit?

Drawing instruments are needed to produce accurate technical drawings. Instruments can be purchased as individual items or in sets, also called **case instruments**. **Figure 3-11** shows a basic set of drawing instruments. Note that many instruments have pointed ends that are very sharp and can cause injury. They should always be carefully handled and stored in their case when not in use.

A full set of instruments usually includes compasses with pen part, pencil part, lengthening bar, dividers, bow pen, bow pencil, bow dividers, and one or two ruling pens (optional). Most drafters favor large-bow sets similar to the one in Figure 3-11. These are known as *master*, or *giant*, bows and are made in several patterns. With large bows, 6" (152 mm) or longer, circles can be drawn up to 13" (330 mm) in diameter or, with lengthening bars, up to 40" (1016 mm) in diameter.

## Dividers

You can divide lines, arcs, and circles into equal parts and transfer distances from one place to another with **dividers** (see **Figure 3-12**).

Bow dividers are generally more rigid than friction-joint dividers and are therefore more accurate. Although friction-joint dividers are more quickly adjusted, they are also more easily knocked out of adjustment.

ASME (Inches)		ISO (Millimeters)	
Drawing Size	Overall Paper Size	Drawing Size	Overall Paper Size
A	8.50" × 11.00"	A0	841 × 1189 mm
B	11.00" × 17.00"	A1	594 × 841 mm
C	17.00" × 22.00"	A2	420 × 594 mm
D	22.00" × 34.00"	A3	297 × 420 mm
E	34.00" × 44.00"	A4	210 × 297 mm



**Table 3-1**

Standard drawing-sheet sizes



**Figure 3-11**  
A large-bow set of drawing instruments

## Compasses

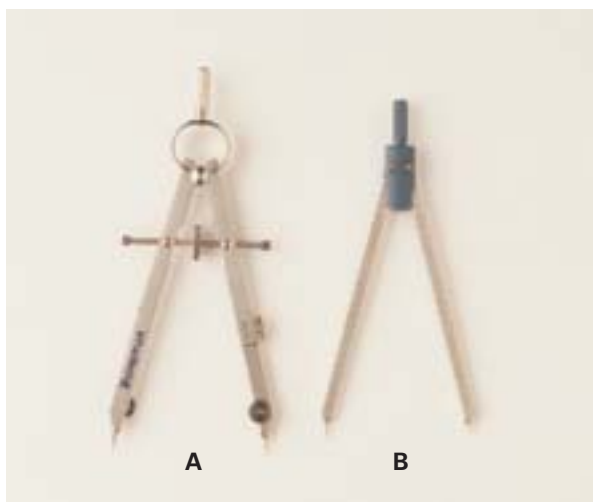
Regular curves are curves with points that are all exactly the same distance from a center point.

These curves can be drawn with a **compass** like the ones in **Figure 3-13**. Bow compasses, like bow dividers, are more rigid than their friction-joint counterparts. Friction-joint compasses are easily knocked out of alignment.

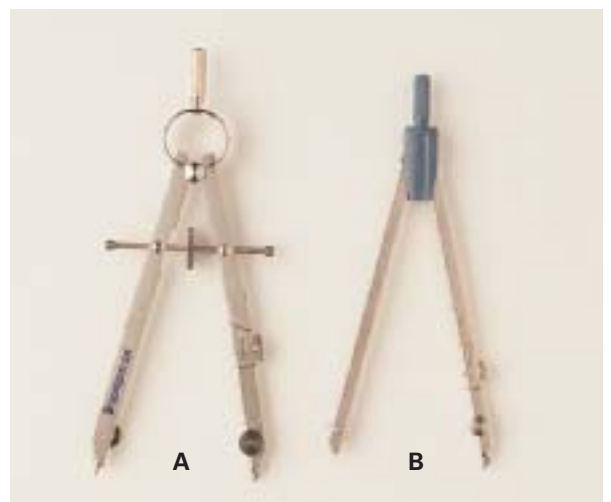
## Beam Compasses

*Beam compasses* like the one in **Figure 3-14** (see page 70) are used to draw arcs or circles with large radii. The beam compass has a bar, or beam, on which movable holders for a pencil (or pen) part and a needle part can be attached and fixed as far apart as desired. By putting a needle point in both holders, you can use a beam compass as dividers.

The usual bar or beam is about 13" (330 mm) long. However, by using a coupling to add extra length, you can draw circles of larger size.



**Figure 3-12**  
Two types of dividers: (A) bow dividers and (B) friction-joint dividers



**Figure 3-13**  
Two types of compasses: (A) bow compass and (B) friction-joint compass





 **Figure 3-14**

Beam compasses are used for large radii.

## Bow Instruments

The bow instruments include the bow pencil, the bow dividers, the bow pen, and the drop-spring bow compass; these are shown in **Figure 3-15**. Bow instruments, except for the drop-spring bow compass, are available with either a center wheel or a side wheel for making adjustments.

The bow instruments are easy to use and are accurate for distances or radii less than 1.25" (32 mm). They hold small distances better than the large instruments. Use them for the following purposes:

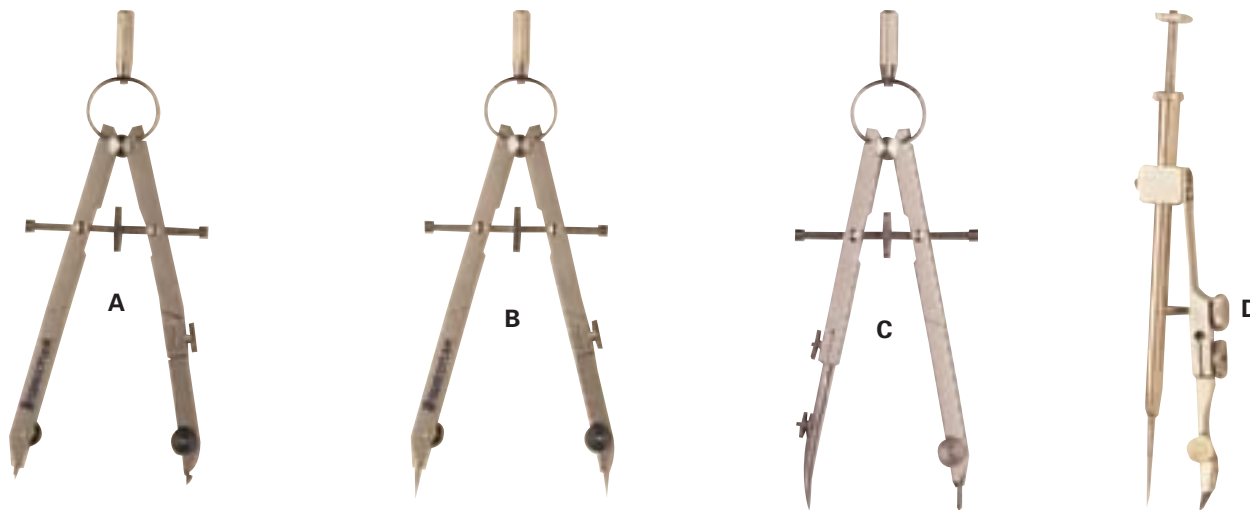
- *Bow pencil* (**Figure 3-15A**) — to draw small circles.
- *Bow dividers* (**Figure 3-15B**) — to transfer small distances, mark off a series of small

distances, and divide a line into small spaces.

- *Bow pen* (**Figure 3-15C**) — to draw small circles. It is included in a set of bow instruments to offer drafters a choice of making circles or arcs in pen or pencil.
- *Drop-spring bow compass* (**Figure 3-15D**) — to draw very small circles. It is especially useful for drawing many small circles of the same size, such as rivets.

### Reading Check

**Identify** What tool is used to divide lines and transfer distances from one place to another?



 **Figure 3-15**

Bow instruments are used for drawing small circles and arcs and for stepping off short distances: (A) bow pencil, (B) bow dividers, (C) bow pen, and (D) drop-spring bow compass.

# Drafting Pencils and Pens

## How do pencils, pens, and erasing tools affect the quality of a drawing?

Several types of pencils and pens have been developed specifically for drafting. The type you select depends on the drawing sheet you use and the characteristics of the line you want to draw.

### Drafting Pencils

Both regular wooden pencils and mechanical (stick lead) pencils are used for technical drawing. However, mechanical drafting pencils are favored because they maintain line consistency better than wooden pencils. Many types of lead are available, but graphite lead is most commonly used.

### Grades of Graphite Sticks or Pencils

Graphite drafting pencils are made in 17 degrees of hardness, or grades (see **Table 3-2**). The pencil grade you use depends on the type of drawing surface and the nature of the drawing itself. It also depends on how opaque (dark)

6B	softest and blackest
5B	extremely soft
4B	extra soft
3B	very soft
2B	soft, plus
B	soft
HB	medium soft
F	intermediate, between soft and hard
H	medium hard
2H	hard
3H	hard, plus
4H	very hard
5H	extra hard
6H	extra hard, plus
7H	extremely hard
8H	extremely hard, plus
9H	hardest

 **Table 3-2**

Standard grades of drawing pencils

and thick you want the finished line to be. To lay out views on drawing paper with a fairly hard surface, use grades 4H and 6H. When you draw finished views that are to be reproduced using tracing paper or by machine, use an H or 2H pencil. Grades HB, F, H, and 2H are sometimes used for sketching and lettering and for drawing arrowheads, symbols, border lines, and so on. Very hard and very soft leads are seldom used in ordinary drafting.

### Pencils for Film

When film came into use for drawings, new pencil leads were developed. One is a plastic pencil, like a black crayon, with lead that is extruded, or squeezed out using a plasticizing process. It reproduces well on microfilm.

The second type of lead is a combination of plastic and graphite and is made by heating. This type stays sharp, draws a good opaque line, does not smear easily, erases well, and microfilms well. It can be used on paper as well as on film.

The third type does not remain as sharp as the others. However, it draws a fairly opaque line, erases well, does not smear easily, and microfilms well.

These pencils are made in only five or six grades. The companies that make them use different systems to identify the type of lead and how hard it is. You will need to experiment with the various grades.

### Technical Pens

Technical pens contain points of various size to draw a specific line width. Some technical pens have a refillable cartridge for storing ink. Others have a cartridge that is used once and then replaced. The disposable technical pen has a stainless steel point and requires little maintenance. Points for refillable pens are made of finer materials specific to the type of media to be used. The three main types of points are:

- hard-chrome stainless steel, for use on paper or vellum
- tungsten-carbide, for long wear on film, vellum, and paper (most commonly used in pen plotters)
- jewel, for long, continuous use on film

Complete sets of technical pens which include all or most of the point sizes are available. **Figure 3-16** shows the range of point sizes of technical pens.

### Drawing Ink

Ink used for technical drawings is called *drawing ink*. It must be completely opaque to produce good, uniform line tone, but also be erasable on all drafting media.



**Figure 3-16**

The range of lines and point sizes available in technical pens.

### Lettering Guides and Equipment

The lettering set in **Figure 3-17** has three basic tools: a scribe, lettering templates, and technical pens.

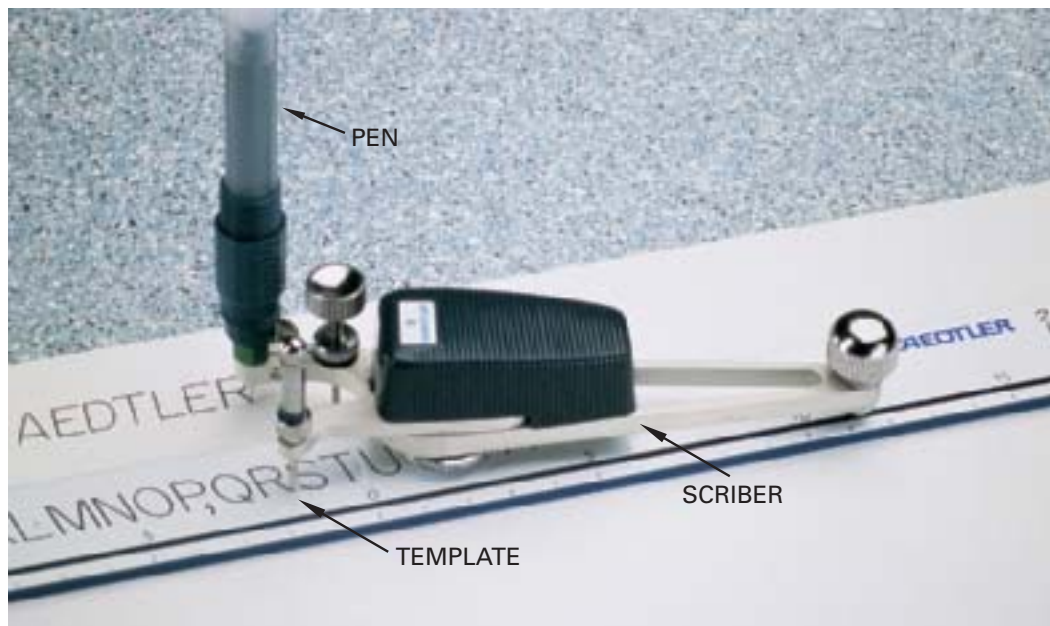
Lettering templates come in many styles and lettering sizes, from about .06" to 2" (1.5 to 50 mm) high. Other templates are used to draw symbols and shapes. The width of the pen point used depends on the height of the letters and size of the symbols.

### Erasers and Erasing Shields

Use soft erasers to clean soiled spots or light pencil marks from drawings. Rubkleen, Ruby, and Emerald erasers are generally good for removing pencil. On film, use a vinyl eraser made especially for film. Electric erasing machines may also be used.

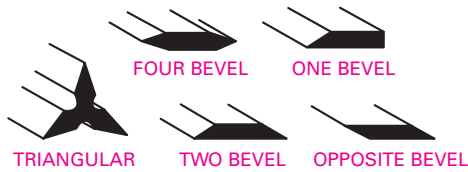
Although drawing ink is waterproof, it can easily be removed from polyester drafting film using erasers made especially for that purpose. Plastic erasers either rub away the ink line or absorb it.

To avoid erasing nearby lines accidentally, most board drafters use an erasing shield. This metal or plastic device has holes of different sizes



**Figure 3-17**

Three basic parts of a lettering set are the pen, the template, and the scribe.



**Figure 3-18**  
Examples of the various scale shapes

and shapes. By positioning the shield so that the part to be erased shows through one of the holes, you can protect other parts of the drawing.

## Scales

**How does a drafter represent objects that are either very large or very small?**

Remember that scales are used to lay off distances and to make measurements. Measurements can be full size or scaled, meaning they are in a specified proportion to full size. **Figure 3-18** shows the shapes of various scales.

## Reading Check

**Evaluate** What determines the width of a pen point to be used in a lettering template?

Some scales, such as those in **Figure 3-19A** and **B**, are open divided, meaning only the units at the end of the scale are subdivided. Other scales are full divided, as shown in **Figure 3-19C** and **D**, with subdivisions over their entire length.

## Customary-Inch Scales

Different scales are used to make different types of drawings. The commonly used inch-based scales include the architect's scale, mechanical engineer's scale, and civil engineer's scale.

## The Architect's Scale

The architect's scale (see **Figure 3-19A** on page 74) is divided into proportional feet and inches. Many schools and some drafting

STEM  
Do The Math

### Measuring Angles

For each of the three angles at right, identify whether they are acute, obtuse, or right.

Math Concept

You can measure an angle in degrees, using your protractor. The number of degrees in an angle will be greater than 0 and less than or equal to 180. You can classify angles by their size. An acute angle measures less than  $90^\circ$ . A right angle measures  $90^\circ$ . An obtuse angle measures greater than  $90^\circ$  and less than  $180^\circ$ .

$90^\circ$

LESS THAN  $90^\circ$

MORE THAN  $90^\circ$

Academic Standards

**Mathematics**

**Measurement** Apply appropriate techniques, tools, and formulas to determine measurements (NCTM)

For help with this math activity, go to the Math Appendix located at the back of this book.

offices use the triangular form because it shows many different scales, and so is versatile. However, a flat scale can be easier to use, especially when only one scale is required.

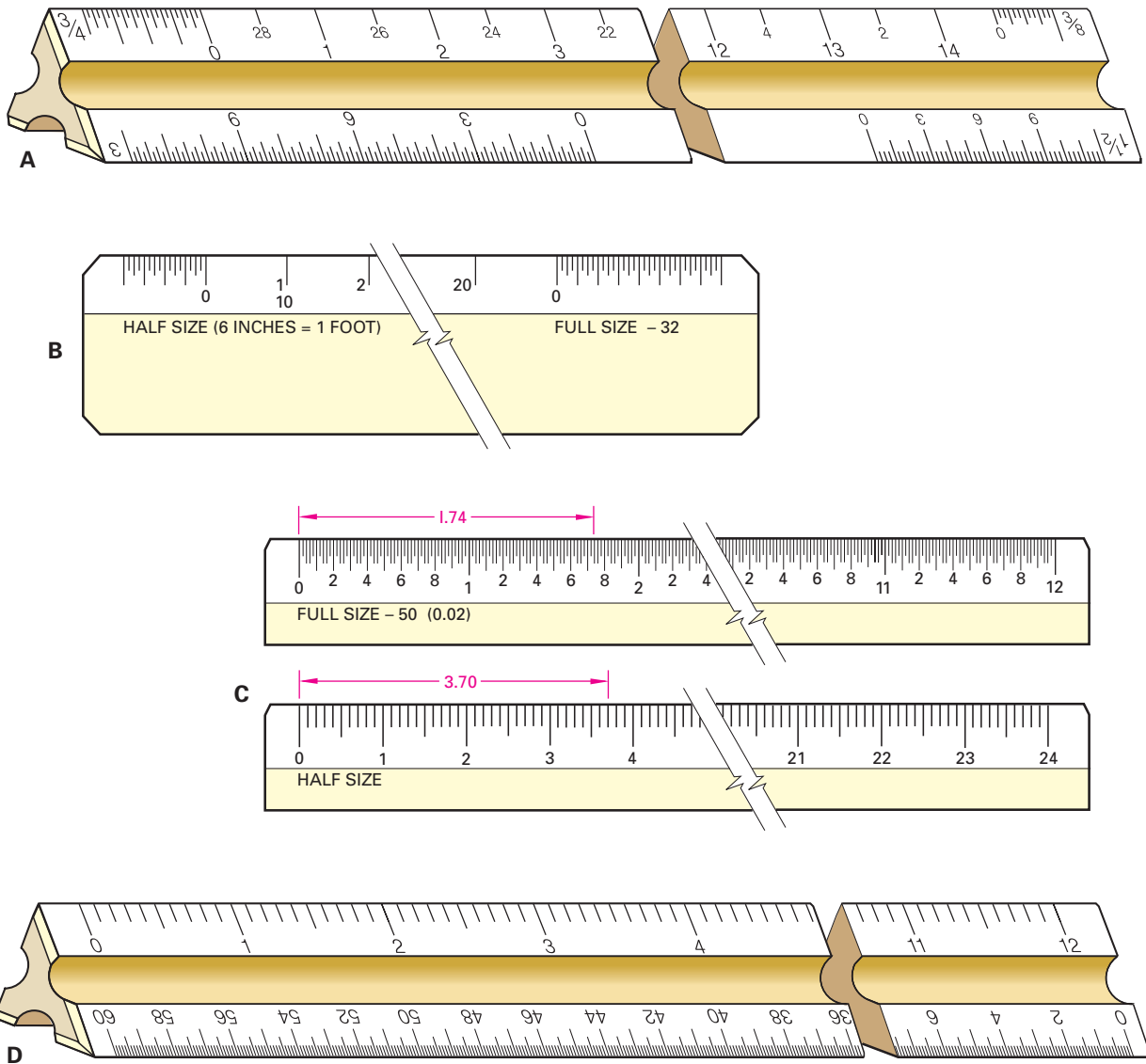
See **Table 3-3** for the usual proportional scales.

Symbols are used to represent feet (') and inches ("). For example, three feet four and one-half inches is written 3'-4½". When all dimensions are in inches, the inch symbol is usually left out. Also, on architectural and structural drawings, the inch symbol is

not shown, and the dimension is given as 3'-4½".

*Proportional scales* are used for drafting in general and particularly for drawing buildings and making mechanical, electrical, and other engineering drawings. The proportional scale to which the views are drawn should be given on the drawing.

If you use only one scale, you indicate this in the *title block*. The title block is the area on a drawing where reference information such as the drawing's title, the name of the company



**Figure 3-19**

Customary-inch scales: (A) Architect's scale, open divided. The triangular form has many proportional scales. (B) Mechanical engineer's scale, open divided. (C) Civil engineer's scale, divided into decimals. (D) Decimal-inch scales are often used in drawing machine parts.

Proportion	Gradations	Ratio
Full size	12' = 1'-0"	1:1
¼ size	3' = 1'-0"	1:4
1/8 size	1½" = 1'-0"	1:8
1/12 size	1" = 1'-0"	1:12
1/16 size	¾" = 1'-0"	1:16
1/24 size	½" = 1'-0"	1:24
1/32 size	3/8" = 1'-0"	1:32
1/48 size	¼" = 1'-0"	1:48
1/64 size	3/16" = 1'-0"	1:64
1/96 size	1/8" = 1'-0"	1:96
1/128 size	3/32" = 1'-0"	1:128

**Table 3-3**

Proportional scales

and the drafter, and the date is shown. If different parts of a drawing are to different scales, the scales are given near the views in this way:

- SCALE: 6" = 1' - 0
- SCALE: 3" = 1' - 0
- SCALE: 1½" = 1' - 0



### Reading Check

**Explain** How does a drafter use proportional scales?

## The Mechanical Engineer's Scale

The mechanical engineer's scale (**Figure 3-19B**) shows inches and fractions of an inch divided to represent inches. The usual divisions are:

- Full size—1" divided into 32nds
- Half size—½" divided into 16ths
- Quarter size—¼" divided into 8ths
- Eighth size—⅛" divided into 4ths

These scales are used for drawing parts of machines or when larger reductions in scale are not needed.

## The Civil Engineer's Scale

The civil engineer's scale (**Figure 3-19C**) divides inches into decimals. The usual divisions are:

- 10 parts to the inch
- 20 parts to the inch
- 30 parts to the inch
- 40 parts to the inch
- 50 parts to the inch
- 60 parts to the inch

With the civil engineer's scale, 1 inch may stand for feet, rods, miles, and so forth. It may also stand for quantities, time, or other units. The divisions may be single units or multiples of 10, 100, and so on. For example, the 20-parts-to-an-inch scale may stand for 20, 200, or 2,000 units.

The civil engineer's scale is used for maps and drawings of roads and other public projects. It is also used when decimal-inch divisions are needed. These uses include plotting data and drawing graphic charts.

The scale used should be given on the drawing in the following way:

- SCALE: 1" = 500 POUNDS
- SCALE: 1" = 100 FEET
- SCALE: 1" = 500 MILES
- SCALE: 1" = 200 POUNDS

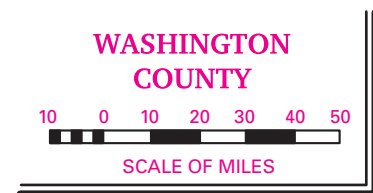
For some uses, a graphic scale is put on a map, drawing, or chart, as shown in **Figure 3-20**.

## The Decimal-Inch Scale

Like the civil engineer's scale, the decimal-inch scale (see **Figure 3-19D**) is divided into tenths of an inch. Because many manufacturers now use decimals rather than fractions (4.25" rather than 4¼"), the decimal-inch scale is used for many machine drawings.

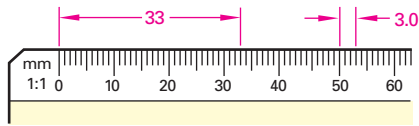
## The Metric Scale

Metric scales are divided into millimeters (**Figure 3-21**). The usual proportional scales



**Figure 3-20**

Civil engineers place graphic scales on maps to show people how to interpret them.



**Figure 3-21**

Metric scales are divided into millimeters.

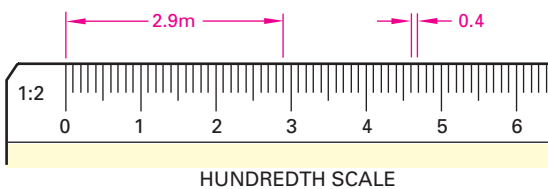
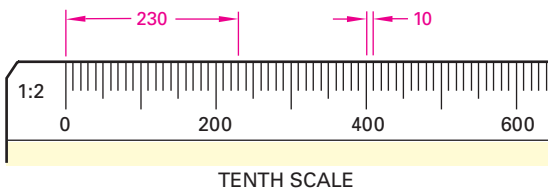
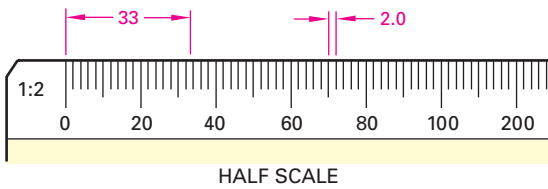
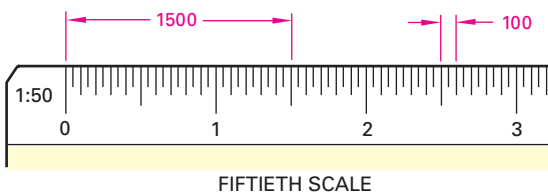
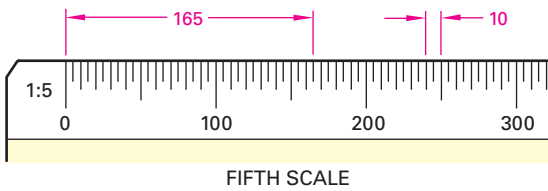
in the metric system are listed as ratios as in **Table 3-4**.

The numbers shown indicate the difference in size between the drawing and the actual part. For example, the ratio 10:1

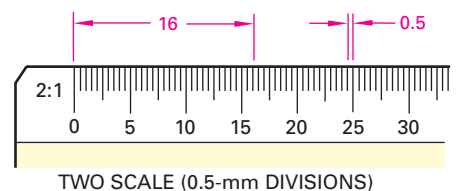
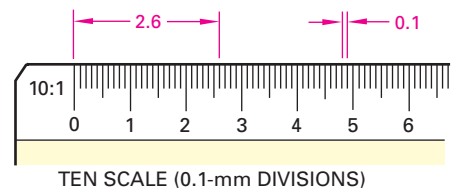
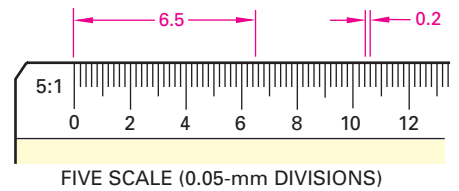
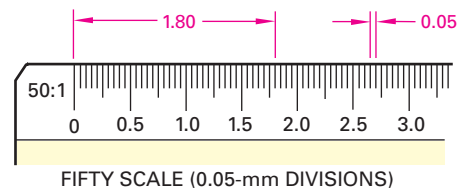
shown on the drawing means that the drawing is 10 times the actual size of the part. A ratio of 1:5 on the drawing means the object is 5 times as large as it is shown on the drawing.

If different parts on the same drawing are to different scales, the scales are specified near the views in this way:

- SCALE: 1:2
- SCALE: 1:5
- SCALE: 1:10
- SCALE: 2:1
- SCALE: 20:1



**A**



**B**

**Figure 3-22**

Metric scales: (A) for reduction and (B) for enlargement

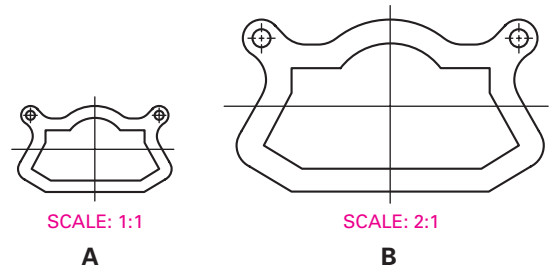
Enlarged	Same Size	Reduced
1000:1	1:1	1:2
500:1		1:5
200:1		1:10
100:1		1:20
50:1		1:50
20:1		1:100
10:1		1:200
5:1		1:500
2:1		1:1000

**Table 3-4**

Metric proportional scales

Notice that scales are generally given in multiples of 2 or 5.

To reduce an object's drawing size, use one of the scales shown in **Figure 3-22A**. To enlarge an object's drawing, use one of the scales in **Figure 3-22B**. See **Figure 3-23**



**Figure 3-23**

A part drawn at two different scales

for an example of an enlarged-scale drawing. In **Figure 3-23A**, the drawing is shown at a scale of 1:1 (same size). In **Figure 3-23B**, the same part is enlarged to 2:1 (double size).

## Section 3.1 Assessment After You Read

### Self-Check

1. **Identify** the basic equipment used in board drafting.
2. **List** and **describe** various types of drafting media.
3. **Describe** the different scales used for architectural, mechanical, and civil drafting.

### Academic Integration

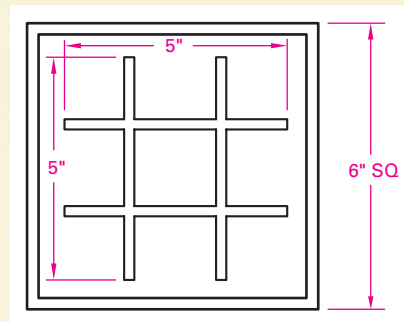
#### Mathematics

4. **Draw Angles Using a Protractor**  
Draw an example of an acute angle, a right angle, and an obtuse angle. Label each and provide the angle measurement.

### Drafting Practice

In Chapter 2 you learned about free-hand sketching. The following problem is designed to give you additional practice. This sketching problem is designed to fit on an 8.5" × 11" drawing sheet. Quarter-inch grid paper may be used. A straightedge may be used for drawing long straight lines. Do not add dimensions (sizes). Estimate sizes not given.

5. Make a freehand sketch of the tic-tac-toe board shown in **Figure 3-24**.



**Figure 3-24**



# 3.2

## Computer-Aided Drafting (CAD) Equipment

### READING GUIDE

#### Before You Read

**Preview** It is important to have a functional work area. What would you consider if you were told that you could design your own work space and purchase the furniture and equipment for it?

#### Content Vocabulary

- CPU
- CAD software
- ergonomics

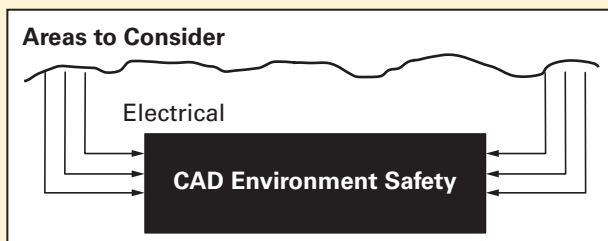
#### Academic Vocabulary

Learning these words while you read this section will also help you in your other subjects and tests.

- compatible

#### Graphic Organizer

On a chart like the one below, organize facts about safety areas to consider in the CAD environment



Go to [glencoe.com](http://glencoe.com) for this book's OLC for a downloadable version of this graphic organizer.

#### Academic Standards



##### English Language Arts

Read text to acquire new information (NCTE)



##### Mathematics

**Measurement** Understand measurable attributes of objects and the units, systems, and processes of measurement (NCTM)



##### Science

**Personal and Social Perspectives** Environmental Quality and Human Health (NSES)

**NCTE** National Council of Teachers of English

**NCTM** National Council of Teachers of Mathematics

**NSES** National Science Education Standards

## CAD Hardware Equipment

### What factors should you consider when setting up a CAD system?

All CAD workstations require computer *hardware*, the equipment that comprises a computer system. Standard CAD hardware includes the central processing unit (CPU), the monitor, storage devices, input devices, and *peripherals*, or accessories. An output device such as a plotter or printer is an example of a peripheral.

### The CPU

The **CPU (Central Processing Unit)** is the “heart” of the computer. This is where the computations which make up the “work” of a computer are processed. Since drafting software requires the performance of many complex calculations, a fast CPU is essential. This ensures minimal wait times for the user while the computer does its work.

Be sure that the computer you are considering will run the software you will be using. If you will be using AutoCAD, for example, you should not buy a Macintosh computer

because AutoCAD is not **compatible** with the Macintosh operating system.

### Monitors

The computer monitor is the display device for a CAD workstation. A CAD monitor should be at least 17”, large enough to display drawings or parts of drawings effectively (see **Figure 3-25**.)

### Resolution


A monitor’s *resolution* refers to the number of pixels per inch displayed on the screen. A pixel is a set of one red, one blue, and one green dot. The more pixels a monitor displays per inch, the higher the quality of the image on the screen. Keep in mind that as resolution increases, total picture size decreases. Resolution settings range from 640 × 480 to 1600 × 1280 or more, depending on the monitor. Choose a resolution that is appropriate for the monitor size. A 17” monitor can display a 1600 × 1280 resolution, but this combination is usually not practical because any details become too small to see. **Table 3-5** (see page 80) shows appropriate resolutions for various monitor sizes.



**Figure 3-25**

Some high-end CAD workstations have two monitors to help designers visualize the products they are drawing.

Monitor Size	Resolution
17"	1024 × 768
20"	1024 × 768 or 1600 × 1280
21"	1024 × 768 or 1600 × 1280
35"	at least 1600 × 1280

 **Table 3-5**  
Monitor resolutions

## Input Devices

The most common input devices for CAD workstations are the keyboard, the mouse, and the digitizer.

Digitizers are specialized equipment used to convert paper drawings to digital format. Although not every CAD workstation includes a digitizer, many companies keep at least one digitizer, so that drawings can be converted as needed. These companies may leave older drawings in their paper form until revisions are needed. At that time, the drawings are digitized, the revisions are made, and the drawings are stored in their new digital format.

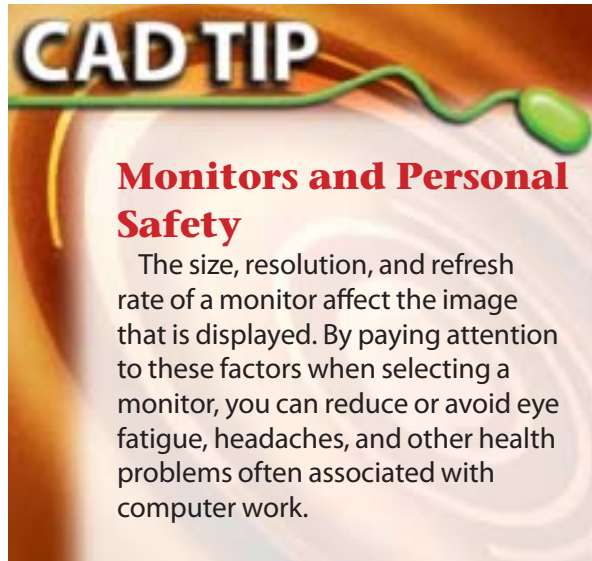
Before a digitizer can be used with a CAD system, it must be calibrated. Each digitizer has a specific procedure for calibration, and some need to be recalibrated periodically. If you need to use a digitizer, consult the user's manual to find out how to calibrate it.

## Printers and Plotters

Laser and inkjet technologies have become the standards for printing technical drawings. They replaced pen plotters which were first used to print CAD drawings. Printers are available in a variety of sizes to fit most drafting needs. Prices vary according to the size of the printer and the quality of the images it produces.

Before selecting a printer or plotter, consider how you will use it. Will you be producing mostly A- or B-size drawings, or will you need to print E-size drawings, too?

Also consider the quality level you will need. Very accurate, high-resolution printers are available for the most exacting needs, but they are very expensive. Lower-priced printers are suitable for printing proofs and for most school uses.



### CAD TIP

#### Monitors and Personal Safety

The size, resolution, and refresh rate of a monitor affect the image that is displayed. By paying attention to these factors when selecting a monitor, you can reduce or avoid eye fatigue, headaches, and other health problems often associated with computer work.



### Reading Check

**Identify** What hardware can be used to input data to a CAD system?

## CAD Software

### Why might a CAD drafter require more than one CAD program?

In addition to hardware, a CAD system require the computer programs used to create technical drawings, or the **CAD software**. The software determines a CAD system's drafting capabilities, so you should select it carefully. In industry, the software a company uses depends on the products or services it provides.

In general, there are three types of CAD software:

- general-purpose drafting software
- specialty software for architectural, electrical, and other special drafting needs
- third-party software that works with general-purpose drafting software to extend its functions

AutoCAD, DataCAD, and TurboCAD are examples of common general-purpose programs. These programs provide the tools needed to create drawings for many different fields and applications.

Specialized software is often used in fields such as architecture, geographic information systems (GIS), and electronics. Examples include:

- Revit Architecture, for architectural drafting
- Pro/Engineer, for mechanical drafting
- CATIA, for aeronautical and electronic engineering drafting

Third-party software works with a general-use program to provide special features. Welding, plant processing, and electronics are common examples of fields that commonly use third-party packages.

CAD utility software is another type of third-party software. Although it is not actually CAD software, it performs special functions that enable CAD files to be used for specific purposes. For example, utilities are available to prepare CAD files for use with computer-aided manufacturing (CAM) systems.

## Maintenance and Repair

Read any manuals that come with your equipment. Perform routine maintenance as specified and have the equipment serviced at the intervals suggested. A decrease in computer performance may mean that the hardware or software needs maintenance. Check for indicators that the equipment is not performing correctly. Frayed cords should be replaced immediately. Keep liquids and beverages away from all computer equipment to avoid accidents that could damage the equipment.

To decrease the chance of equipment malfunction, store all equipment safely and properly when you are not using it. For example, if you have a digitizer but use it rarely, cover it when it is not in use or disconnect it and store it away. If you work in a dusty environment, keep your equipment covered when it is not being used.



### Reading Check

**Name** What are examples of fields that commonly use third-party design software?

## The CAD Workstation

### What considerations should determine your choice of computer furniture?

There are a number of issues concerning your CAD workstation.

### CAD Furniture

Standard drafting desks and tables are not required for CAD workstations. Typical computer furniture like a computer desk can usually be used. However, you should take your drafting needs into consideration before you select the furniture for your workstation. Ask yourself the following questions:

- *Will the furniture accommodate my monitor?* Make sure the part of the computer desk designed to hold the monitor is large enough and sturdy enough to hold the monitor you will use.
- *Will I be using a digitizer?* Workstations that include a digitizer may require additional table space.
- *Where will I put the printer?* The printer drawers supplied with generic computer desks are not large enough to hold printers used for large drawings. If you plan to use a printer that can print E-size drawings, the printer must stand on the floor. Measure to make sure that the cables connecting the printer to your CPU are long enough to reach through the computer desk to your printer without straining.
- *How much working surface do I need?* Be sure the computer desk provides enough desktop working space for notes, hand-drawn sketches, and other materials you may need.

### Safety

Safety should be a primary goal when you design the workstation. There are many things you should know to maintain a safe CAD work environment.

### Ergonomics

You should pay close attention to ergonomics when you select hardware and furniture for your CAD workstation. **Ergonomics** is a field of study in product design that promotes the personal safety and comfort of the user.

Ergonomically designed products “fit the person” instead of requiring that the person fit the product.

Studies have shown that improper use of computer equipment can cause temporary or permanent physical injuries. Some of these injuries are:

- musculoskeletal disorders (MSDs)
- carpal tunnel syndrome
- repetitive stress injuries (RSIs)
- “tennis elbow”

Choosing ergonomically designed products helps to avoid these injuries. For example, many different types of ergonomic keyboards (**Figure 3-26**) and mice have been developed.

Some can be separated into two pieces which are placed at the most comfortable spot for each hand. Others are designed to keep your hands and forearms straight. **Figure 3-27** shows the proper positioning of equipment for a CAD workstation:

- Select a computer desk that has an adjustable keyboard shelf or drawer. Adjust the keyboard height so that your forearms (elbow to wrist) are parallel with the floor.
- Use an office chair with adjustable height and a proper back support. Adjust the chair height so that your feet rest comfortably on

the floor without cutting off the circulation in your legs.

- Place the monitor at or slightly above eye level to help reduce eye fatigue.

## Electrical Safety

To avoid the risk of injury or electrical fire:

- Place wires and cords out of the way so that people will not trip over them, possibly harming themselves and/or the equipment.
- Avoid overloading a circuit by connecting too many electrical devices to it.
- Never connect a multiple-outlet extension cord into another multiple-outlet extension cord.
- Make sure that any equipment such as a CPU or printer with a cooling vent is placed so the vents are not blocked.

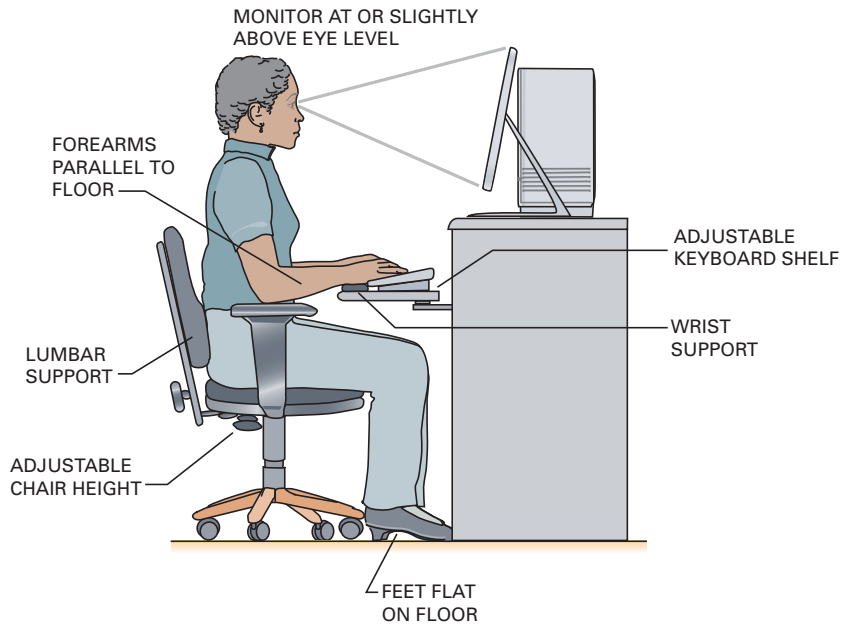
## Hazardous Waste

Some equipment used in CAD workstations and drafting rooms either use or produce hazardous waste. For example, toner for laser printers and copiers can be hazardous. Read the instructions that come with all supplies, especially toners, inks, and ordinary batteries, to find out how to use and dispose of them properly and explore recycling options in your community.



**Figure 3-26**

Many types of ergonomic keyboards have been developed.



**Figure 3-27**

Arrange your equipment to minimize stress and potential injury.

## Section 3.2 Assessment After You Read

### Self-Check

1. **Describe** the computer hardware components of a CAD workstation.
2. **Identify** the three main types of CAD software.
3. **Describe** the characteristics of efficient CAD furniture.
4. **Summarize** the ergonomic and personal safety factors to be considered when setting up a CAD workstation.

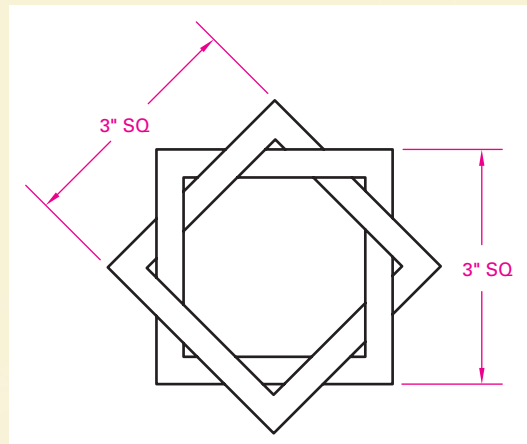
### Academic Integration

#### English Language Arts

5. **Create a Presentation** Organize your notes from this section and create a poster or PowerPoint presentation that illustrates your understanding of the CAD components and the importance of ergonomics when working at a CAD station.

### Drafting Practice

6. Make a freehand sketch of the puzzle shown in **Figure 3-28**.



**Figure 3-28**

Go to [glencoe.com](http://glencoe.com) for this book's OLC for help with this drafting practice.

# Review and Assessment

## Chapter Summary

### Section 3.1

- Basic board-drafting equipment includes drawing tables or desks, drawing boards, and various instruments that improve accuracy, such as T-squares and triangles.
- Standard drawing sheet sizes are specified by the American National Standards Institute (ANSI) and the International Standards Organization (ISO).
- Technical drawings can be made on vellum or polyester film (board drafting) or using computer software.
- Drawing instruments include the dividers, compass, beam compass, and bow instruments.
- Board drafters use various drafting pencils and technical pens to create accurate technical drawings.
- Scales are used to lay off distances and to make measurements.

### Section 3.2

- The hardware for a computer workstation includes a CPU, at least one monitor, input devices, and a printer.
- CAD software is a computer program that allows drafters to create technical drawings using a computer.
- Before purchasing CAD furniture, you should consider how well the furniture meets your individual drafting needs.
- Drafters should take ergonomic and safety into account when considering CAD hardware and furniture.

## Review Content Vocabulary and Academic Vocabulary

1. Use each of these content and academic vocabulary words in a sentence or drawing.

### Content Vocabulary

- drawing board (p. 65)
- true edge (p. 65)
- T-square (p. 65)
- protractor (p. 66)
- scales (p. 66)
- irregular curve (p. 67)

- template (p. 67)
- vellum (p. 68)
- case instruments (p. 68)
- dividers (p. 68)
- compass (p. 69)
- CPU (p. 79)

- CAD software (p. 80)
- ergonomics (p. 81)

### Academic Vocabulary

- media (p. 65)
- minimal (p. 68)
- compatible (p. 79)

## Review Key Concepts

2. **Identify** and describe the basic equipment used in board drafting.
3. **List** and describe various types of drafting media.
4. **Describe** the different scales used for architectural, mechanical, and civil drafting.
5. **Describe** the components of a CAD workstation.
6. **Identify** the three main types of CAD software.
7. **Describe** the characteristics of efficient CAD furniture.
8. **Identify** safety issues that should be addressed when setting up a CAD workstation.

## STEM Science

### 9. Managing Human-Induced Hazards

CAD workstations can produce hazardous waste that can affect personal and community health if handled improperly. What precautions should you take when disposing of hazardous materials? Create a poster for your classroom that details how to correctly dispose of hazardous materials such as ink cartridges, paint, and batteries.

### 21st Century Skills

### 10. Critical Thinking

Bill Stumpf, recipient of the Lifetime Achievement Award from the Industrial Design Society of America, said good design isn't just good business, it is a moral obligation. When he looked around, though, he said that too often he saw design that "denies the human spirit" because architecture acknowledges money, not people. What do you think he meant by this statement? Write a one-page essay on what you think Stumpf meant by these remarks.

## STEM Mathematics

### 11. Calculate Percentage

When shopping for a case of drawing instruments, you find one that suits your needs costs \$50. Another case with a few more instruments costs \$65. Describe the difference between the two prices using a percentage.

#### Math Concept

#### Number and Operations: Percents

To describe how much more the \$65 case costs, create a fraction using the difference in price as the numerator and the cost of the less expensive case as the denominator. To convert the fraction to a percent, divide the numerator by the denominator and multiply the product by 100.

## Standardized Test Practice

### Multiple Choice Questions

**Directions** Choose the letter of the best answer. Write the letter for the answer on a separate piece of paper.

12. Standard drawing sheet sizes are specified by.
- A. The American Society of Mechanical Engineers (ASME)
  - B. The International Standards Organization (ISO)
  - C. Both ASME and ISO
  - D. Neither ASME nor ISO



### TEST-TAKING TIP

Evaluate your test-taking savvy by answering these questions:

- Do I use my time well during a test?
- Does anxiety get in the way of doing my best on a test?
- How can I prepare for my next test?



## Win Competitive Events

### 13. Job Skills

Organizations such as SkillsUSA offer a variety of architectural, career, and drafting competitions. Completing activities such as the one below will help you prepare for these events.

**Activity** Scan newspaper or online job listings for an entry-level drafting job. Use the ad to outline the skills needed to qualify for the position. Then, summarize in a one-page paper which skills you currently have and which you would need to further develop to qualify for the position.



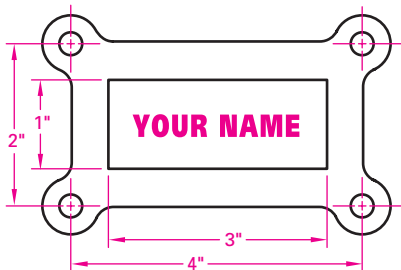
Go to [glencoe.com](http://glencoe.com) for this book's OLC for more information about competitive events.



## Drafting Problems

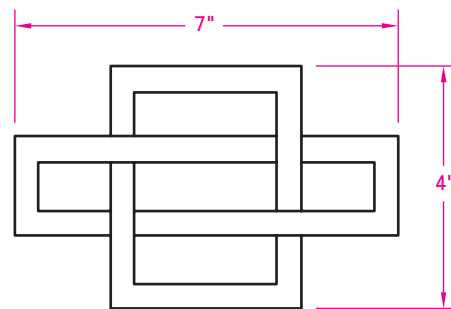
In Chapter 2 you learned about freehand sketching. The following problems are designed to give you additional practice. Each of these sketching problems is designed to fit on an  $8.5'' \times 11''$  drawing sheet. Quarter-inch grid paper may be used. A straightedge may be used for drawing long straight lines. Do not add dimensions (sizes). Estimate sizes not given.

1. Make a freehand sketch of the identification plate shown in **Figure 3-29**. Carefully letter in your own name.



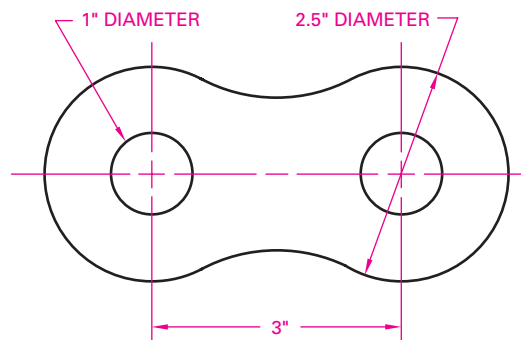
**Figure 3-29**

2. Make a freehand sketch of the inlay shown in **Figure 3-30**.



**Figure 3-30**

3. Make a freehand sketch of the bicycle chain link shown in **Figure 3-31**. Use quarter-inch grid paper if available.

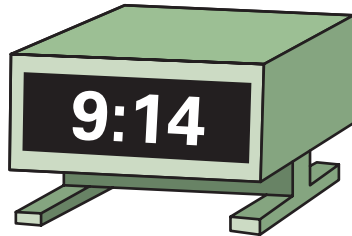


**Figure 3-31**

## Design Problems

Design problems have been prepared to challenge individual students or teams of students. Complete all of the problems using freehand sketching techniques. *Note to CAD students:* After you have studied Chapters 4 and 5, return to the problems in this chapter, complete them using CAD techniques, and compare the advantages and disadvantages of using each method. Be creative and have fun!

1. Redesign the digital clock shown in **Figure 3-32**. Give special attention to the design of the base. Materials: optional. Prepare a three-view sketch of your design idea and use overlays to refine the design. Make an oblique or isometric pictorial sketch of your final design. Keep both function and aesthetics in mind as you proceed.



**Figure 3-32**

### Teamwork

2. Work as a team to design a scooter that could be manufactured and sold by your technology club. Apply the eight steps generally used in the traditional (linear) design process. Choose one member of your team to serve as the design engineer. List each step and describe how it would apply to the design of the scooter. Be sure to document each step as you proceed.

Give every consideration to both function and aesthetics. Design the scooter to fold for easy carrying. Specify lightweight materials. Your final project should include sketches of the product design, general specifications on materials and stock parts, and documentation on the design process.

3. Design a carton (package) for the scooter you designed in the previous problem. It should be lightweight, yet durable enough to protect the scooter during shipping. Work along with the design team so that package design is complete when the scooter design is complete.
4. Design a nameplate for your desk. The base is to be made of walnut wood. Your name is to be engraved on a 1" × 5" brass plate attached to the wooden base. Make a freehand sketch of the parts. Estimate all sizes.

### Teamwork

5. Design a sign for your drafting-room door. It should not be larger than 8" × 22". Material optional. The lettering, DRAFTING ROOM, can be painted on, or metal letters can be purchased.

### Teamwork

6. Design an ergonomic CAD workstation. Keep in mind all of the ergonomic principles discussed in this chapter. Be ready to present your design to the class for discussion and approval.