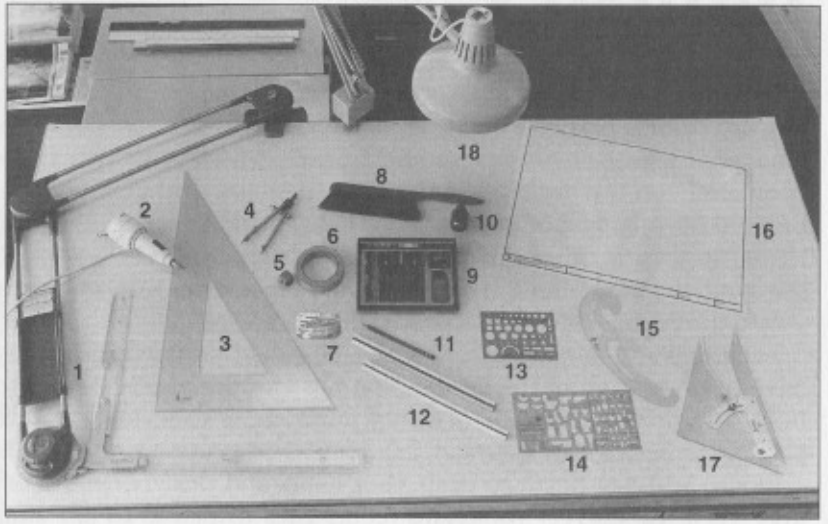
Language of the Industry

Drawing is one of the oldest forms of communication. Drafting, a modern counterpart, is a highly refined form of drawing used to communicate ideas to engineers, architects, and craftspeople. All of these people rely on the drafting professional to create drawings that will be used for planning or building machines, computers, skyscrapers, roads, and many other things. As you begin drafting, you will learn the symbols, lines, and drawing form and techniques that will allow you to turn your sketch into a professional drawing.

Accuracy and simplicity are musts. Not only does your drawing have to present all of the information the craftsperson will need to build the project, but the drawing must show precise, accurate details in a clean, simple format.

Before you can begin to draft your ideas and designs, you must first learn the correct tools and techniques available to aid your efforts. Each discipline in drafting has its own special form, special symbols, and unique drawing-paper format. Learning these rules before you start will ensure successful and satisfying completion of your Drafting merit badge.

Tools of the Trade

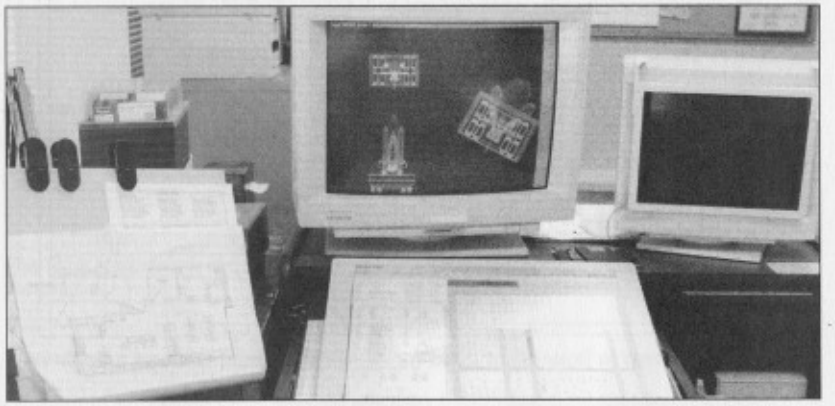


DRAFTING TOOLS

1. Drafting machine
2. Electric eraser
3. 30°/60° triangle
4. Compass
5. Eraser
6. Drafting tape
7. Erasing shield
8. Drafting board brush
9. Technical pens
10. Drafting ink
11. Drafting pencil
12. Architectural and engineering scale
13. Template for general symbols
14. Template for general symbols
15. French curve
16. Drafting vellum paper
17. Adjustable 45° triangle
18. Drafting lamp

Drafting tools are simply the equipment used to produce accurate, readable drawings. Before you can be an effective drafting professional, you must learn about the tools available and how to use them properly. No drafting tool, however, not even a computer, will draw for you. You must first become proficient with drawing formats, special symbols, and clean, accurate drawing practices. Then you can begin using the tools.

Computer-Aided Drafting



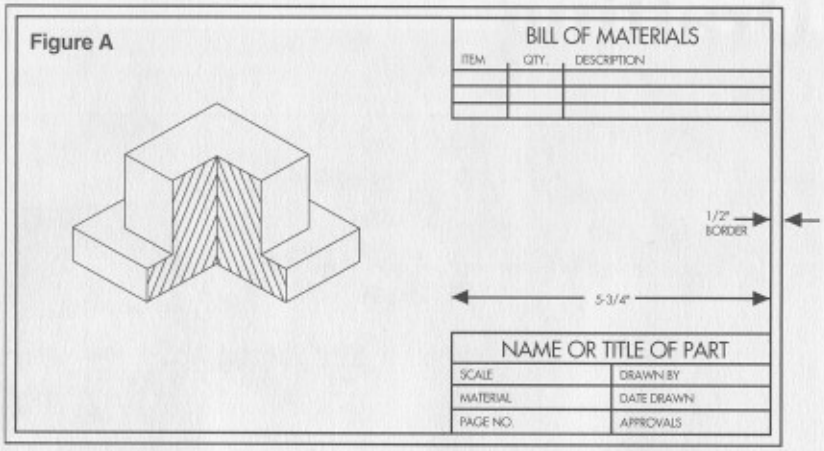
The CAD (computer-aided drafting) system is made up of (a) an input device, (b) an output device (the printer or plotter), and (c) CAD software, the "brains" behind the CAD system.

CAD brings a whole new dimension to the tools available to the drafting industry. CAD systems are used when items must be drawn repeatedly (architects, for instance, need to draw doors and windows many times) or when very high accuracy or many drawing changes are needed.

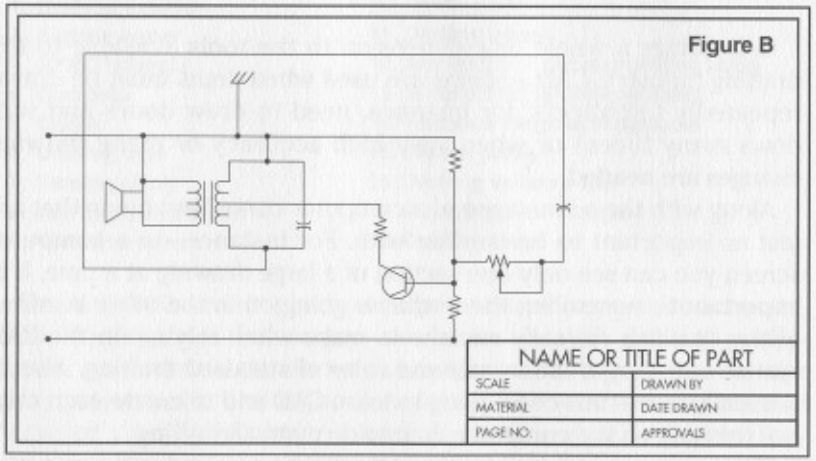
Along with the advantages of a computer come limitations that are just as important to be familiar with. For instance, on a computer screen you can see only one section of a large drawing at a time. It is important to remember, then, what is going on in the other sections of the drawing. An easy mistake to make when relying on the CAD system is to forget the format and rules of standard drafting. Also, it is usually more time-consuming to learn CAD and to create each original drawing on the computer than to do manual drafting.

You or your merit badge counselor may arrange for the use of a CAD system with a local professional architect or engineer. If so, you may choose to complete some of your requirements using CAD.

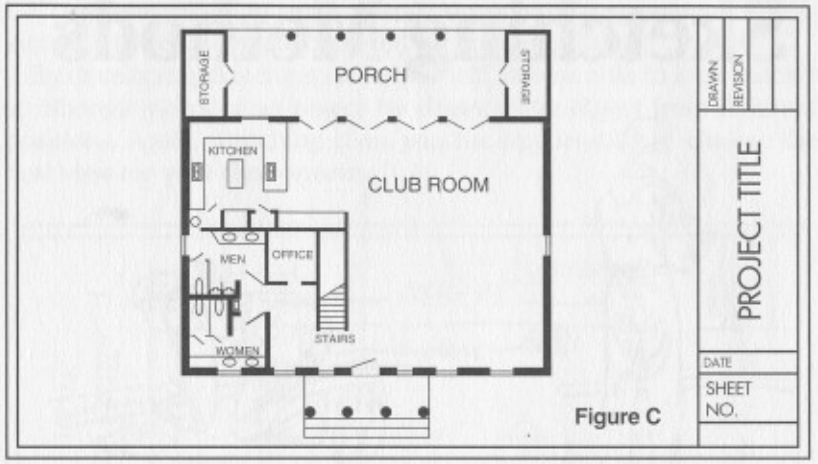
Drafting Formats



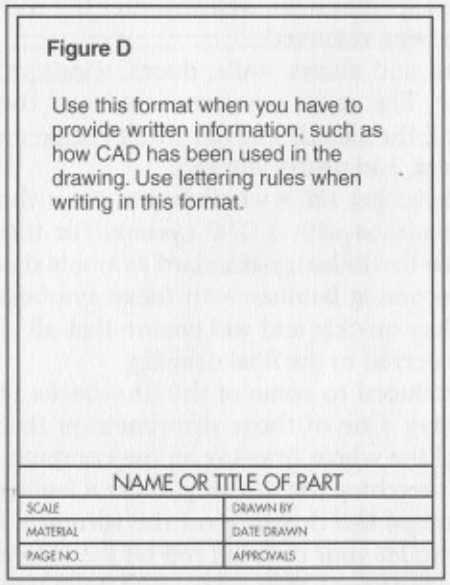
The format shown in figure A is used for drawing objects, such as machines or woodwork.



The format shown in figure B is used for making electrical drawings, of electronic circuits, for example.



The format shown in figure C is used for architectural drawings of buildings, floor plans, etc.

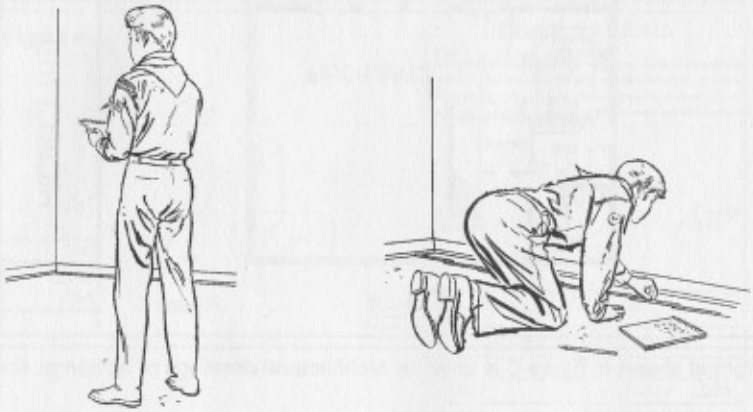


The format shown in figure D is used for lettering, for notes, or for drawing small parts.

Drafting paper is also known as *vellum;* it is almost transparent. Vellum is used so blueprints can be made from the original drawings, and is available in a variety of sizes for the various types of drawings required.

These sample formats are to be used for different types of drawing projects. The title blocks shown should be used regardless of the size of the vellum you use. (See "Vellum Sizes" in the "Making Scale Drawings" section.)

Sketching Methods



The figures on the next page show the progression from sketch to finished drawing. The drawings are of an architectural floor plan. Floor plans are drawn as though seen from an airplane after the roof and ceiling of the building have been removed.

Figure E was drawn freehand and shows walls, doors, windows, electrical outlets, fixtures, etc. The room was measured and the sketch dimensioned. For figure F, the sketch was redrawn to scale on vellum using drafting instruments, and neatly lettered.

It is important to develop sketching skills whether you draw the finished drawing with instruments or with a CAD system. For this type of drawing, you should use the industry-standard symbols discussed in the next section. Becoming familiar with these symbols will help you to develop sketches quickly and will ensure that all of the important features are transferred to the final drawing.

Earlier, you were briefly introduced to some of the drawbacks of using CAD for your final drawing. One of those drawbacks is that you can see only a small part of the whole drawing on the computer screen at a time. Without first sketching the drawing to get a feeling of the size, scale, and position of the drawing on the formatted paper, there will be a tendency to let your drawing run off the paper. Developing good sketching skills is probably more important to a CAD professional than to a someone using hand instruments. A CAD system will not eliminate the need for good sketching.

By developing sketching skills, you will also be able to look quickly at different views of an object by drawing the object from different positions. Again, sketching gives you the opportunity to choose the best view for your final drawing.

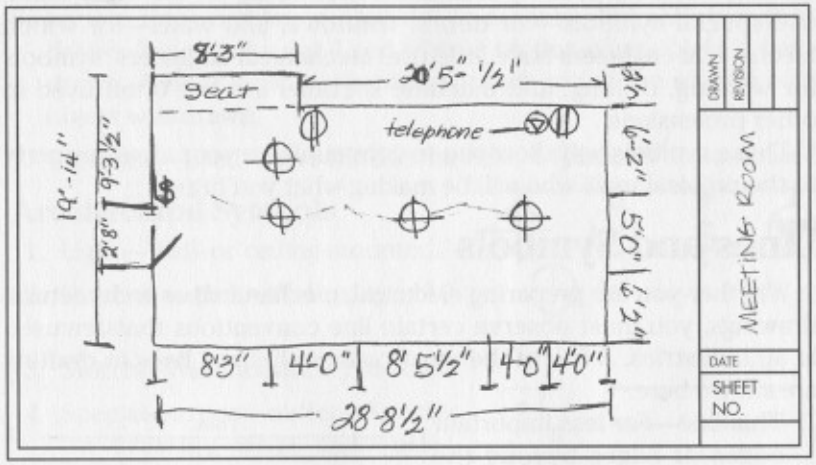


Figure E

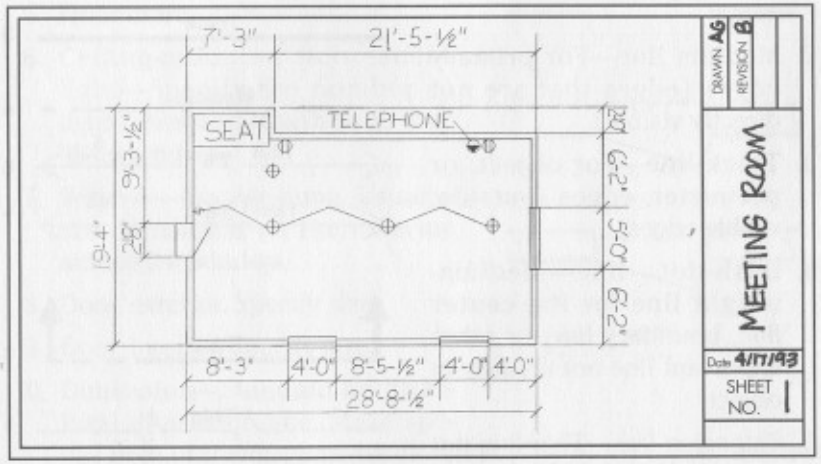


Figure F

Symbology

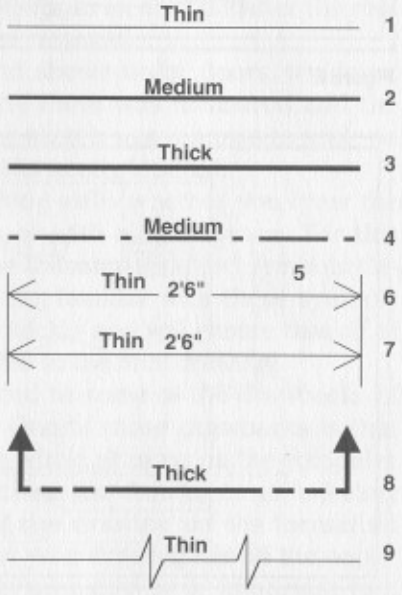
Each industry has its own symbols that help its professionals. Electrical engineers have symbols for resistors and transistors; these are seldom used by architects. Architects, on the other hand, use special symbols—for doors, windows, and walls—for which mechanical engineers have little use. Mechanical engineers' symbols for welding, drilling, and machine sections are not often used in other professions.

These symbols will allow you to communicate your ideas properly to the professionals who will be making what you draw.

Lines and Symbols

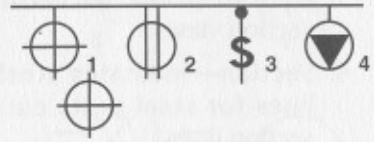
Whether you are preparing electrical, mechanical, or architectural drawings, you must observe certain line conventions that are used in all industries. A few of the most commonly used lines in drafting are shown here.

1. Thin line—For less important edges or edges beyond the section plane (i.e., electrical outlets, windows, appliances, etc.).
2. Medium line—For primary edges (edges that are not directly visible).
3. Thick line—For object, or perimeter, edges (outside, visible edges).
4. Dash-dot line—Medium-weight line for the center line, boundary line, or other important line not actually in object.
5. Extension line—Thin line not connected to the object; used to show the limits of a dimension.

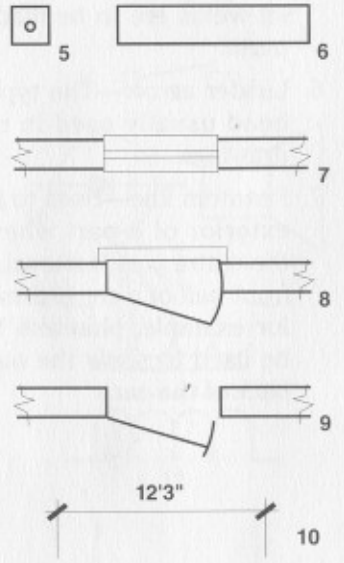


6. Dimension line—Thin line with arrow points touching the dimension line and with a break in the middle for dimension numeral (in a mechanical drawing), or
7. Dimension line—Thin line with dimension numerals on top of the line. This type is more commonly used.
8. Section line—Similar to dash-dot line, above, but with two short dashes instead of a dot. Used when a section of an object is being drawn. Arrows indicate the view through which the section of an object was drawn.
9. Breakline—Used where the section view, or plane, is discontinued.

Architectural Symbols

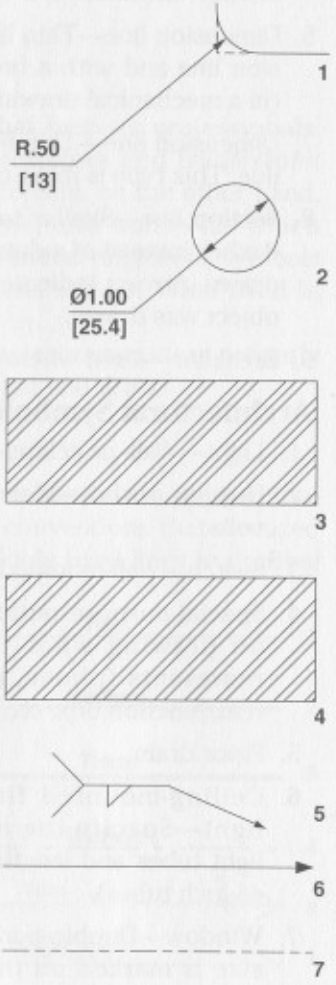


1. Light—Wall- or ceiling-mounted.
2. Duplex outlet—Wall plug, 110 volts.
3. Switch—Wall-mounted, 110 volts.
4. Special-purpose outlet—Specify on drawing what the outlet represents (phone, alarm system, junction box, etc.).
5. Floor drain.
6. Ceiling-mounted fluorescent light—Specify the number of light tubes and length (e.g., four 48-inch tubes).
7. Window—Double-hung. Usually, size is marked on the exterior side of the window.
8. Door, exterior. Specify size.
9. Door, interior. Specify size.
10. Dimension—Standard architectural dimension line. Make special note of the diagonal hatch marks. The hatch marks are used in the same way that arrowheads are used in mechanical drafting.



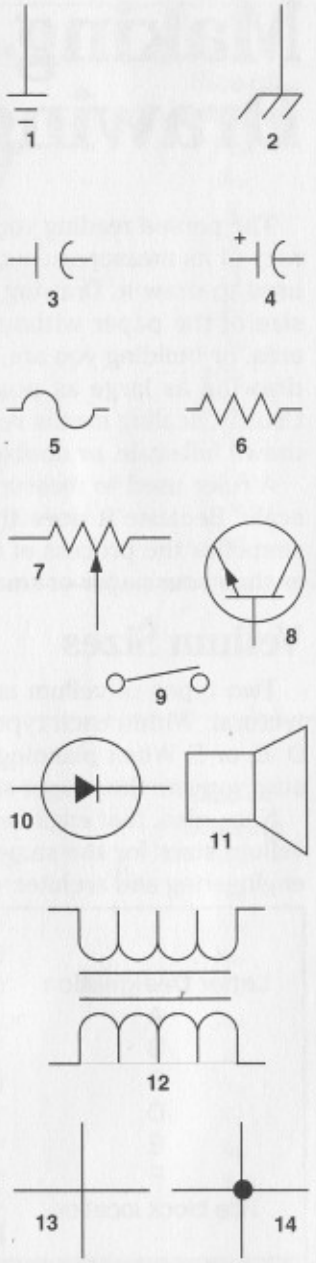
Mechanical Symbols

1. Radius arrow—The letter R is used to designate radius. The top number expresses the radius in decimal inches; the bottom number, in square brackets, is the dimension in millimeters.
2. Diameter—The ø symbol indicates diameter. The letters DIA can also be used.
3. Section—Indicates plastic section lines for plastic parts cut to show section views.
4. Section—Indicates steel section lines for steel parts cut to show section lines.
5. Weld—Indicates where standard fillet welds are to be made on metal parts.
6. Leader arrow—The type of arrowhead usually used in mechanical drawings.
7. Phantom line—Used to indicate the exterior of a part when less than the entire part is shown. (If only the front half of a car is drawn in detail, for example, phantom lines would be used to show the outline of the back of the car.)



Electronics Symbols

1. Earth ground—Indicates where a circuit is to be connected to the ground.
2. Chassis ground—Indicates where a circuit is to be connected to the chassis, or frame, of the electronic equipment.
3. Capacitor.
4. Capacitor (polarized).
5. Fuse.
6. Resistor (fixed value).
7. Resistor (variable resistance).
8. Transistor.
9. Switch (opened, or "off").
10. Diode (semiconductor type).
11. Loudspeaker.
12. Transformer.
13. Circuit crossover (wires not connected).
14. Circuit junction (wires connected).



The electronics symbols shown here are only a few of the symbols found in electronics drafting, however, they are some of the most common and are sufficient for drafting a complete circuit. Your counselor can help you with specialized electronics symbols.

Making Scale Drawings

The person reading your drawing will be concerned with the accuracy of its measurements, and must be able to refer to the scale you used to draw it. Drawing to scale means fitting your drawing to the size of the paper without changing the proportions of the object, area, or building you are drawing. Choose a scale that will make the drawing as large as possible without crowding it on the paper. Usually, scaling means reducing, but if the object is small, it can be drawn full-scale, or double or more its original size.

A ruler used to measure or draw a scale drawing is itself called a scale. Because it does the division of dimensions for you, a scale simplifies the process of measuring or drawing objects that are larger than your paper or smaller than you want them shown.

Vellum Sizes

Two types of vellum are commonly used: engineering and architectural. Within each type are six different sizes, designated A, B, C, D, E, or F. When planning the scale to use for your drawings, make sure you use the proper size paper, too.

Note, also, that engineer's vellum sizes are smaller than architect's vellum sizes for the same letter designation. The title blocks of the engineering and architectural formats also differ.

Letter Designation	Vellum Sizes Engineering	Architectural
A	8½" × 11"	9" × 12"
B	11" × 17"	12" × 18"
C	17" × 22"	18" × 24"
D	22" × 34"	24" × 36"
E	34" × 44"	36" × 48"
F	34"-wide roll	36"-wide roll
Title block location	Bottom left	Left edge

Marked on End of Scale	Architect's Scale Letter on Title Block	Size of Drawing
16	Scale: 12"=1'-0" or	Full
	Scale: 1/16"=1'-0"	1/192
(No mark)	Scale: 6"=1'-0"	½
3	Scale: 3"=1'-0"	¼
1½	Scale: 1"=1'-0"	⅛
1	Scale: 1"=1'-0"	1/12
¾	Scale: ¾"=1'-0"	1/16
½	Scale: ½"=1'-0"	1/24
⅜	Scale: ⅜"=1'-0"	1/32
¼	Scale: ¼"=1'-0"	1/48
3/16	Scale: 3/16"=1'-0"	1/64
⅛	Scale: ⅛"=1'-0"	1/96
3/32	Scale: 3/32"=1'-0"	1/128

Marked on End of Scale	Engineer's Scale Letter on Title Block	Size of Drawing
10	Scale: 1"=10.0' or	1/120
	Scale: 1"=.100"	1/100
20	Scale: 1"=20.0'	1/240
30	Scale: 1"=30.0'	1/360
40	Scale: 1"=40.0'	1/480
50	Scale: 1"=50.0' or	1/600
	Scale: 1"=.50"	½
60	Scale: 1"=60.0'	1/720
⅛	Scale: ⅛"=1'-0"	1/96
¼	Scale: ¼"=1'-0"	1/48
½	Scale: ½"=1'-0"	1/24
1	Scale: 1"=1'-0"	1/12

Dimensioning

In making drawings to scale, it is important to get the right proportions, but it is not good to rely only on the scale for the dimensions of the object that you are drawing. The drawing parts might be small and hard to measure, and the paper might shrink or expand with heat or cold and moisture. Since a craftsperson might need to use your scale drawing to make an object, it is important that you also clearly indicate the dimensions of the object, using the dimension and extension lines discussed in the section on symbology.

Dimensioning should be so complete that the person reading the drawing need not use mathematics to understand sizes, however, do not include more dimensions than are necessary for the use the drawing will be put to.

All dimensions are read either from the bottom or from the right edge of the sheet. This is according to the first rule of dimensioning: make the drawing clear and easy to read and understand. To assure accuracy, letter the dimensions neatly so they can be read easily. The figures and fractions should be positioned so they can be read from the bottom of the sheet. The dimensions of angles are indicated by an arc inside the angle.

Advanced Drafting Techniques

Orthographic Projections

One of the most common and easily understood ways to communicate a project, or part of one, through a drawing is with an orthographic projection.

Before you can start a drawing, you have to formalize in your mind what you wish to draw. If you visualize the front view, top view, or side view independently, you are looking at your project in only two dimensions—height and width—without depth. If you set a book on a table and stoop over to look at it with your eye at tabletop height, you will see a rectangle with a certain height and width. Consider this the front view. To see the depth, you will have to walk around the table and again put your eye at tabletop height. You will see another height and width, but likely different from the front view. You can consider this the side view. Now stand up and look straight down on the book. You will see another set of dimensions from the top.

You have just created an orthographic projection of the book—that is, you have viewed various planes of the book from different sides, with each side having a relationship to the other sides.

In figure G, you will see a properly formatted drawing of a river raft. This orthographic projection shows the craftsperson all the information necessary to build the raft.

In this drawing, the side, front, and top views are all drawn in natural relationship to each other. The side view shows where the barrels are to be attached to the cross-tie poles and how they are to be lashed with the rope. You will also notice that the raft's deck poles, which run left and right, are attached to the cross-tie poles at specific locations. Dimensions are important to give the craftsperson critical locations.

The front view shows only the front of the first two barrels; the two rear barrels are behind the front barrels but are unseen from this view. Remember that each view gives the craftsperson only

two-dimensional information. You can see that the dimensional information in the front view could not possibly have been given to the craftsperson in the side view. In the side view, you can see where and how the deck poles are first lashed to the cross-tie poles.

Now look at the top view. You will see the length and width of the raft, each of which you saw in the front and side views. This time, however, you see them both at the same time. The length and width dimensions are not shown in this view since they are already shown in the other two views. It is unacceptable to dimension the same object of length more than one time in any single drawing.

If you look through the deck in the top view, you will see hidden lines. These represent the four flotation barrels located underneath the deck.

To complete the drawing, important notes, a bill of materials, and the corresponding item numbers located in a bubble with an arrow pointing to each item are added. (A bill of materials is a list of materials, and the quantity of each, used to build something.) Remember that the entire drawing needs to be centrally located on the paper, with no lines extending beyond the vellum border. Fill in the title block sections, being sure to include the drawing scale. The drawing is now ready to blueprint, and the building of the raft can begin.

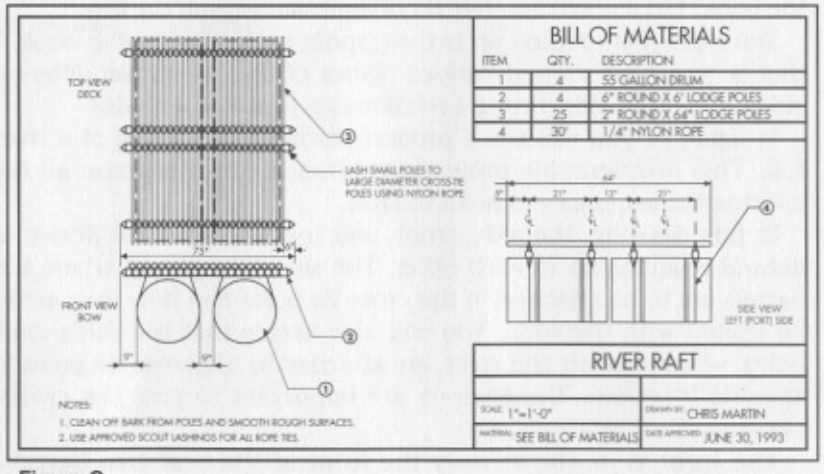


Figure G

Isometric Drawings

The purpose of isometric drawings is to combine several views of an object in one three-dimensional picture. This picture then can be reduced or enlarged, through simple scale measurements, to the size required.

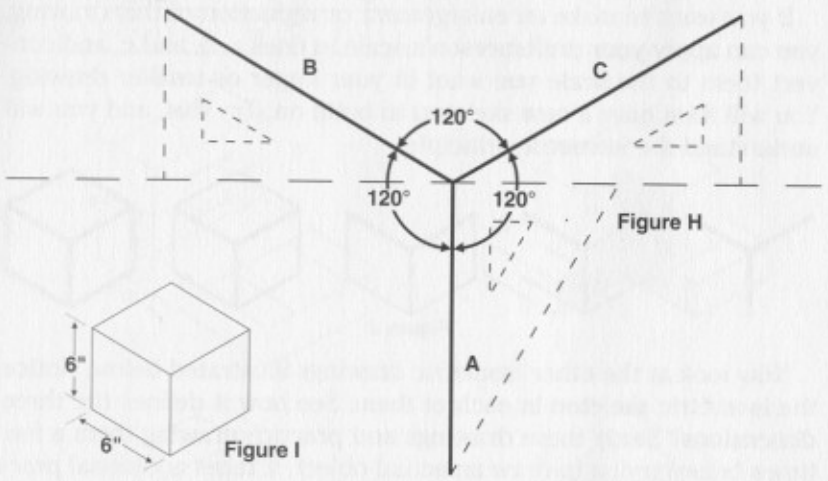


Figure H

Figure I

This kind of drawing is built on a skeleton of three lines called isometric axes (figure H), forming three equal angles of 120 degrees each. (From this equality comes the term *isometric,* which means equal measures.)

If you were to draw an object in three dimensions as it looks to you, it would have perspective. The parts farther from your eye would look closer than those closer to your eye (figure I). This drawing would look realistic, but making scale enlargements or reductions from it would be very difficult. The lines farthest from your eye would not be scaled to their actual length, and you would have to calculate proportions that the person reading the drawing would have difficulty interpreting.

By building your drawing around the isometric skeleton, you can make a three-dimensional picture, without the perspective problems. You can then use the axes of the skeleton as "measuring sticks" to make scale enlargements or reductions.

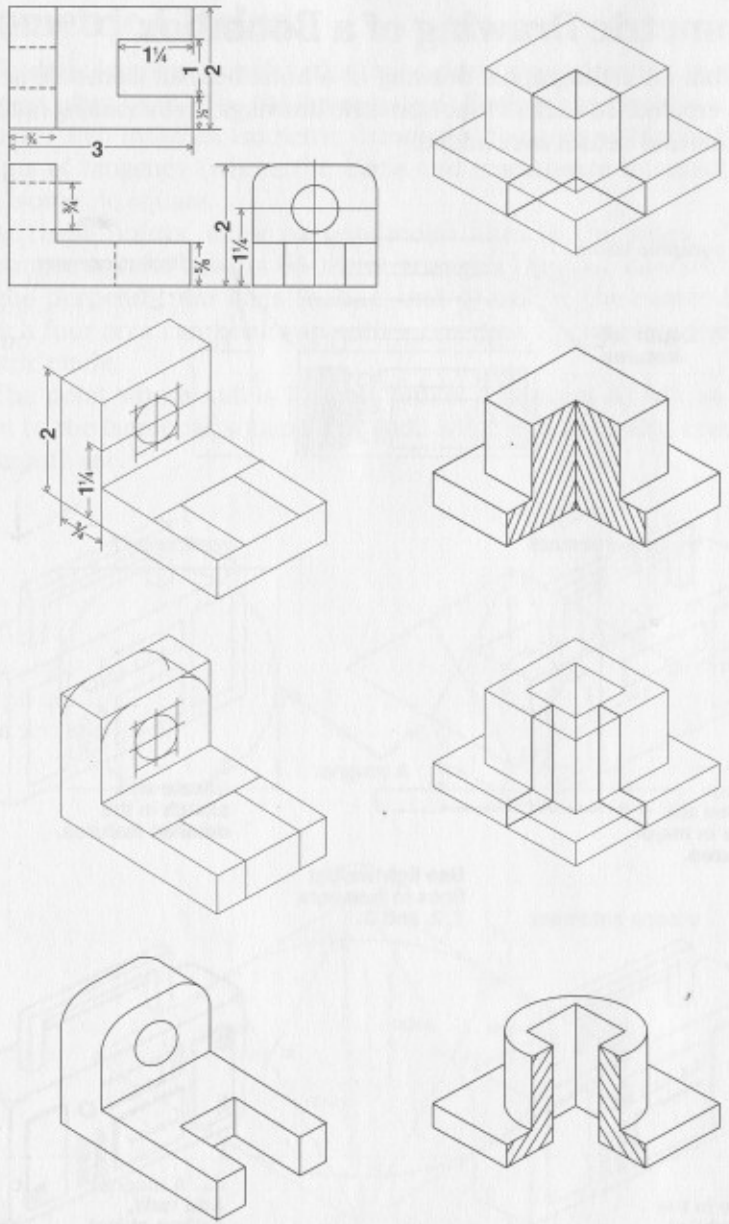
Let's start by drawing an isometric cube (figure J). Do you see the isometric skeleton? Notice that all edges of the cube that are supposed to be the same length are actually drawn that way. You can see that all lines that would be vertical in an orthographic drawing are also vertical in isometric drawings, but that lines that would be horizontal in an orthographic drawing are tilted upward 30 degrees from horizontal (see figure J).

If you want to make an enlargement or reduction of this drawing, you can apply your draftsperson's scale to lines a, b, and c, and convert them to the scale you want in your larger or smaller drawing. You will then have a new skeleton to build on. Try this, and you will understand the isometric principle.

Figure J

Now look at the other isometric drawings illustrated below. Notice the isometric skeleton in each of them. See how it defines the three dimensions? Study these drawings and practice drawing them a few times before trying to draw an actual object. It takes additional practice to figure out which edges should be based on the isometric axes. Notice that a framework is drawn before the shapes are defined.

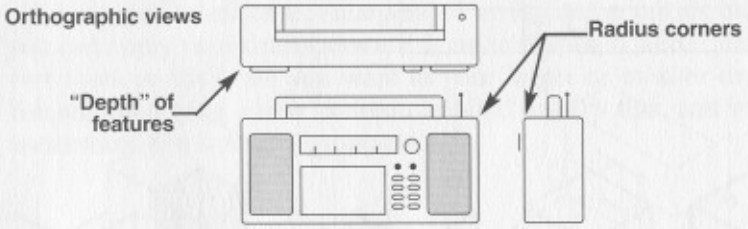
It is easier to create the illusion of three dimensions by manual drawing than by using a CAD system. To generate these drawings in CAD, two-dimensional orthographic drawings must first be developed in the database. Then, by calling up the three-dimensional project, a three-dimensional isometric drawing can be made on the CAD system. This process is time-consuming, and illustrates one of the drawbacks of CAD.

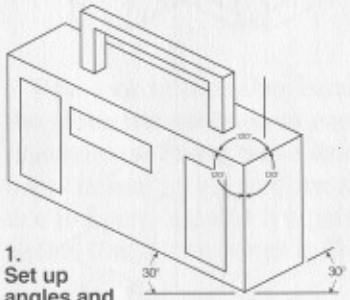


Computer-aided drawings

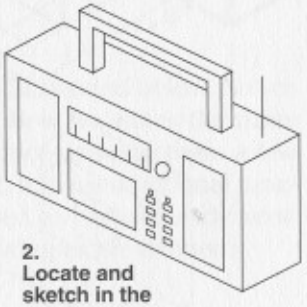
Isometric Drawing of a Boombox

From an orthographic drawing of a boombox, an isometric series was created. To each of four isometric drawings, an increasing number of radii and details were added.



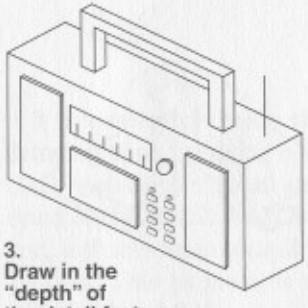


1. Set up angles and draw in major features.

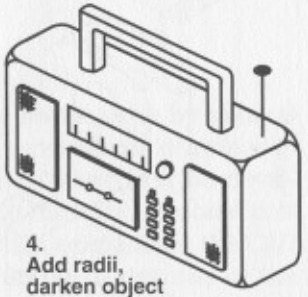


2. Locate and sketch in the detailed features.

Use lightweight lines in numbers 1, 2, and 3.



3. Draw in the "depth" of the detail features.



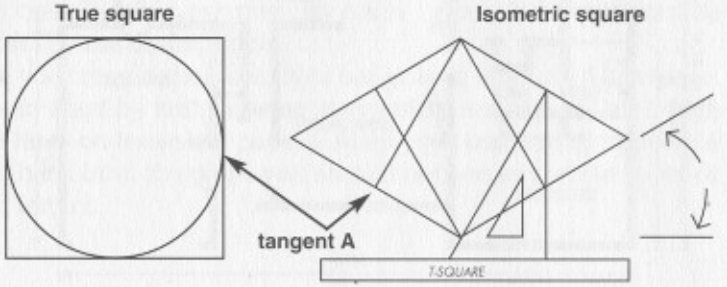
4. Add radii, darken object lines, add detail.

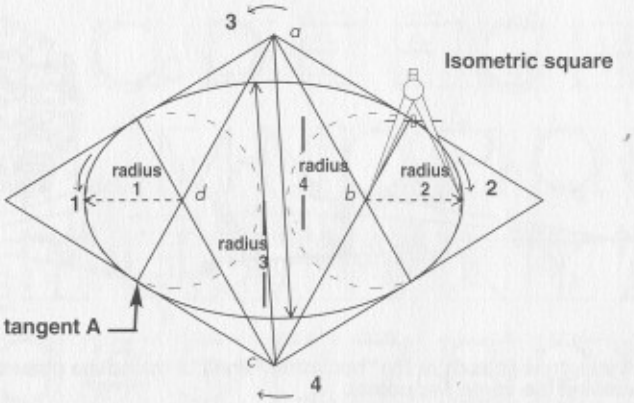
Isometric Circles

To draw isometric circles, the four-center approximation method is most often used. (See the figure below.) Enclose the circle in a true square, then make an isometric drawing of the square. Mark off the points of tangency (where the circle and true square intersect) on the isometric square.

At these points, draw perpendicular lines to the sides of the isometric square, using a 60-degree triangle. The four intersections of the perpendicular lines (a, b, c, and d) will be the center from which four arcs can be drawn with a compass to complete the isometric circle.

The point where radius 1 meets radius 4 (tangent A) will be tangent to the isometric square. The radii will blend naturally, creating a smooth arc.



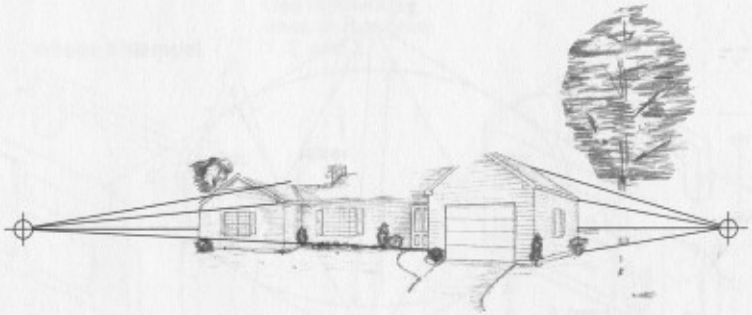


Perspective Drawing

A drawing of your home can best be made by first drawing a floor plan. Measure the room to get the proper scale. After the floor plan is completed, look over your house from the outside to determine which view is attractive and yet shows important construction details. Notice that the drawing in the figure below shows the pitch of the roof, window and siding details, how the garage is attached, etc.

If you have a camera, take a few pictures of your home from different angles and select the view you like best.

Floor Plan



If you draw lines from the "horizontal" lines of the house pictured, they meet at the *vanishing points.*

Lettering

In drafting, Gothic and Roman letters are used because they are easy to read and draw. Engineering professionals use only single-stroke Gothic letters, either vertical or inclined. Architectural draftspeople use a more stylized variation of single-stroke Roman letters, usually inclined. Either style of lettering can be extended or compressed to fit a certain length of line.

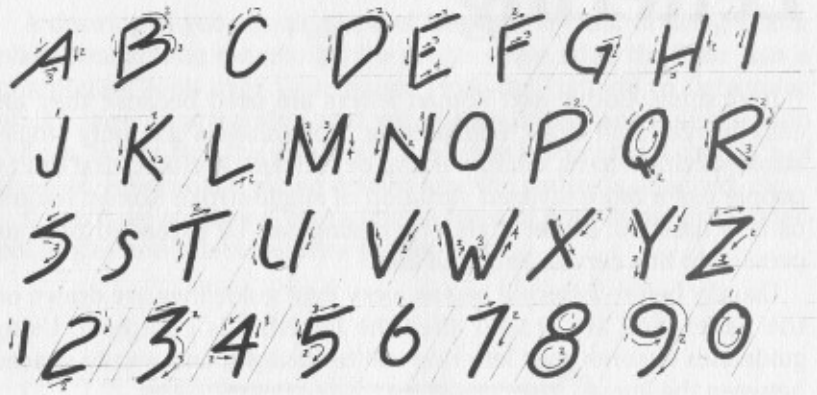
Usually before lettering begins, very light guidelines are drawn on the paper, and are erased after the lettering is complete. Using guidelines ensures your lettering will be straight, and evenly spaced between the lines.

Lettering is no less important to master than other drawing techniques. Often, more information is contained in the notes than in the drawing itself. Illegible printing can cause critical information to be overlooked by the craftsperson.

One of your requirements for this badge is to letter an A-size page. You should start by first drawing your guidelines about ¼ inch high (like the lines on loose-leaf paper). Keep your text evenly spaced; if you step back from the page, you should not see any white spots or crowded letters.

Mechanical and Electrical

Architectural



Lettering templates are available to assist rapid lettering, but it is necessary to master freehand lettering before moving on to a template

In CAD, lettering is called *printing*. The draftsperson has only to type the notes and lettering. The lettering style in CAD is called the *font*. Roman and Gothic letters are considered fonts. There are literally hundreds of fonts available for the draftsperson to use.

Reproducing Drawings

Blueprints

A blueprint is a copy, on special paper, of a drawing made on vellum. By laying the vellum on light-sensitized blueprint paper and passing a high-intensity light through the drawing onto the blueprint, a special coating on the blueprint turns blue. The lines on the drawing prevent light from passing through the paper; in this way, they remain white. The coating of the paper is then washed off and dried; the result is white lines on a blue background. This process is no longer used in the industry. As it is used today, the term *blueprint* refers more accurately to the *blueline diazo* method of reproducing drawings.

Diazo

The diazo process produces prints exactly the opposite of blueprints, that is, white copies with blue, brown, or black lines. These resemble the original drawing more closely. Diazo uses a bright light that passes through the vellum drawing, exposing the light-sensitive diazo paper underneath. The copy is then immediately fed through a section of the print machine containing ammonia developer, which turns the unexposed paper (the lines of the drawing) blue. Diazo paper is also available in brownline and blackline. Blueline copies come out of the machine dry, speeding up production, and are easily read and corrected.

Electrostatic Copiers

Until recently, the size limitations and cost of standard photocopiers made this duplication process impractical. Now, however, continuous, roll-fed copy paper can be used to reproduce any size of drawing. Drawings can be duplicated even on new vellum. The process is more expensive than blueline, but it allows the user to enlarge or reduce the drawing on the copy, a feature not available with other copy methods.

CAD Plotters

Pen plotters are used to create original or duplicate drawings from the CAD computer. Usually, only the original drawing is made with the plotter; other copy methods are used to reproduce the original.

Careers in Drafting

Drafting has always been the backbone of technical support for the aircraft, automotive, architectural, and civic and mechanical engineering industries. Now, with the rapid expansion of the electronics industry, the opportunities for drafting professionals have expanded dramatically.

If you are interested in pursuing a career in drafting, you should start by taking a specialized drafting course in high school. It is advisable also to take as many shop courses as you can, to give you experience in reading blueprints and valuable knowledge of the craftsperson's use of tools in creating objects shown on the prints. In addition, you may want to take other science and math courses, such as physics, geometry, algebra, and trigonometry. All the skills you learn here will help you land that first drafting job and give you advanced skills that lead to rapid promotion. After high school, you will have to continue your specialized training in drafting. Numerous drafting and engineering-technician courses are offered by trade schools or community colleges, and can usually be completed in one and a half to two years.

In addition to learning the manual drafting skills, many of which you were introduced to in this manual, you will also receive extensive training in CAD. Since personal computers are now in almost every engineering or architectural office, CAD skill is now as necessary as manual drafting skill.

Just as many doctors specialize after general training, draftspeople also specialize. Electronics, printed circuit board, and mechanical and electromechanical specialty drafting skills are needed to support the many industries that rely on drafting of steel, plastic, glass, wood, and electronic processes today. Drafting opportunities exist in the building, computer, plastics, automotive, recreational products, civil engineering, and many other industries.