

FIELD MANUAL

GENERAL DRAFTING

CONVERSION TABLE: FRACTIONS TO DECIMALS

Fraction	To two places	To three places	Fraction	To two places	To three places	Fraction	To two places	To three places	Fraction	To two places	To three places
$\frac{1}{64}$	.02	.016	$\frac{17}{64}$	.27	.266	$\frac{33}{64}$	.52	.516	$\frac{49}{64}$	.77	.766
$\frac{1}{32}$	.03	.031	$\frac{9}{32}$	.28	.281	$\frac{17}{32}$	.53	.531	$\frac{25}{32}$	.78	.781
$\frac{3}{64}$	.05	.047	$\frac{19}{64}$	.30	.297	$\frac{35}{64}$	.55	.547	$\frac{51}{64}$	.80	.797
$\frac{1}{16}$	.06	.062	$\frac{5}{16}$	.31	.312	$\frac{9}{16}$	.56	.562	$\frac{13}{32}$	.81	.812
$\frac{5}{64}$	.08	.078	$\frac{21}{64}$	.33	.328	$\frac{37}{64}$	.58	.578	$\frac{53}{64}$	.83	.828
$\frac{3}{32}$	.09	.094	$\frac{11}{32}$	.34	.344	$\frac{19}{32}$	.59	.594	$\frac{27}{32}$	.84	.844
$\frac{7}{64}$	.11	.109	$\frac{23}{64}$	.36	.359	$\frac{39}{64}$	.61	.609	$\frac{55}{64}$	.86	.859
$\frac{1}{8}$	.12	.125	$\frac{3}{8}$	.38	.375	$\frac{5}{8}$	.62	.625	$\frac{7}{8}$	.88	.875
$\frac{9}{64}$	.14	.141	$\frac{25}{64}$	.39	.391	$\frac{41}{64}$	.64	.641	$\frac{57}{64}$	.89	.891
$\frac{5}{32}$	.16	.156	$\frac{13}{32}$	.41	.406	$\frac{21}{32}$	.66	.656	$\frac{29}{32}$	.91	.906
$\frac{11}{64}$	.17	.172	$\frac{27}{64}$	.42	.422	$\frac{43}{64}$	.67	.672	$\frac{59}{64}$	.92	.922
$\frac{3}{16}$	.19	.188	$\frac{7}{16}$	.44	.438	$\frac{11}{16}$	.69	.688	$\frac{15}{16}$	.94	.938
$\frac{13}{64}$	.20	.203	$\frac{29}{64}$	.45	.453	$\frac{45}{64}$	.70	.703	$\frac{61}{64}$	.95	.953
$\frac{7}{32}$	.22	.219	$\frac{15}{32}$	.47	.469	$\frac{23}{32}$	.72	.719	$\frac{31}{32}$	.97	.969
$\frac{15}{64}$.23	.234	$\frac{31}{64}$.48	.484	$\frac{47}{64}$.73	.734	$\frac{63}{64}$.98	.984
$\frac{1}{4}$.25	.250	$\frac{1}{2}$.50	.500	$\frac{3}{4}$.75	.750	1	1.00	1.000

ESSENTIALS OF DRAFTING

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To KENDRA

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PREFACE

This book has been written for the student who is taking drafting either to satisfy a curriculum requirement or as an elective, but who is not a drafting major. This student usually wishes to gain a basic working knowledge of drafting fundamentals so that he can apply it to other courses, but he is often hindered in obtaining this knowledge by a combination of limited class time (basic drafting is normally a one semester course) and large class enrollments. This situation forces the student to rely heavily on the instructor's lectures and on his own ability to read and understand the text.

To make it easier for the student to learn from this text, the material is presented using a step-by-step problem-solving format accompanied by many illustrations. The written portion of the text may be described as a "how to" approach. The idea is to present not only drafting theory, but also the procedures and conventions used to apply the theory. This will enable the student to work directly from the text to the board while doing his class and homework drawings.

The scope of the material presented has been limited to those subjects most often needed to prepare technical drawings, with heavy emphasis on orthographic views (including sectional views and auxiliary views) and dimensioning. Fasteners, oblique, isometric and development drawings are also covered. Although limited in scope, the material is presented in depth. Four chapters, for example, discuss how to draw three views of an object.

Special care was taken in choosing exercise problems for each chapter. The problems are directly related to the subject of the chapter, and are, for the most part, presented in isometric form to help the student learn visualization. Many are presented on grid background in order to force the student to create all his own dimensions without any hints or leads from dimensions used to state the problem. The problems which are dimensioned are done so using decimals and the unidirectional system, although most of the decimals are convenient fractional equivalences.

The text also includes metrics. Chapter 13 is entirely devoted to linear metric measurements (as used on technical drawings) and first angle projection. All other chapters contain at least one exercise problem done in metrics.

Several people deserve my special thanks for their contributions to this book. My wife, Kendra, not only did all the typing but also did the initial editing for grammar and spelling errors. Chris Duncombe

contributed his photographic skills to create interesting and imaginative photographs. George Cushman, my colleague at Wentworth Institute, was always willing to argue and discuss a method or teaching approach. And Cary Baker and Stu Horton of Prentice-Hall always answered all my questions promptly and clearly. Thanks to you all.

Finally, I would like to make a request of you, the reader. Please send me your comments. A formal letter isn't necessary—just a marked up xerox copy of the sections in question would be fine. Being a teacher myself, I'm well aware that every text has certain sentences or illustrations which, although not wrong, consistently cause confusion. I would sincerely appreciate your pointing these out to me.

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DRAFTING TOOLS AND THEIR USE 1

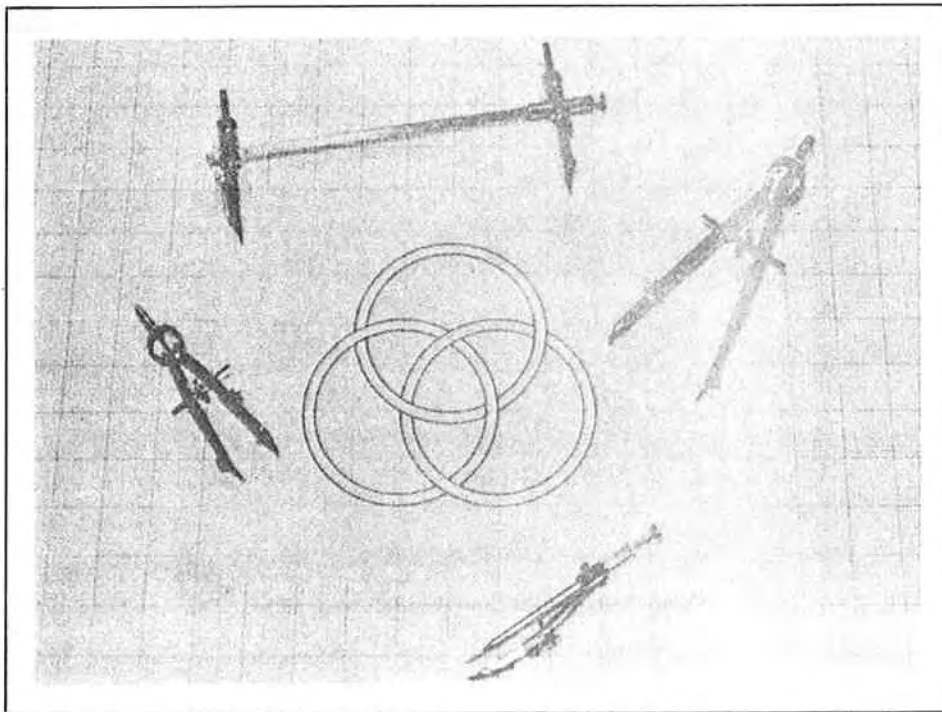


Figure 1-0 Illustration courtesy of Teledyne Post, Des Plaines, Illinois 60016.

1-1 INTRODUCTION

This chapter explains and demonstrates how to use basic drafting tools. Most sections in the chapter are followed by exercises especially designed to help you develop skill with the particular tool being presented. Try each tool immediately after reading about it by doing the appropriate exercises. As you work, try to learn the capabilities and usage requirements of each tool, because it is important that you know how to use each tool with technical accuracy, skill, and creativity.

1-2 PENCILS, LEADHOLDERS, AND ERASERS

Figure 1-1 shows several different pencils and leadholders. Most draftsmen prefer to draw with leadholders instead of pencils because leadholders maintain a constant weight and balance during use which makes it easier to draw uniform lines.

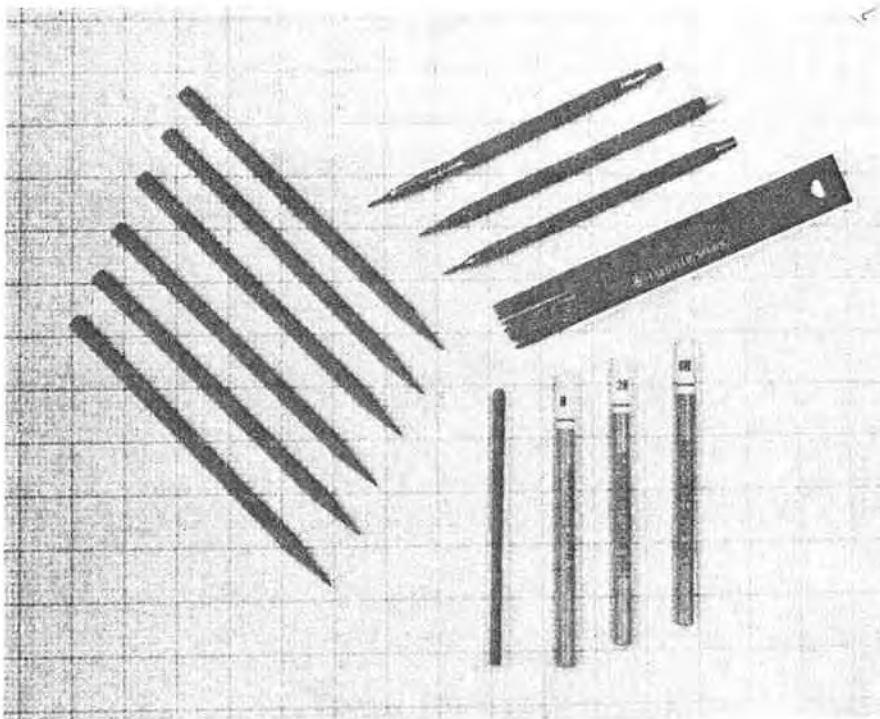


Figure 1-1 Pencils and lead holders.

Regardless of whether a leadholder or pencil is used, its lead must be kept sharp with a tapered, conical point like the one shown in Figure 1-2. Figure 1-3 shows several different lead sharpeners and Figure 1-4 shows how to sharpen a lead by using a sandpaper block.

When sharpening a lead, care should be taken to keep the graphite droppings away from the drawing. Most draftsmen keep a cloth or piece of clay handy to wipe the excess graphite from a newly sharpened lead.

Leads come in various degrees of hardness, graded H to 9H. The higher the number, the harder the lead. Light layout and projection lines are usually drawn with the harder leads; darker lines, used for detailing and lettering, are drawn with the softer leads.

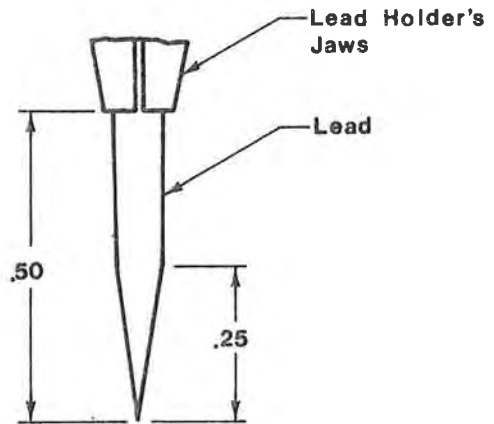


Figure 1-2 The shape of a properly sharpened lead.

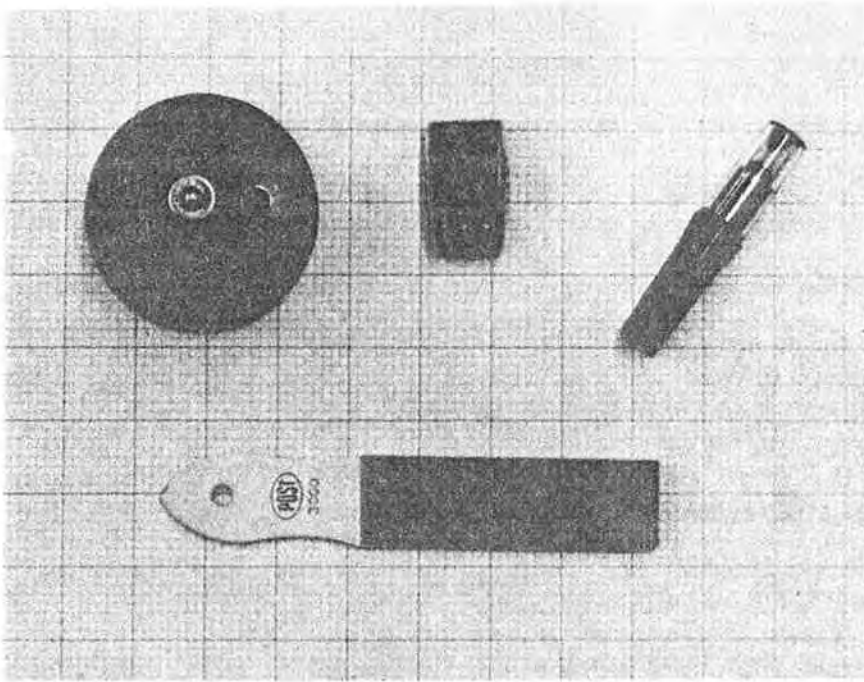


Figure 1-3 Lead sharpeners.

Figure 1-5 shows several different kinds of erasers and an erasing shield. The harder erasers are used for removing ink lines and the softer ones are used for removing pencil lines. Gum erasers (very soft) are used when large amounts of light erasing are required.

An erasing shield enables a draftsman to erase specific areas of a drawing and thereby prevents excessive redrawing of lines that might otherwise have been erased. To use an erasing shield, place it on the drawing so that the area to be removed is exposed through one of the cut-outs. (The various cutouts are shaped to match common drawing configurations.) Hold the shield down firmly and rub an eraser into the aligned cutout until the desired area is removed. When the erasing is finished, the excess eraser particles should be brushed off. Figure 1-6 demonstrates the above method.

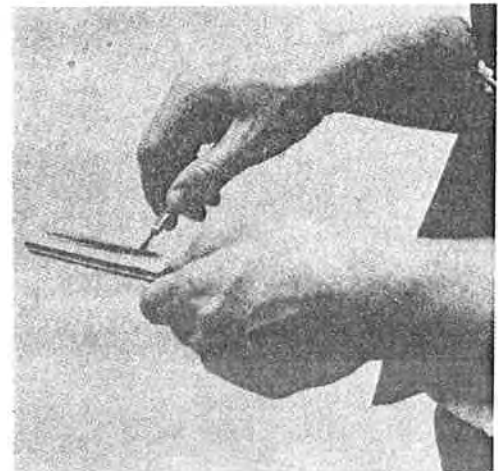


Figure 1-4 Sharpening a lead using a sandpaper block.

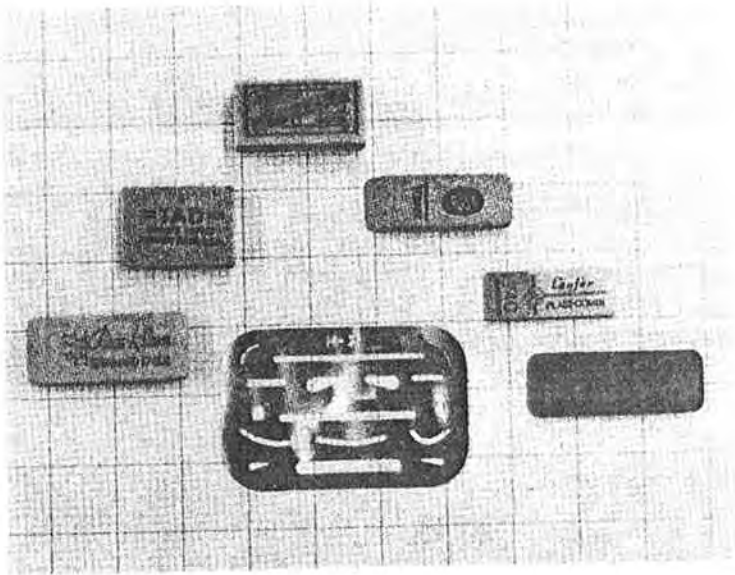


Figure 1-5 Erasers and an erasing shield.

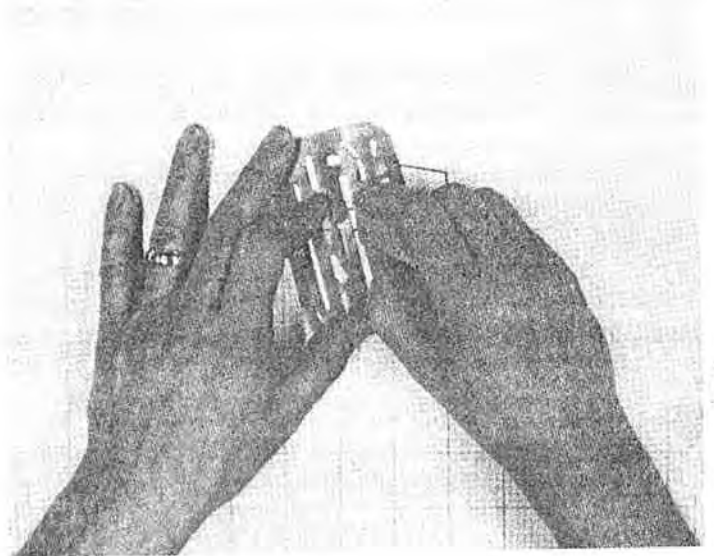


Figure 1-6 Using an erasing shield.

1-3 SCALES

Scales are used for linear measuring. Figure 1-7 shows a grouping of several different kinds of scales. The scale most commonly used by draftsmen is one with its inches graduated into 16 divisions with each division measuring one-sixteenth of an inch. Figure 1-8 shows part of a "16-to-the-inch" scale along with some sample measurements. Unlike a real scale, the scale in Figure 1-8 has the first inch completely labeled to help you become familiar with the different fractional values. Measurements more accurate than one-sixteenth must be estimated. For example, $1/32$ is halfway between the 0 and the $1/16$ marks.

Figure 1-9 shows part of a decimal scale. Each inch is divided into 50 equal parts making it possible to make measurements within 0.01

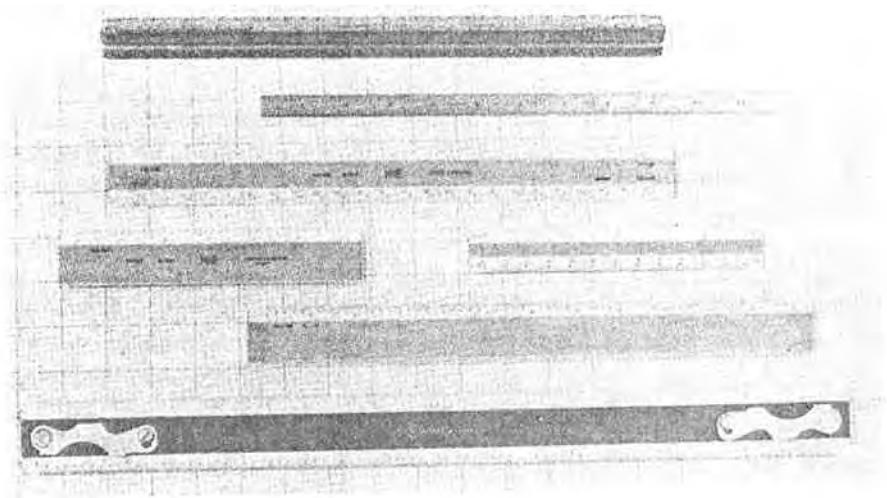


Figure 1-7 Scales.

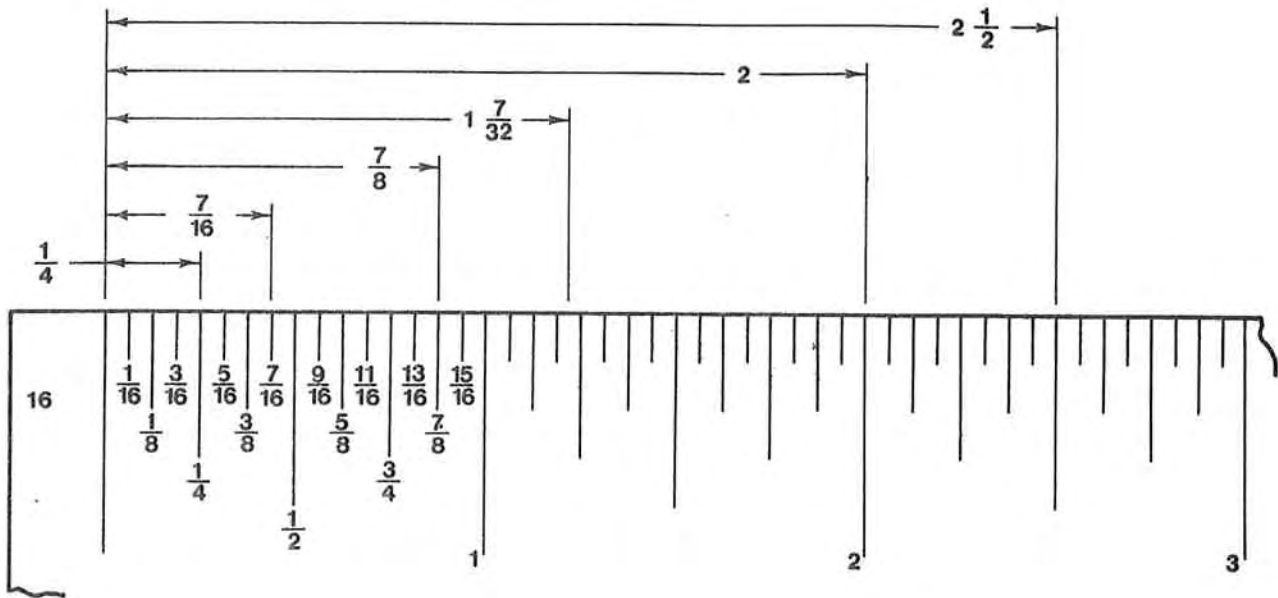


Figure 1-8 A 16-to-the-inch scale with some sample measurements.

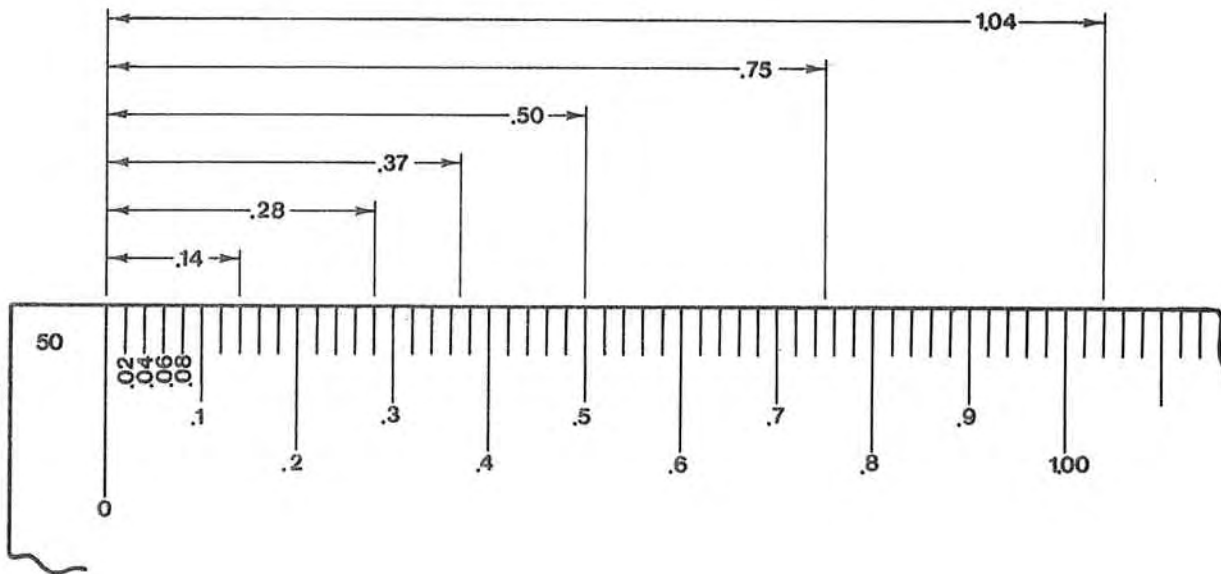


Figure 1-9 A decimal scale with some sample measurements.

inch (hundredth of an inch) accuracy. Several sample readings have been included and the first 0.10, unlike a real decimal scale, has each graduation mark labeled.

Many scales are set up for other than full-sized drawing. For example, the $\frac{1}{2}$ scale enables a half-sized drawing to be made directly without having to divide each dimensional value by 2. Three-quarter scales enable direct $\frac{3}{4}$ -sized drawings to be made, and so on.

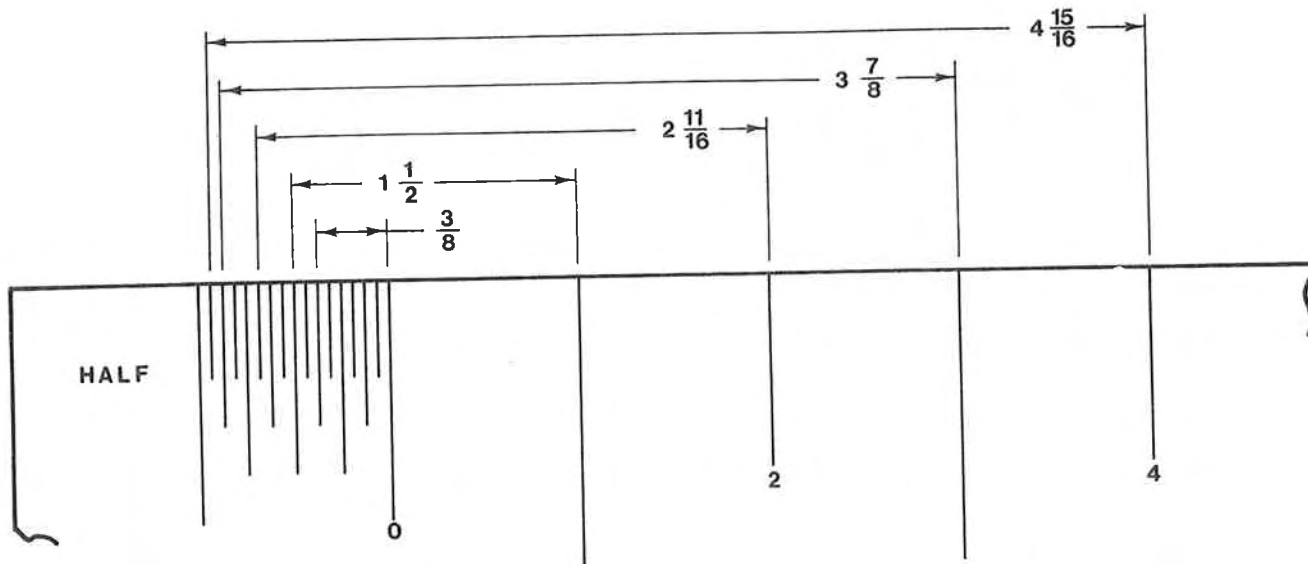


Figure 1-10 A half scale with some sample measurements.

All fractional scales are read as shown in Figure 1-10. Only one of the sections representing an inch is graduated into fractional parts. This graduated section is located to the left of the "0" mark. When making a reading (for example, $3\frac{7}{8}$) on a fractional scale, read the whole (3) part of the number to the right of the "0" and the fractional part ($\frac{7}{8}$) to the left. See Figure 1-10 for an example of a $3\frac{7}{8}$ reading on a half scale.

1-4 T-SQUARE AND TRIANGLES

A T-square is used as a guide for drawing horizontal lines and as a support for triangles which, in turn, are used as guides for drawing vertical and inclined lines. Figure 1-11 shows a T-square and several different sizes and types of triangles, including an antique wooden one.

Figure 1-11 T-square and triangles.



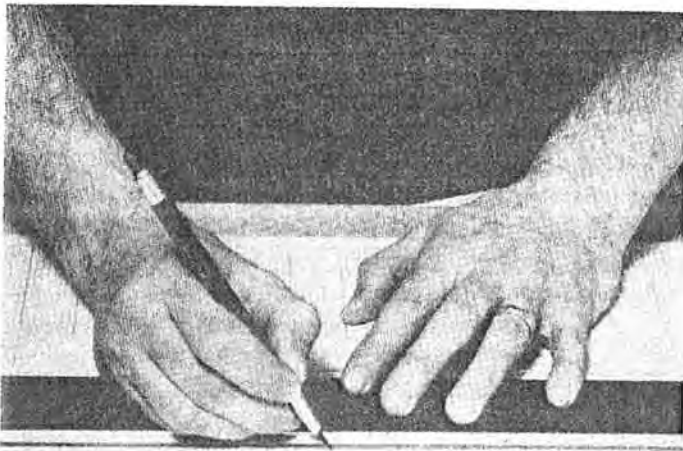


Figure 1-12(a) Drawing a horizontal line using a T-square as a guide.

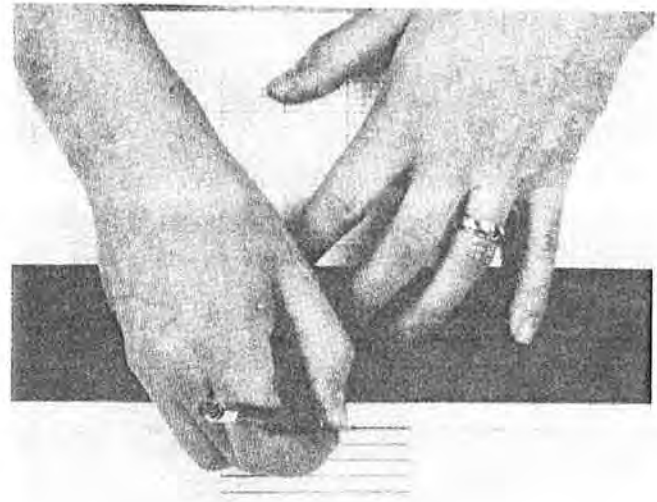


Figure 1-12(b) Drawing a horizontal line using a T-square as a guide.

To use a T-square or triangle as a guide for drawing lines, hold the pencil as shown in Figures 1-12(a) and 1-12(b) and pull the pencil along the edge of the straight edge from left to right. (These instructions are for right-handed people. Left-handed people should reverse these directions.) Rotate the pencil as you draw so that a flat spot will not form on the lead. Flat spots cause wide, fuzzy lines of uneven width. Always remember to keep your drawing lead sharp.

When using a T-square, hold the head (top of the T) firmly and flat against the edge of the drawing board. Use your left hand to hold the T-square still and in place while you draw. When you move the T-square, always check to see that the head is snug against the edge of the drawing board before you start to draw again.

When a T-square and a triangle are used together to create a guide for drawing, the left hand must not only hold the T-square in place; it must also hold the edge of the triangle firmly and flat against the edge of the T-square. To accomplish this, use the heel of your hand to hold the T-square in place and your fingers to keep the triangle against the T-square (see Figure 1-13).

It is important that all your tools be accurate. A T-square, for example, must have a perfectly straight edge. If it does not, you will draw wavy lines and inaccurate angles with the triangles. To check a T-square for accuracy, draw a long line by using the T-square as a guide. Then flip the T-square over, as shown in Figure 1-14, and, using the same edge you just used as a guide, see if the T-square edge (now upside-down) matches the line. If it does not, the T-square is not accurate.

Triangles should be checked for straightness in the same manner used to check a T-square, but, in addition, they must be checked for "squareness." To check a triangle for squareness, align the triangle against the T-square and draw a line by using the edge of the triangle which forms a 90°-angle to the T-square as a guide. Holding the T-square in place, flip the triangle over, as shown in Figure 1-15, and see if the triangle edge matches the line. If it does not, the triangle is not

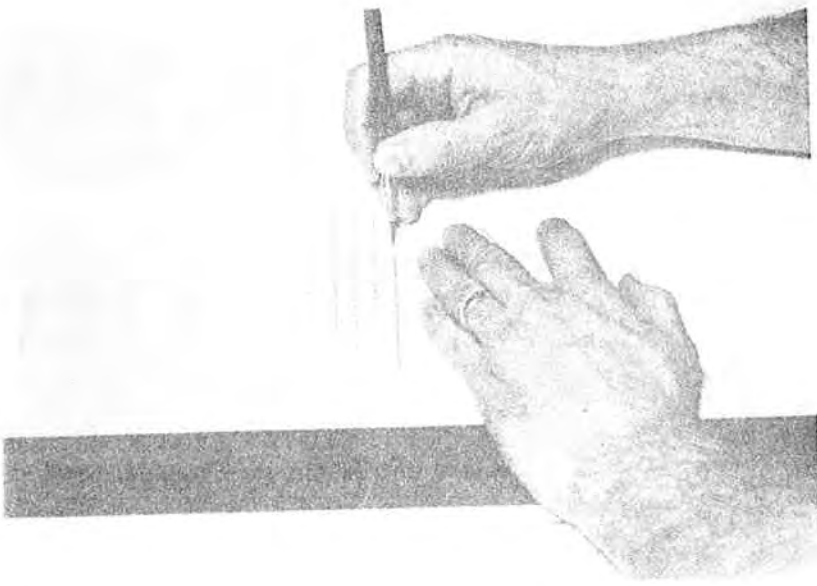


Figure 1-13 Drawing a vertical line using a T-square and a triangle as a guide.

Figure 1-14 Measuring the following angles

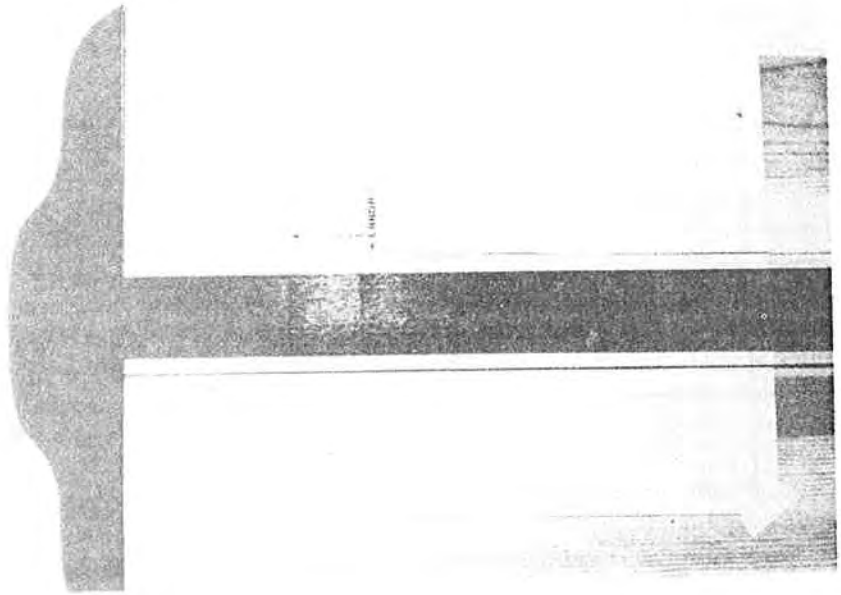


Figure 1-15 Checking a triangle for squareness.



square, meaning either that the 90° -angle is not 90° , or that the edge of the triangle is curved, or that the edge of the T-square is curved.

To use the T-square and triangle as a guide for drawing a line parallel to a given inclined line, align the long leg of the triangle with the given line and then align the T-square to one of the other legs of the triangle, as shown in Figure 1-16. By holding the T-square in place with your left hand, you can slide the triangle along the T-square and the long leg will always be parallel to the originally given line. You may substitute another triangle in place of the T-square, as shown in Figure 1-17, and obtain the same results. Note that in either setup, the short leg of the moving triangle is 90° to the long leg, meaning that you have a guide not only for parallel lines, but also for lines perpendicular to those parallel lines.

A T-square may be used in combination with a 30-60-90 triangle and a 45-45-90 triangle to produce a guide for drawing lines which are 15° and 75° to the horizontal. Figure 1-18 illustrates how this is done.

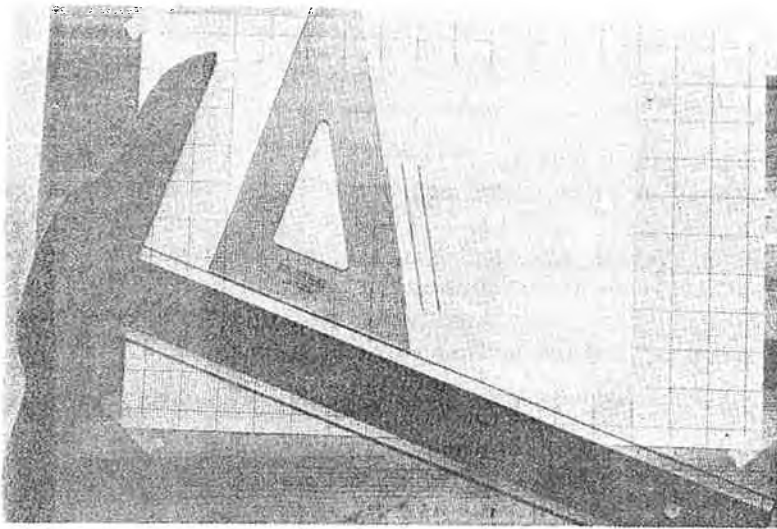


Figure 1-16 Using a T-square and a triangle as a guide for drawing inclined parallel lines.

Figure 1-17 Using two triangles as a guide for drawing inclined parallel lines.

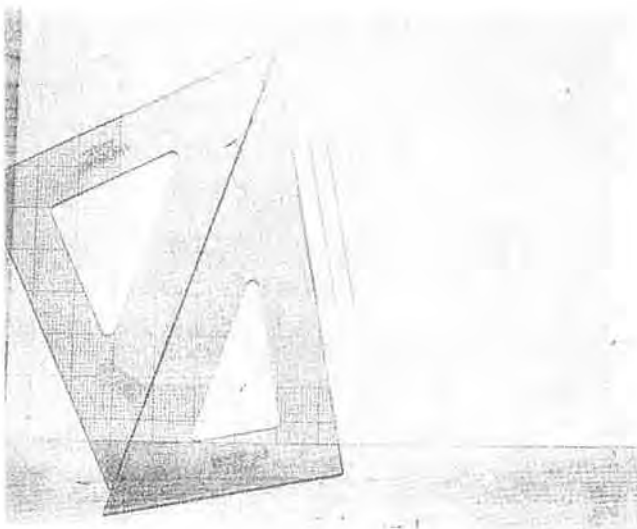
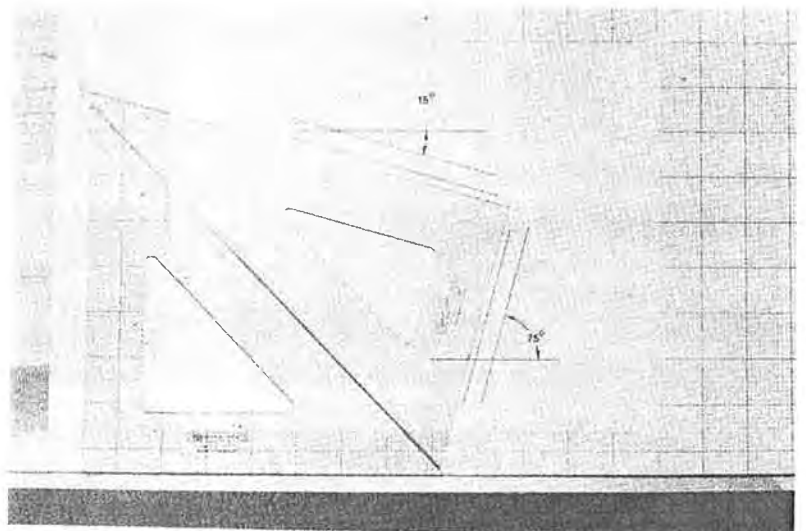


Figure 1-18 Using a T-square, a 45-45-90 triangle, and a 30-60-90 triangle to draw lines 15° and 75° to horizontal.



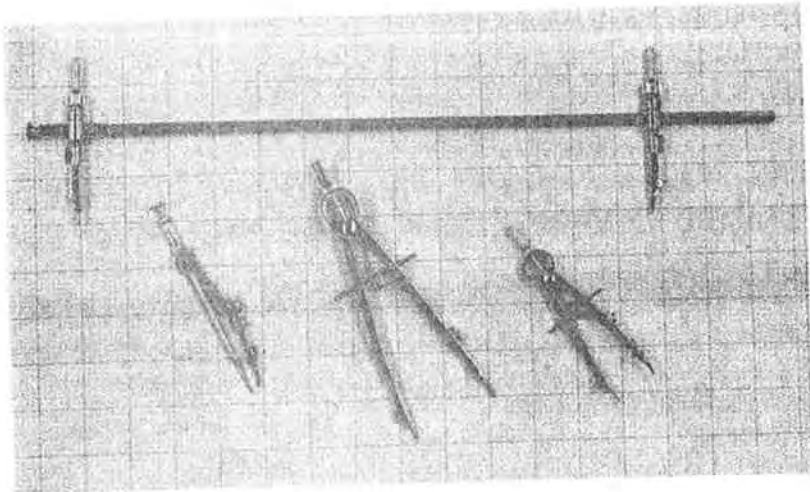


Figure 1-19 Compasses.

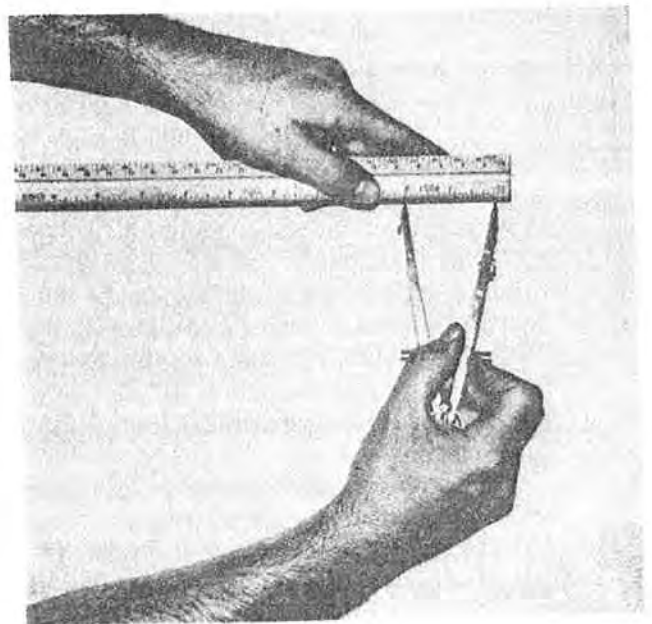


Figure 1-20 Setting a compass.

1-5 COMPASS

A compass is used to draw circles and arcs. The three basic kinds of compasses are drop, bow, and beam. The bow is the most common (see Figure 1-19).

To use a compass, set the compass opening equal to the radius of the desired circle or arc by using a scale as shown in Figure 1-20. Then place the compass point directly on the circle center point and, using only one hand and shown in Figures 1-21(a) and 1-21(b), draw in the circle.



Figure 1-21(a) Drawing with a compass. Illustration courtesy of Teledyne Post, Des Plaines, Illinois 60016.

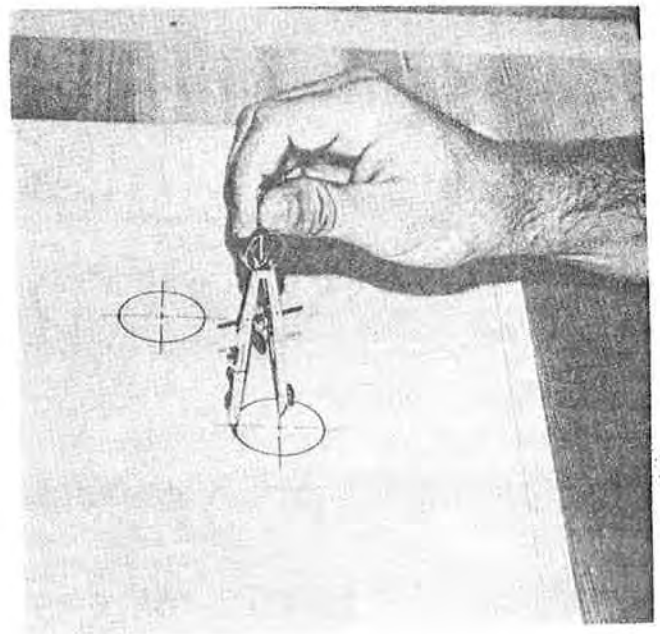


Figure 1-21(b) Drawing with a compass.

A compass lead must be sharpened differently from a pencil lead since the compass lead cannot be rotated during use to prevent flat spots from forming. Figure 1-22 shows how to sharpen a compass lead and Figure 1-23 shows a close-up of a properly sharpened compass lead.

1-6 PROTRACTORS

A protractor is used to measure angles. Figure 1-24 shows three different kinds of protractors. The edge of a protractor is calibrated into degrees and half degrees. Figure 1-25 shows part of a typical protractor edge along with some sample measurements. Measurements more accurate than half a degree (0.5°) must be estimated.

To measure an angle, place the center point of the protractor on the origin of the angle so that one leg of the angle aligns with the 0° mark on the protractor. Read the angle value where the other leg of the angle intersects the calibrated edge of the protractor.

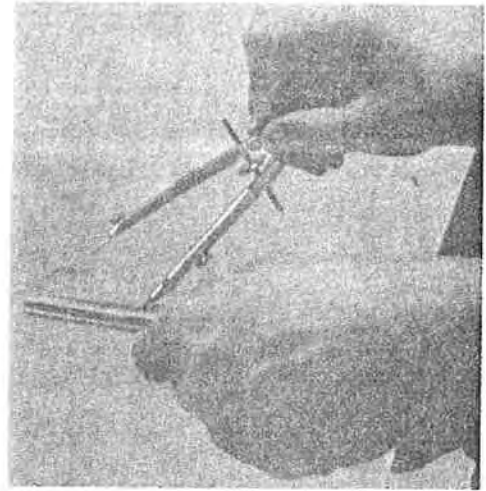


Figure 1-22 Sharpening a compass lead.

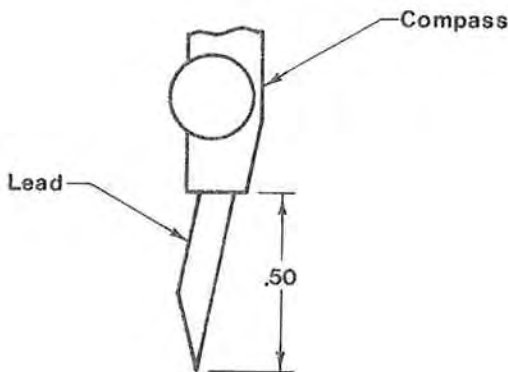


Figure 1-23 The shape of a properly sharpened compass lead.

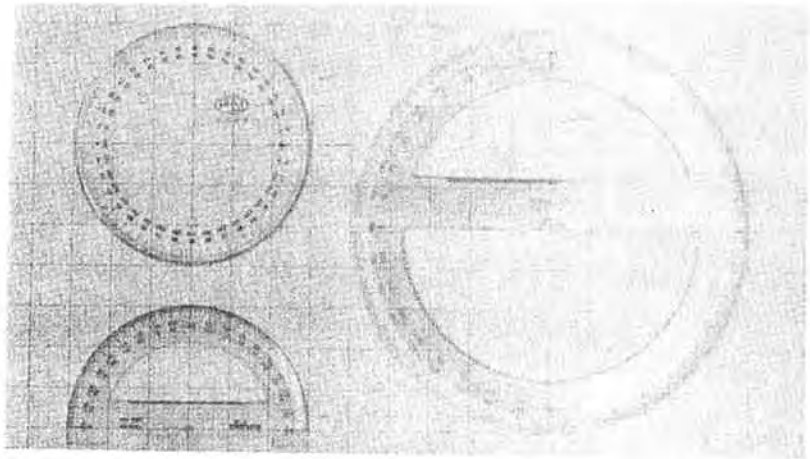


Figure 1-24 Protractors.

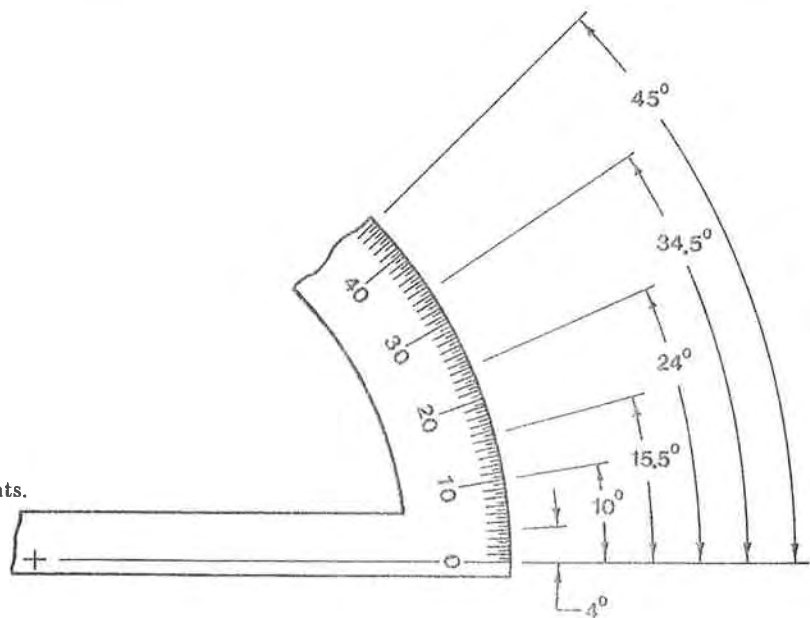


Figure 1-25 A protractor with some sample measurements.

1-7 CURVES

Curves are used to help draw noncircular curved shapes. Draftsmen refer to them as *French curves* or *ship's curves*, depending on their shapes (ship's curves look like the keel of a ship). Figure 1-26 shows a grouping of curves.

Noncircular shapes are usually defined by a series of points and a curve is used to help join the points with a smooth, continuous line. Using a curve to help create a smooth line is difficult and requires much practice. Most students make the error of trying to connect too many points with one positioning of the curve. Figure 1-27 shows a series of points that are partially connected. The curve is in position to serve as a guide for joining *only* points 3 and 4—not 3, 4, and 5—even though all three seem to be aligned. To join point 5 using the shown curve position would make it almost impossible to draw a continuous smooth curve.

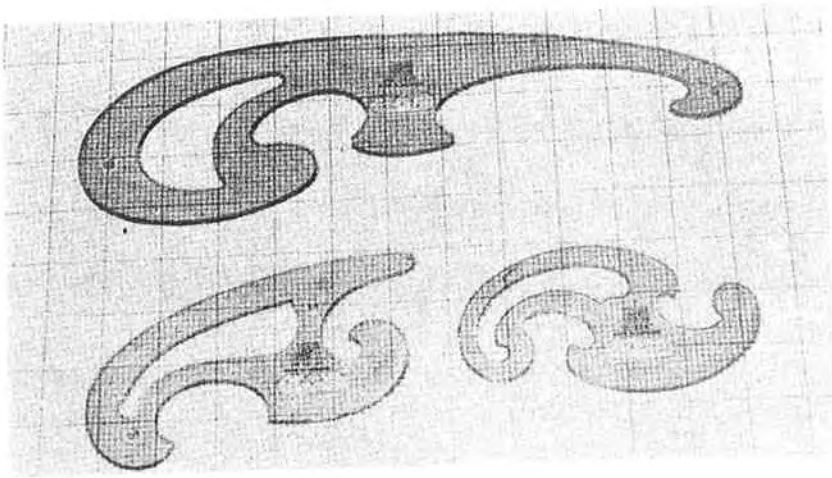


Figure 1-26 Curves.

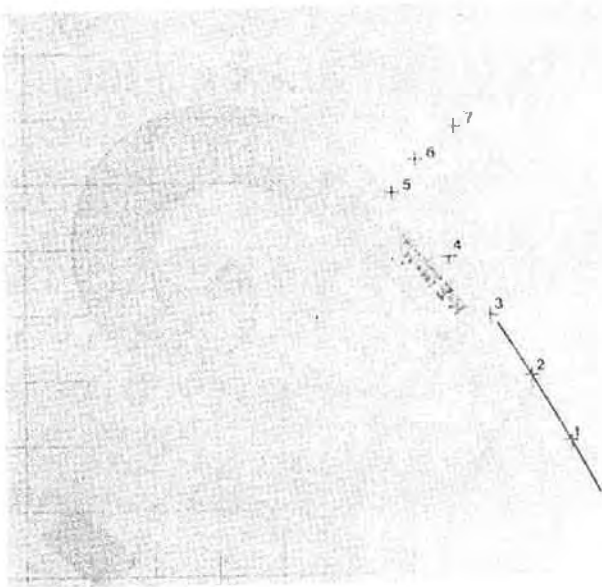


Figure 1-27 Aligning a curve with given points.

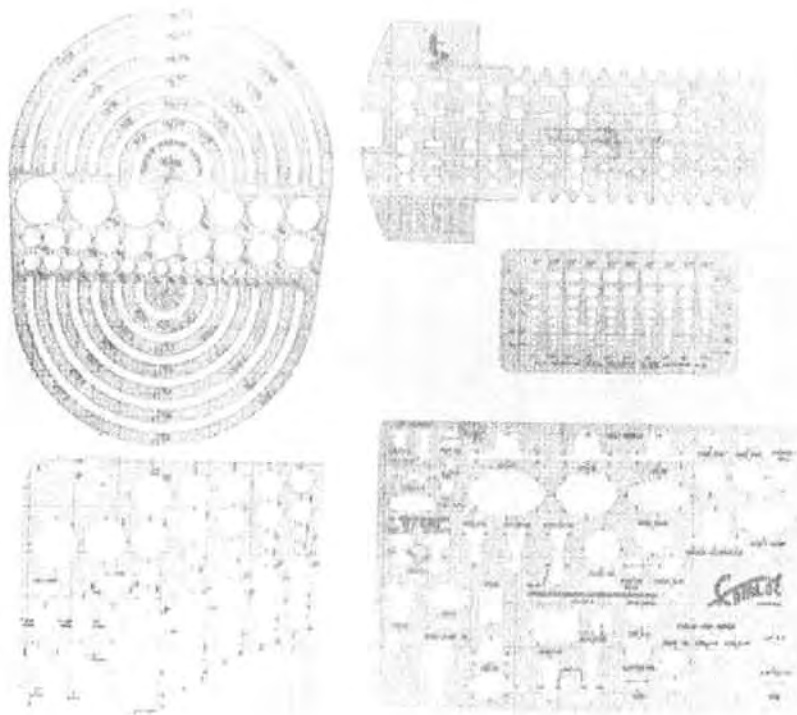


Figure 1-28 Templates.



Figure 1-29 Circle templates.

1-8 TEMPLATES

Templates are patterns cut into shapes useful to a draftsman. They save drawing time by enabling the draftsman to accurately trace a desired shape. Some templates provide shapes that are difficult to draw with conventional drawing tools (very small circles, for example). Other templates provide shapes that would be tedious and time-consuming to layout and draw (ellipses, for example). Figure 1-28 shows a sampling of templates.

The most common template used in mechanical drafting is the circle template (see Figure 1-29). The holes of a circle template are

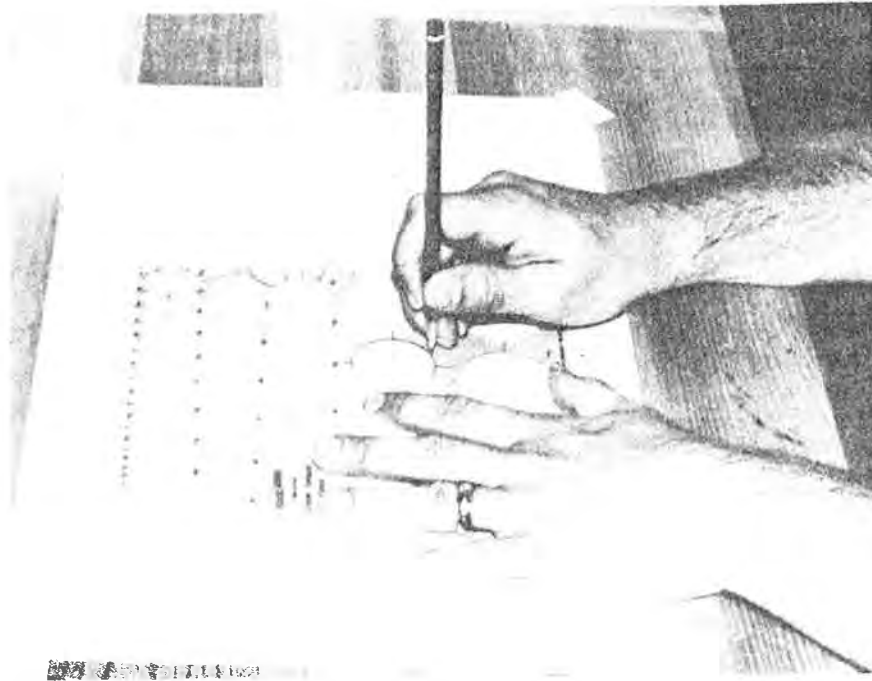


Figure 1-30 Using a circle template.

labeled by diameter size and are generally made slightly oversized to allow for lead thickness. Always check a circle template before initial use to see if lead allowance has been included.

To use a circle template, locate the center point of the future circle with two lines 90° to each other. Align the template with the two 90° lines by using the four index marks printed on the edge of the template hole. Draw in the circle. Keep the leadholder vertical and constantly against the inside edge of the hole pattern. Check the finished circle with a scale. Figure 1-30 shows how to use a circle template.

1.9 OTHER TOOLS

There are many tools, other than the ones already presented, which are used to help create technical drawings. Figure 1-31, for example, shows an adjustable curve ("snake") which is very helpful when drawing unusually shaped curves. Figure 1-31 also shows several other tools.

Figures 1-32(a) and 1-32(b) illustrate a drafting machine. A drafting machine is a combination T-square, triangle, protractor, and scale which, when used properly, will greatly increase drawing efficiency. The information previously presented for using a T-square, triangle, protractor, and scale may be directly applied to using a drafting machine. Check the manufacturer's instructions for the specific functions of the machines.

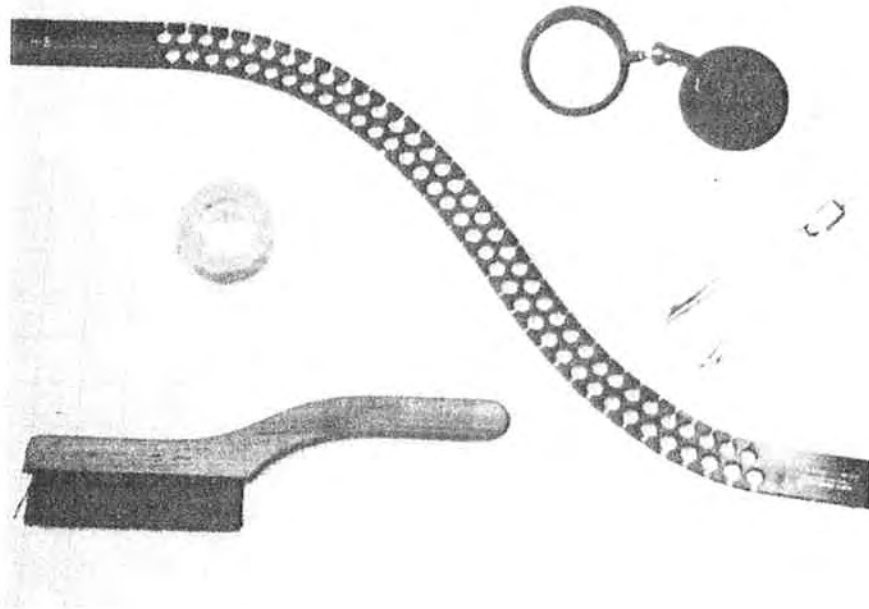


Figure 1-31 Magnifying glass, dividers, adjustable curve (snake), tape, and brush.

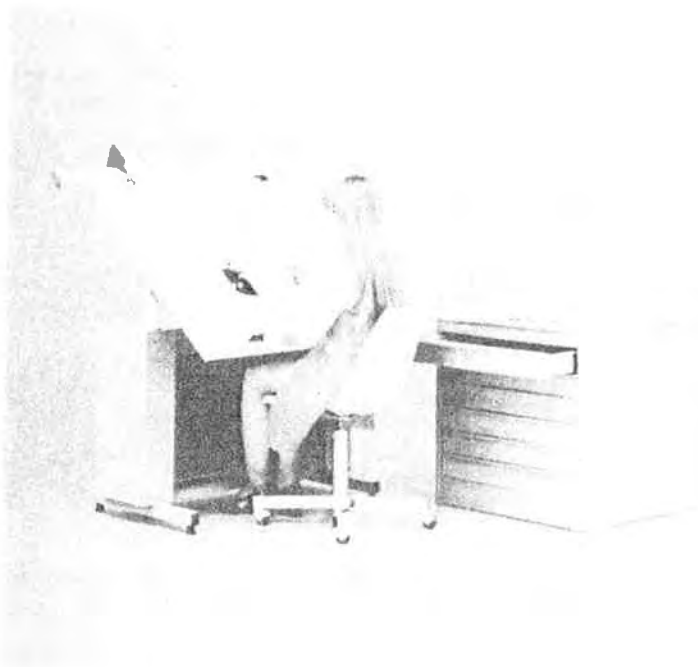


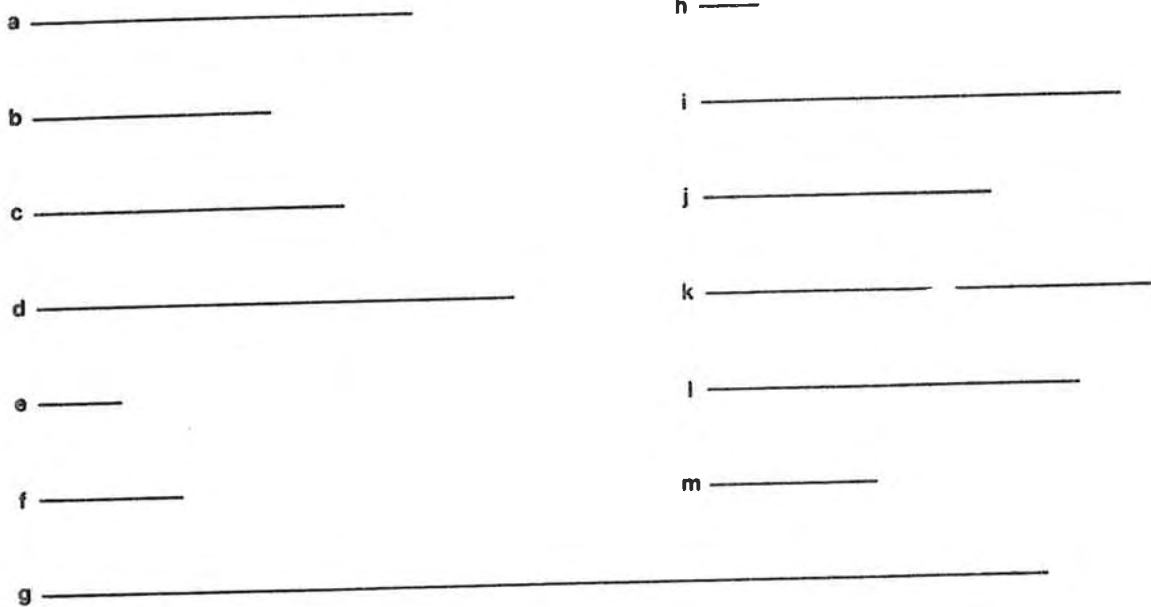
Figure 1-32(a) Using a drafting machine and an adjustable drawing board. Illustration courtesy of Teledyne Post, Des Plaines, Illinois 60016.



Figure 1-32(b) Using a drafting machine. Illustration courtesy of Teledyne Post, Des Plaines, Illinois 60016.

PROBLEMS

- 1-1 (a) Measure the following lines to the nearest 1/16 of an inch:
 (b) Measure the following lines to the nearest .01 of an inch:



- 1-2 Draw four 8"-lines as shown in Figure P1-2. Make the lines very light and very thin. Define the left end of each line as point 1.

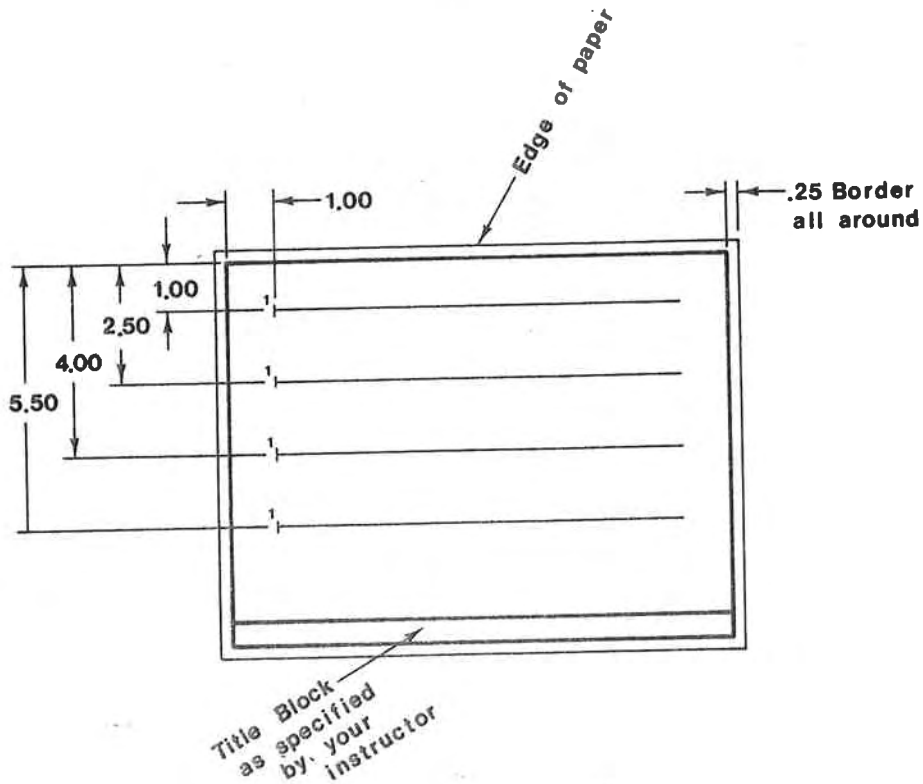


Figure P1-2

Using point 1 as a starting point, measure off and label the following points:

Line 1	Distance	Value
	1-2	1-3/8
	1-3	1-9/16
	1-4	2-1/4
	1-5	2-7/8
	1-6	3-21/32
	1-7	5
	1-8	5-3/8
	1-9	5-3/4
	1-10	6-5/16
	1-11	7-15/16

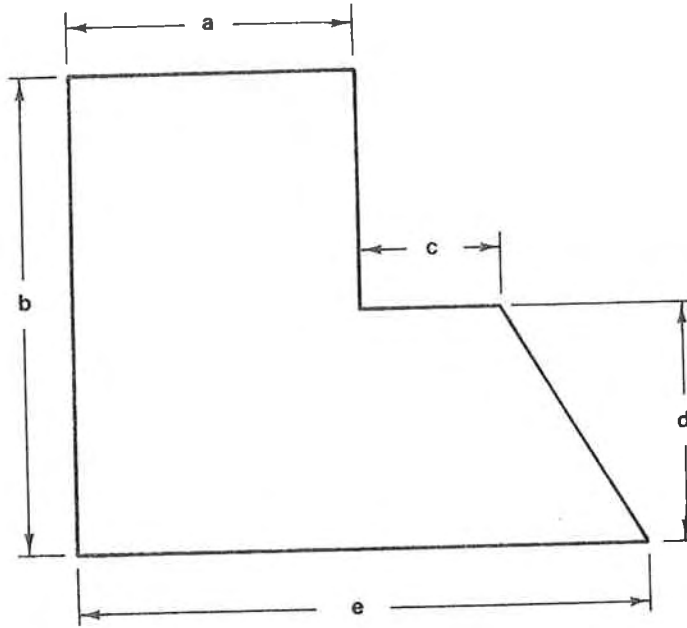
Line 2	Distance	Value
	1-2	0.8
	1-3	1.4
	1-4	2.6
	1-5	3.1
	1-6	4.3
	1-7	5.0
	1-8	5.5
	1-9	6.2
	1-10	6.9
	1-11	7.7

Line 3	Distance	Value
	1-2	0.38
	1-3	1.25
	1-4	2.44
	1-5	3.06
	1-6	4.22
	1-7	5.00
	1-8	5.50
	1-9	6.13
	1-10	6.94
	1-11	7.88

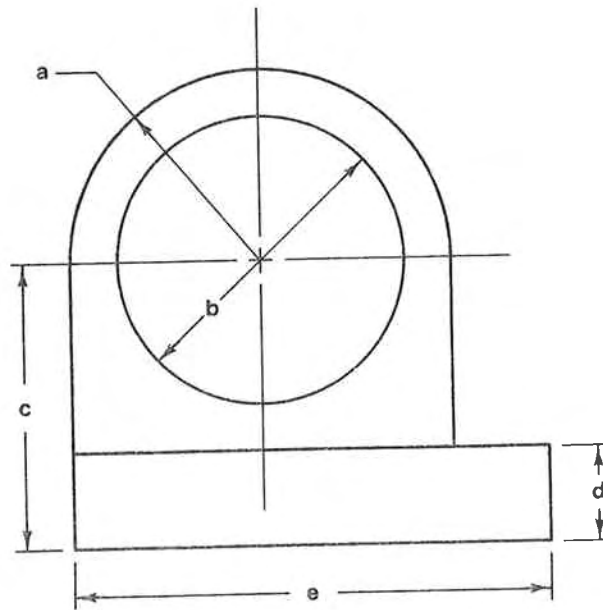
Line 4 The values given must be reduced by a factor of 2 to fit on the line. Therefore, using a $\frac{1}{2}$ scale, draw the values.

Distance	Value
1-2	1.75
1-3	2.25
1-4	4.38
1-5	6.75
1-6	8.63
1-7	10.00
1-8	11.50
1-9	12.88
1-10	13.75
1-11	16.00

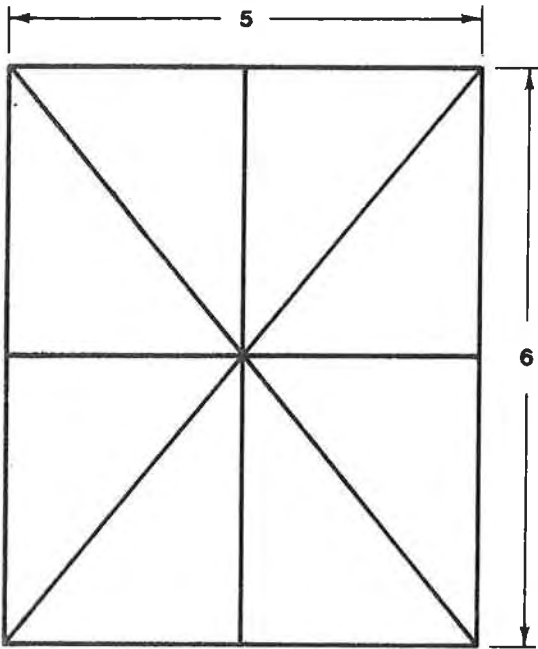
- 1-3 Measure the following lettered distances to the nearest $\frac{1}{16}$ of an inch.



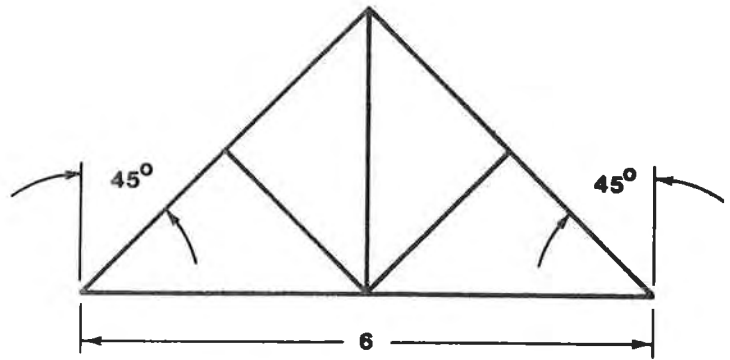
- 1-4 Measure the following lettered distances to the nearest .01 inch.



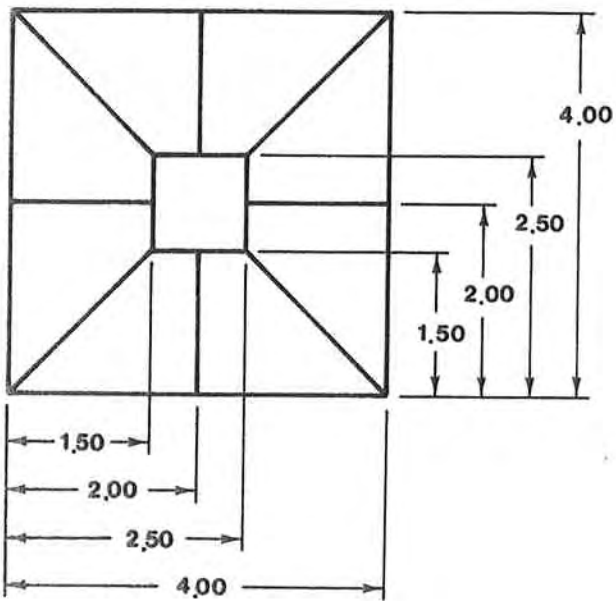
1-5 Redraw the following figure.



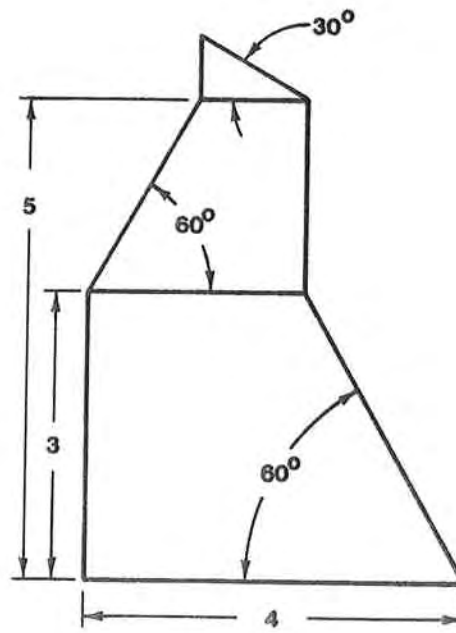
1-6 Redraw the following figure.



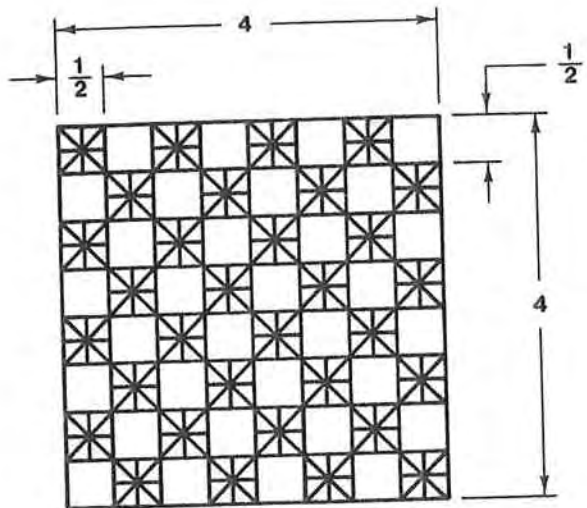
1-7 Redraw the following figure.



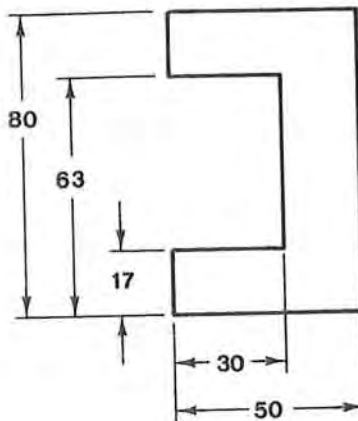
1-8 Redraw the following figure.



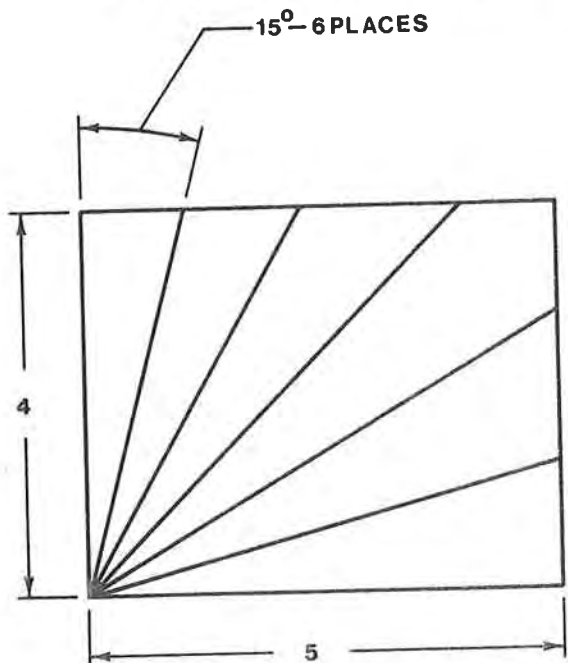
1-9 Redraw the following figure.



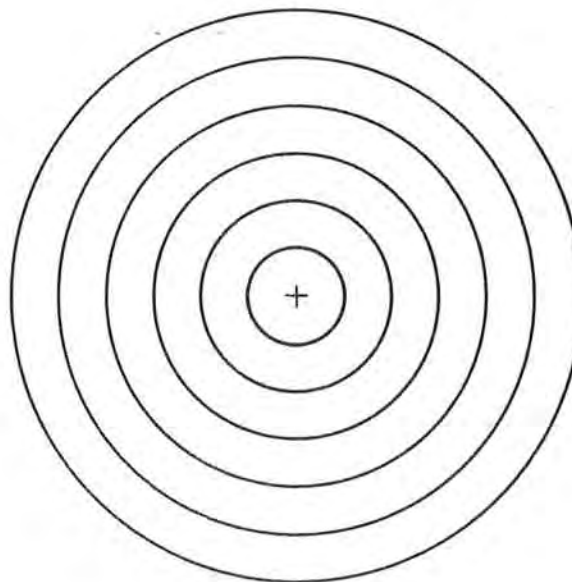
1-10 Redraw the following figure. All dimensions are in millimeters.



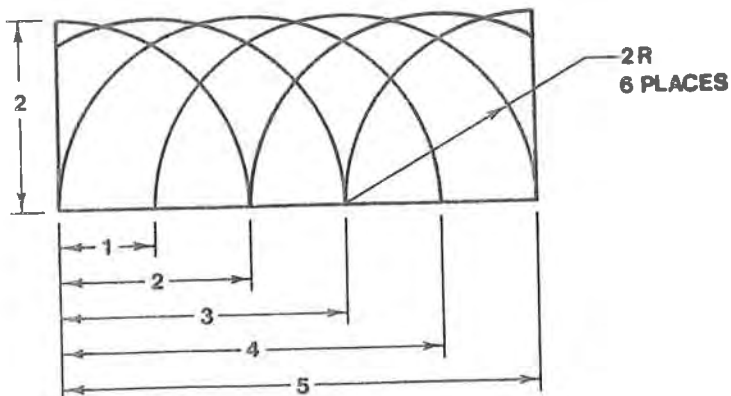
1-11 Redraw the following figure. Use only a T-square, a 30-60-90 triangle, and a 45-45-90 triangle or a drafting machine.



1-12 Redraw the following figure. The smallest circle is 1" in diameter and each additional circle is 1" larger in diameter up to 6".



1-13 Redraw the following figure.



1-14 Redraw the following figure.

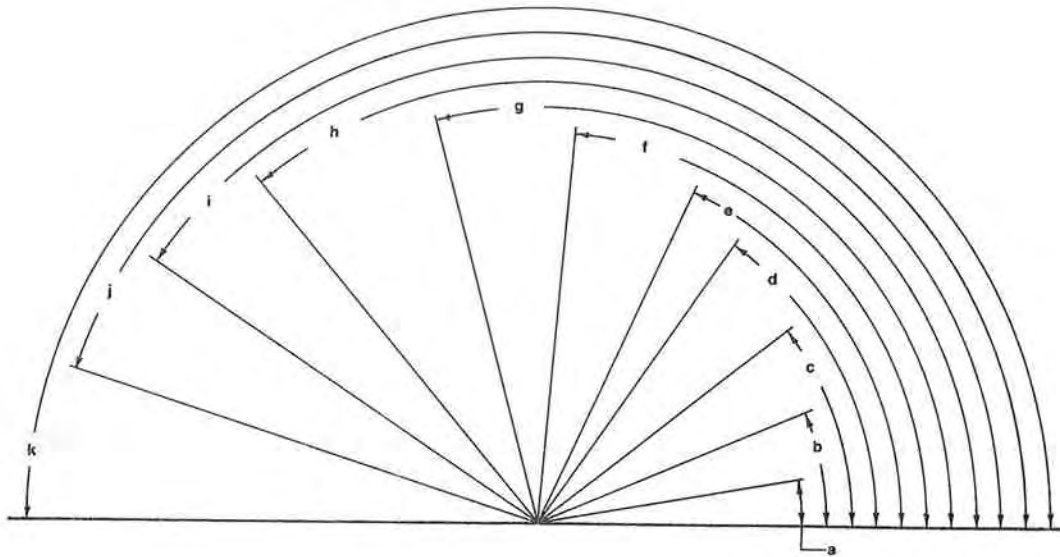


Figure P1-14 (a)

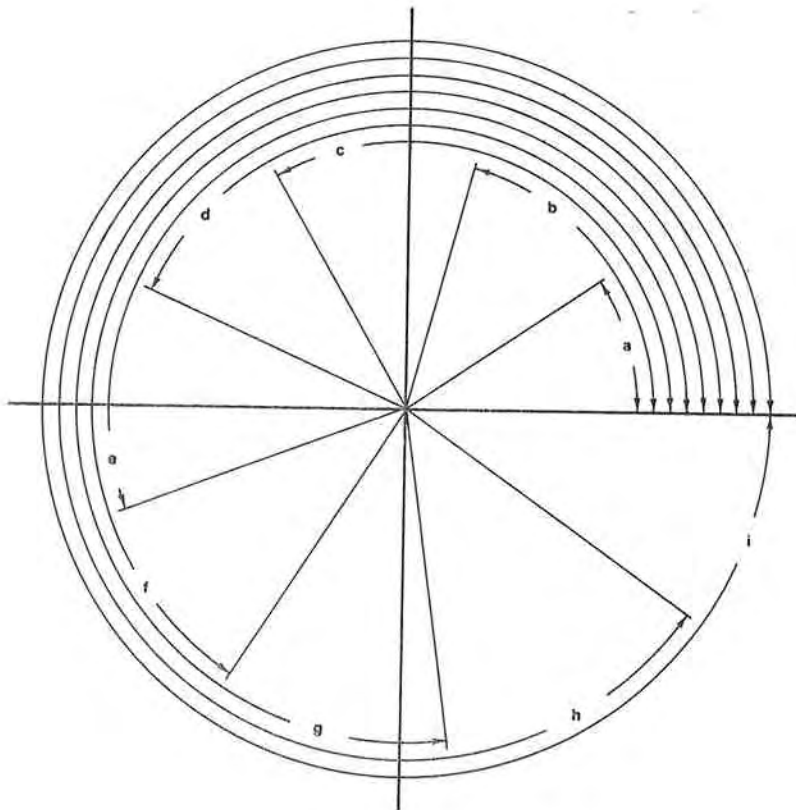
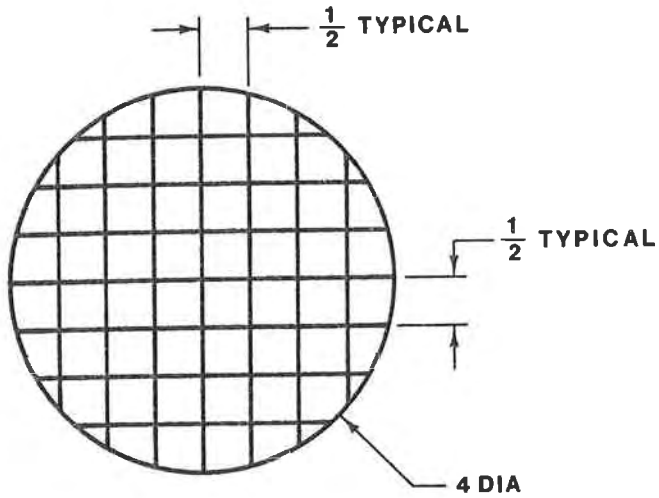
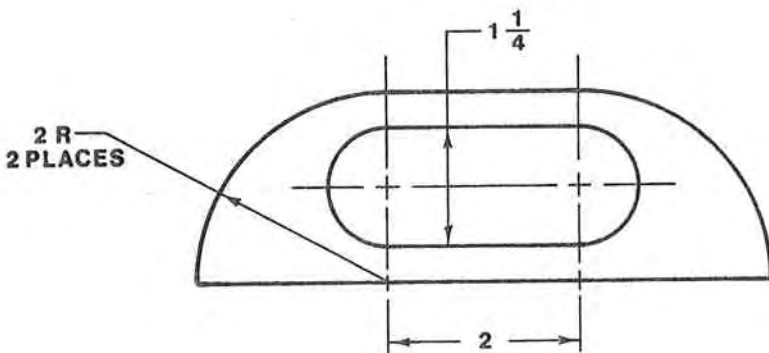


Figure P1-14(b) Measure the following angles.

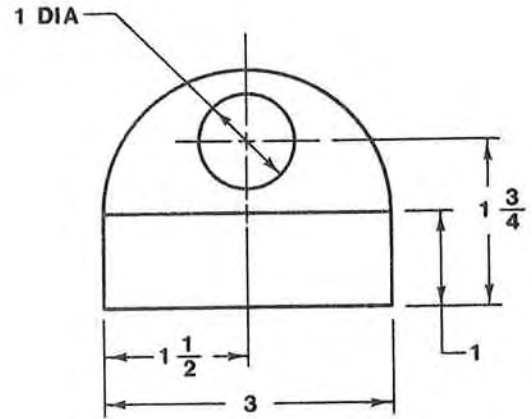
1-15 Redraw the following figure.



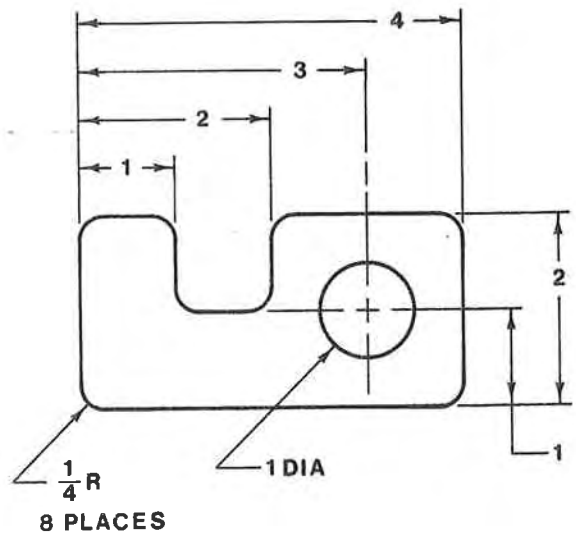
1-17 Redraw the following figure.



1-16 Redraw the following figure.

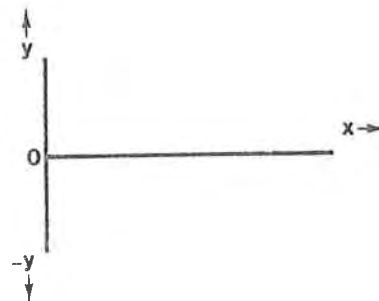


1-18 Redraw the following figure. Use a circle template to draw in the rounded corners.

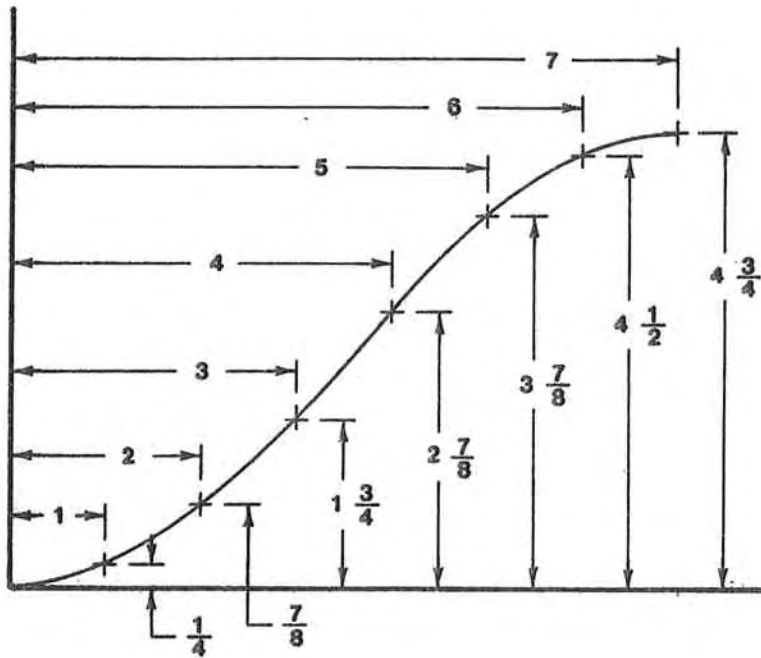


1-19 Draw two curves x versus y_1 and x versus y_2 using the data points provided. Use an axis system like the one presented and carefully label each curve.

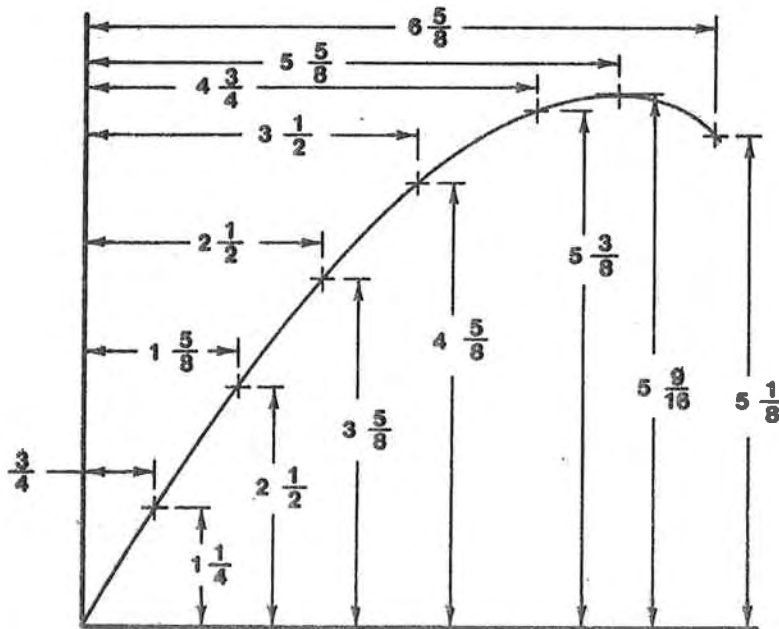
x	y_1	y_2
.00	.00	2.00
.50	1.00	1.74
1.00	1.74	1.00
1.50	2.00	.00
2.00	1.74	-1.00
2.50	1.00	-1.74
3.00	.00	-2.00
3.50	-1.00	-1.74
4.00	-1.74	-1.00
4.50	-2.00	.00
5.00	-1.74	1.00
5.50	-1.00	1.74
6.00	.00	2.00



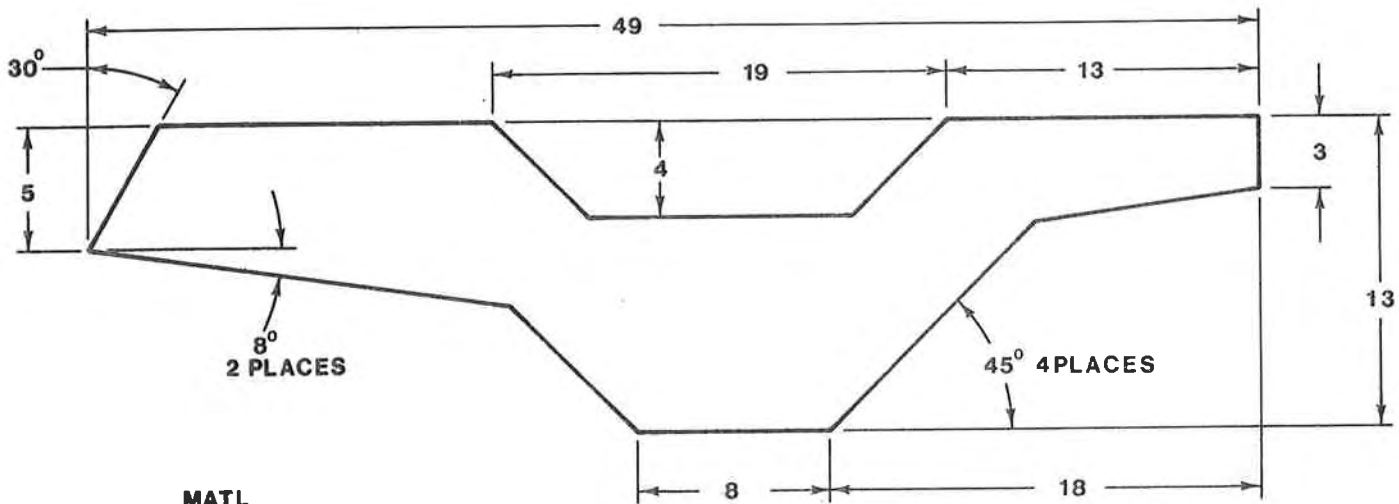
1-20 Redraw the following curve.



1-21 Redraw the following curve.



- 1-22 The following panel is part of a monocoque chassis design for a dirt track motorcycle. It was created by Bob Gould and Peter Morgan. Draw the panel on B-size (11 × 17) paper and use the $\frac{1}{4}$ scale on your triscale. Label the finished drawing "Scale $\frac{1}{4} = 1$."



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- 1-23 The performance data for the Yamaha 350RD pictured below is given in the table provided. Plot the data, draw in the curves, label each curve, and then write a short paragraph explaining what the curves mean.

Engine Performance for Yamaha RD 350:

Engine Speed (rpm)	Horsepower (bhp)	Torque (ft-lb)
2000	6.0	15.0
3000	10.5	17.0
4000	15.0	19.5
5000	21.0	21.5
6000	29.0	25.0
7000	37.0	28.0
8000	36.5	23.0
9000	24.0	12.0



Figure P1-23 Photograph courtesy of YAMAHA Corp.



DEPARTMENT OF THE ARMY
OFFICE OF THE ADJUTANT GENERAL
WASHINGTON, D.C. 20310

REPLY TO
ATTENTION OF

DAAG-PAP-A

6 January 1984

SUBJECT: General Drafting, FM 5-553

TO: HOLDERS OF FM 5-553

1. This commercial publication has been assigned Army publication number FM 5-553 and supersedes TM 5-581A.
2. This publication provides a central source of information for the technical drafting specialist, MOS 81B.
3. This letter will be permanently affixed to the book for the purpose of authenticating its use as an official DA training publication.

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LINES AND LETTERS 2

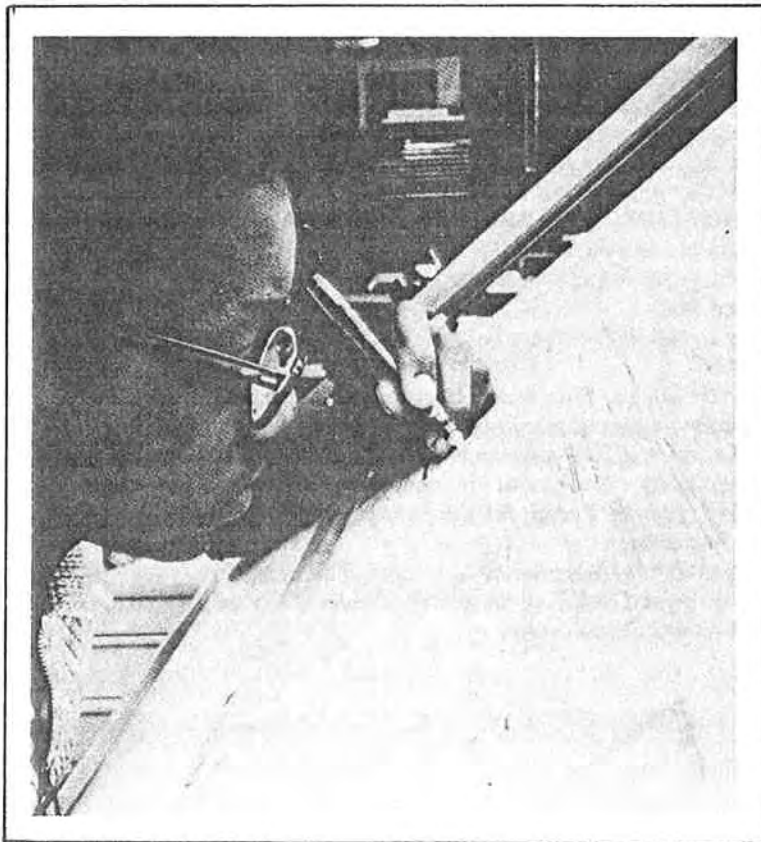


Figure 2-0 Illustration courtesy of Teledyne Post, Des Plaines, Illinois 60016.

2-1 INTRODUCTION

This chapter deals with drawing some of the many different kinds of lines used in technical drawings and deals with creating freehand lettering. Since each of these techniques will require a great deal of practice before proficiency is developed, don't be discouraged if your first attempts seem shaky. The more you draw, the better your techniques will become.

2-2 KINDS OF LINES

There are many kinds of lines commonly used on technical drawings: visible, hidden, center, leader, and phantom to name but a few. Each has its own specific configuration, thickness, intensity, and usage, some of which are defined below. They are illustrated in Figure 2-1. Those lines not defined in this chapter have a very specialized usage which will be explained in conjunction with the subjects to which they are related.

VISIBLE LINES: *Heavy, thick, black lines approximately 0.020 inches thick. Uniform in color and density. It may be helpful to draw object lines with a slightly rounded lead in order to generate the necessary thickness. To form a slightly rounded lead point, first sharpen the lead and then draw a few freehand lines on a piece of scrap paper to take the initial sharpness off the lead.*

—Used to define the visible edges of an object.

HIDDEN LINES: *Medium, black, dashed lines approximately 0.015 inches thick. The dashes should be approximately four times as long as the intermittent spaces. Hidden lines should be a little thinner and a little lighter than visible lines.*

—used to define the edges of an object which are not directly visible.

For further explanation, see Section 5-3.

LEADER LINES: *Thin, black lines about 0.010 inches thick. Leader lines should be noticeably thinner (about half as thick as visible lines). To achieve the required line contrast, draw leader lines with a sharply pointed lead.*

—used to help dimension an object. For further explanation, see Section 6-2.

CENTER LINES: *Thin, black, lines drawn in a long line-space-short line-space pattern approximately 0.010 inches thick. The long sections may be drawn at any convenient length, but the short sections must be approximately 1/8 long and the intermittent spaces should be approximately 1/16 long. Except for this configuration, center lines are identical to leader lines.*

—used to define the center of all or part of an object. They are most commonly used to define the center of holes. They may also be used to help dimension an object.

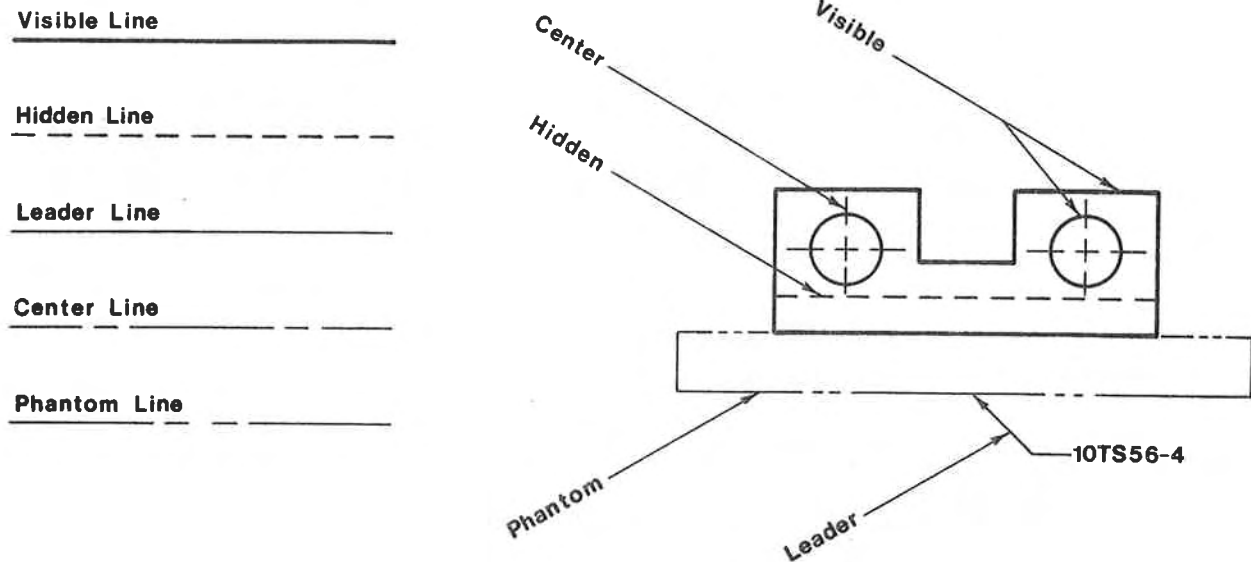


Figure 2-1 Five different types of lines commonly used on technical drawings.

PHANTOM LINES: Thin, black lines drawn in a long line-space-short line-space-short line configuration approximately 0.010 inches thick. The long sections may be varied in length, but the short lines must be 1/8 long and the intermittent spaces should be approximately 1/16 long. —used to show something that is relative to but not really part of a drawing.

After you have studied Figure 2-1, try the exercises included at the end of the chapter. Concentrate on line intensity and thickness and on the contrast between the different kinds of lines. Intensity and thickness are important, but equally important is that there be a noticeable difference between the lines. For example, visible lines must be approximately twice as thick as leader lines.

2-3 FREEHAND LETTERING

Figures 2-2 and 2-3 show the shape and style of the letters and numbers most commonly used on technical drawings. Either the vertical or inclined style is acceptable. The most widely accepted height for letters and numbers is 1/8 or 3/16, although this may vary according to the individual drawing requirements.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 a b c d e f g h i j k l m n o p q r s t u v w x y z
 0 1 2 3 4 5 6 7 8 9

Figure 2-2 Vertical letters and numbers.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z

0 1 2 3 4 5 6 7 8 9

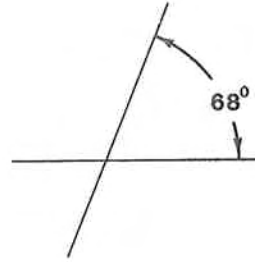


Figure 2-3 Inclined letters and numbers.

When you are lettering, see that the lead is tapered and slightly rounded at the tip. This differs from the tapered, sharp shape recommended for drawing lines because it is easier to draw letters and numbers with a rounded point.

Also when you letter, use a softer lead (H or 2H) because it is easier to letter with a soft lead than with a harder one. Since soft leads tend to deposit excess amounts of graphite on the drawing, save lettering until the last phase of creating a drawing.

2-4 GUIDE LINES

Guide lines are very light layout lines $\frac{1}{8}$ or $\frac{3}{16}$ apart (or whatever letter height is desired) which serve to help keep freehand lettering at a uniform height. They may be drawn with the aid of a scale and T-square or with the aid of a special guide line tool such as the Ames Lettering Guide. Draftsmen sometimes draw their guide lines using a nonreproducible blue pencil so that when the drawing is reproduced the guide lines seem to have disappeared and only the letters or numbers remain. Figure 2-4 illustrates guide lines.

Draftsmen sometimes avoid putting guide lines on their drawings by slipping a piece of graph paper, whose grid lines are the desired distance apart, under the paper and then lettering within the grid lines. This, of course, may be done only if you are working on a transparent media.

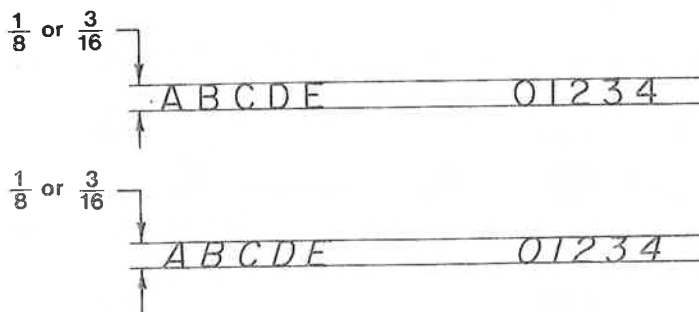


Figure 2-4 Guide lines for lettering.

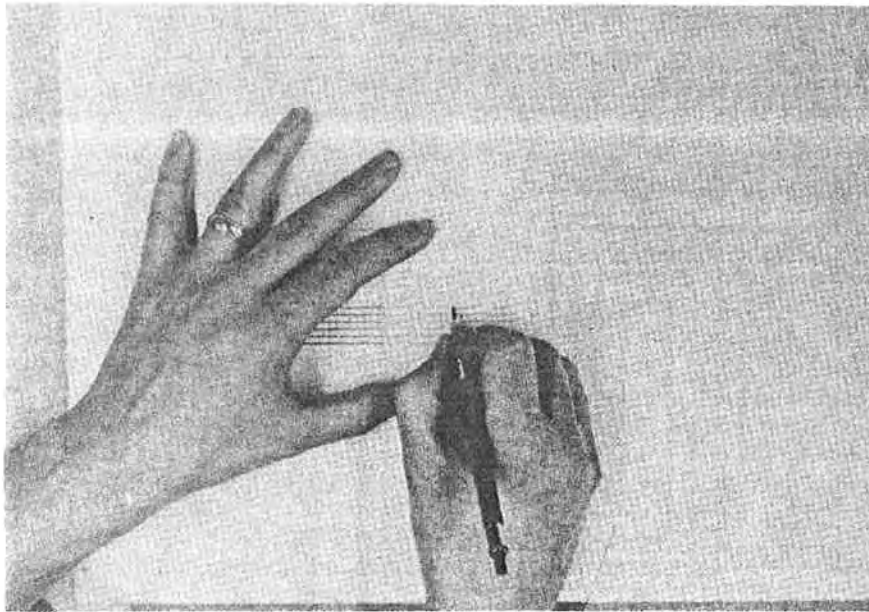


Figure 2-5 Creating guide lines for lettering by sliding a previously prepared set of parallel lines under the drawing paper.

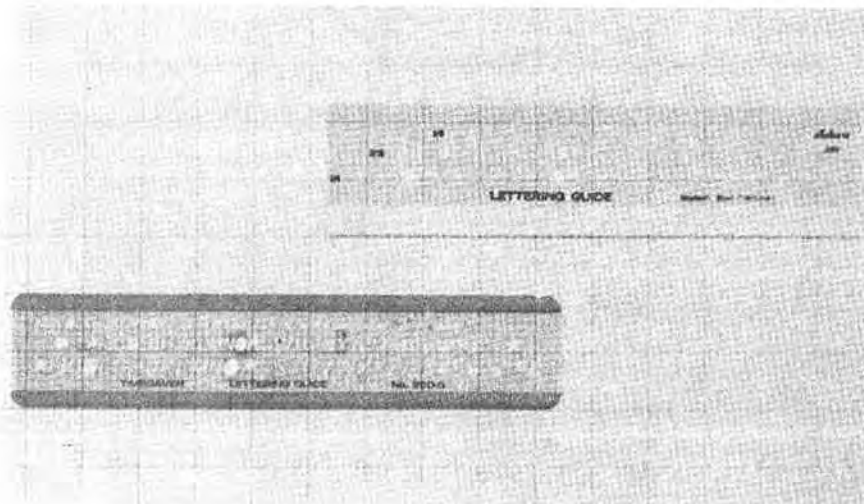
If graph paper is not available or does not have the right size grid, you may make your own guide line pattern on a separate piece of paper and then slide it under your drawing as was recommended for the graph paper. Figure 2-5 shows how this is done. Save the prepared guide line pattern for future use.

2-5 LETTERING GUIDES

There are several different lettering guides that may be used to create letters and numbers for drawings. By far the most widely used guide for pencil work are the stencil kind shown in Figure 2-6.

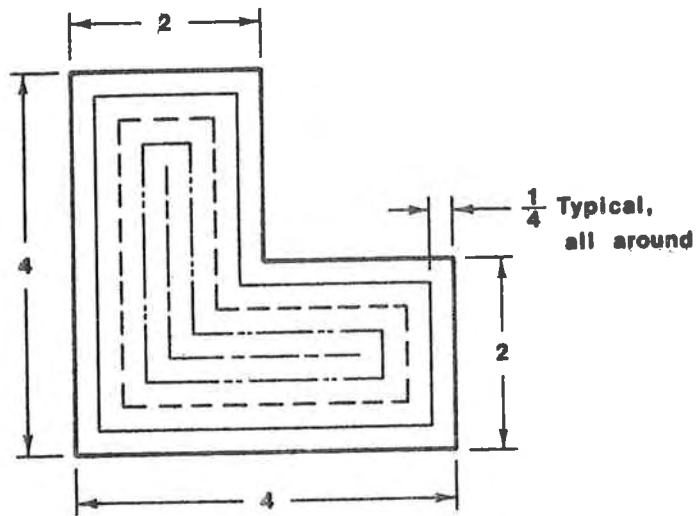
When you use a lettering guide, support it with a rigidly held T-square or other straight edge so that all the lettering is kept in the same line. Use the same lead point shape described for use in freehand lettering (see Section 2-3).

Figure 2-6 Lettering guides.

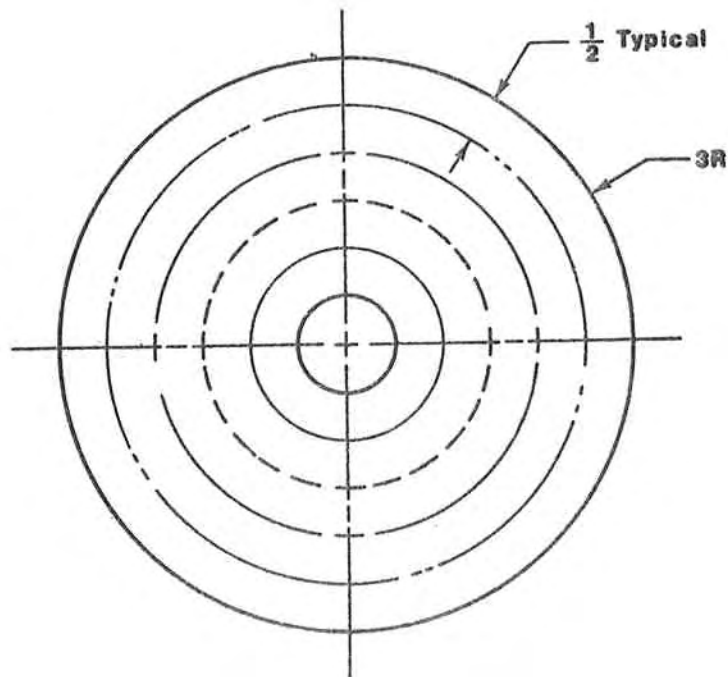


PROBLEMS

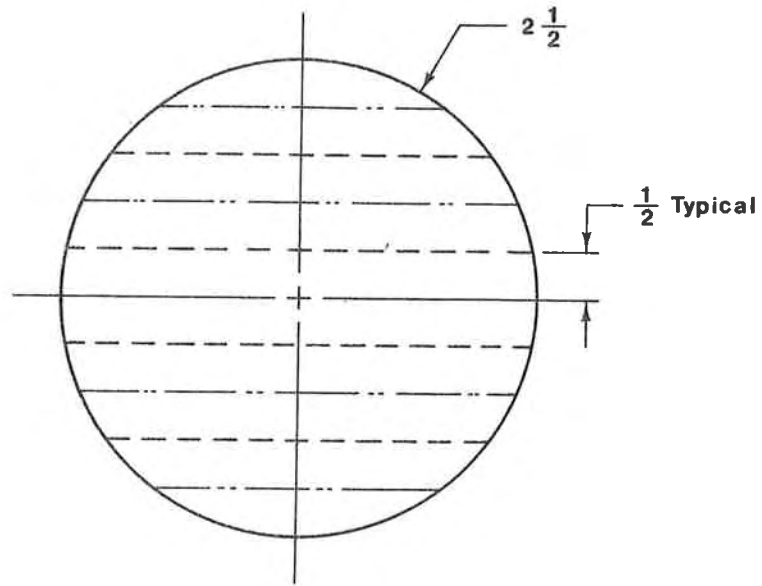
2-1 Redraw the following figure.



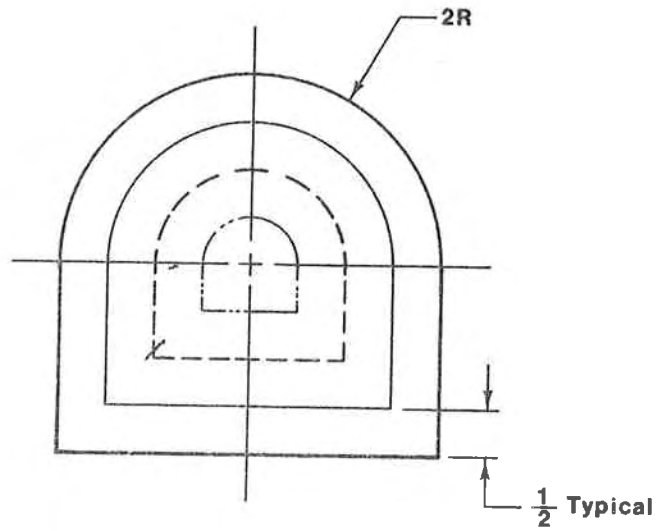
2-2 Redraw the following figure.



2-3 Redraw the following figure.

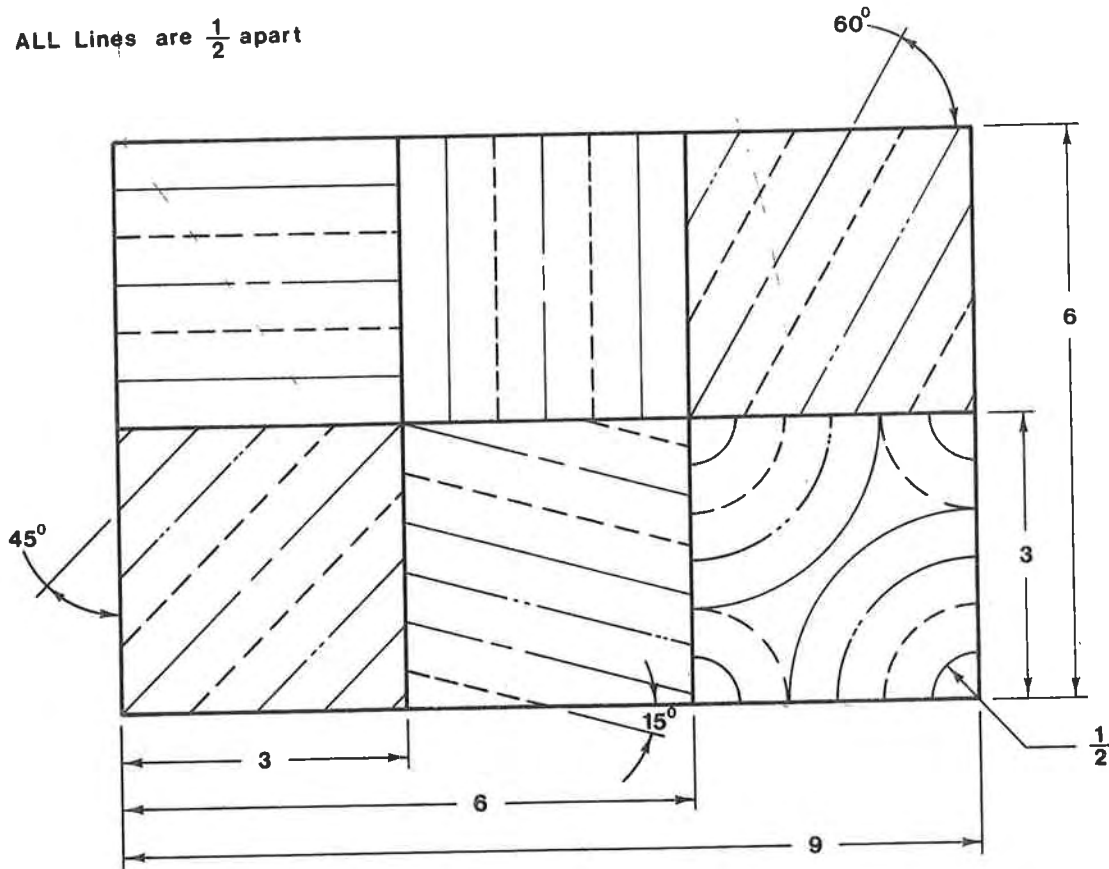


2-4 Redraw the following figure.



2-5 Redraw the following figure.

ALL Lines are $\frac{1}{2}$ apart



2-6 Letter the following notes.* Use the format illustrated in Figure P2-6.

1. Right shown-left-sym. opp.
2. All inside bend radii are 2-times metal thickness unless otherwise shown.
3. Mating surfaces must be coordinated with master die model of parts as shown.
4. Same as 3431906 except as shown & use 3799034 w/wpr motor decal in place of 3431908.
5. For inspection purposes, anchor hole at point A to set dimensions specified, and check points B & C with 50# load applied at point D in direction shown. Do not use tension spring during insp. check.
6. Open tab for access to seat track attachment. Tab must be closed after assy. of track (2-places).
7. Exceptions to PS4480-entire week may be coded with first workday of that week.
8. The terminals shall not loosen or pull off their component assy at less than 15-lb effort applied to either terminal for installation or removal of mating terminal.
9. For additional detail, see master model in Ornamentation Studio Dept 6910.

*Courtesy of Chrysler Corporation.

10. Vendor must obtain location approval for gating & ejector pins & dimensional approval of ejector pin bosses from materials laboratory engineering staff prior to construction.

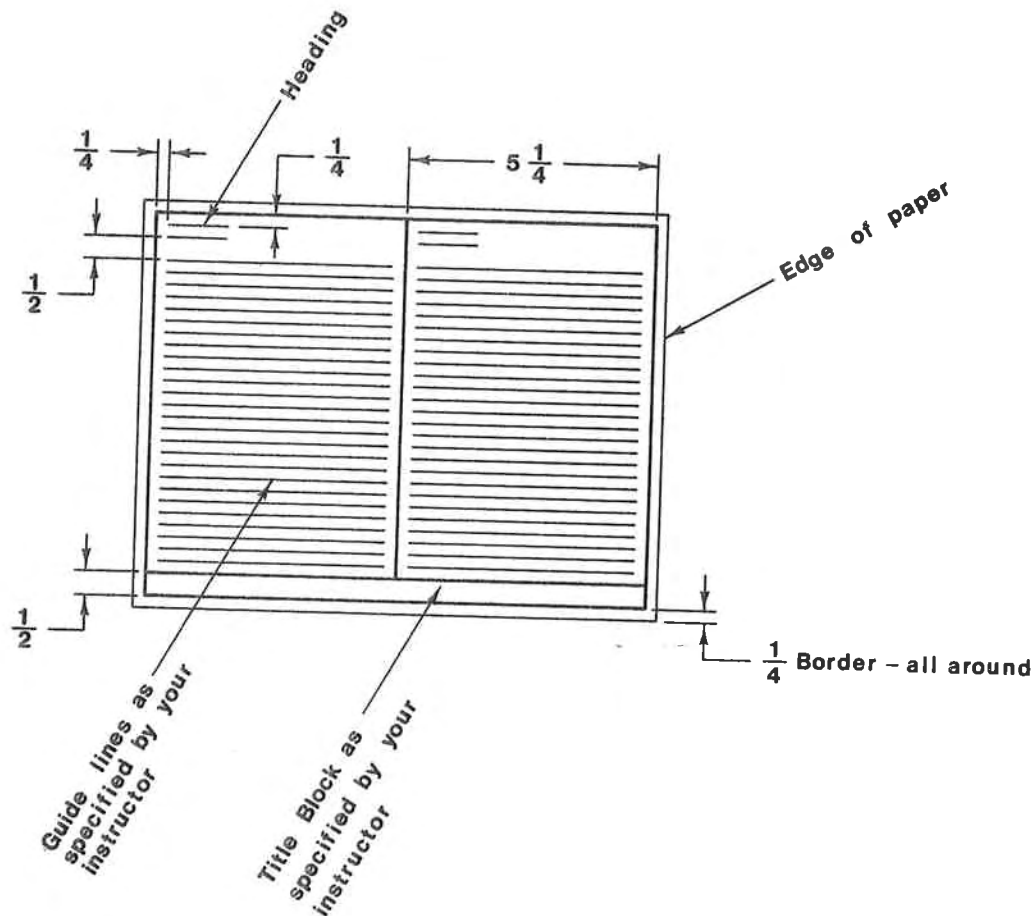


Figure P2-6

2-7 Using the format shown in Figure P2-6, letter in the following notes:*

1. Test per spec. P-72-B.
2. Paint black per spec. M-33.
3. Fan hood opening and fittings that fall on centerline of radiator may vary ± 0.06 from centerline.
4. "Ref" dimensions are for information only and therefore will not be inspected per this print.
5. Permissible quality of hose fittings is 2% of outer diameter.
6. Finish: black paint per AM 6015 to withstand 96-hr salt spray test per AM 6015 except finish on stainless steel flexible blade to withstand 20-hr salt spray test.
7. All stamped identifications must be legible after painting.
8. Remove all fins & burrs.
9. Alternate balancing method: balance by drilling 0.33" dia. max. holes in spider arms. The complete hole must be within 2" of the spider o.d. & the max. depth to drill point must be 0.125".

*Courtesy of American Motors.

10. Part no. & vendor identification (C.F.-RD-69597) to be stamped in this area with 0.25" size letters X .010/.005 deep on one or more arms & must appear on backside of fan blade reinforcement cap.
11. Valve must be fully open (.50 min stroke) at $8.0 \pm .02$ " HG vacuum signal on diaphragm.
12. Engineering approval of samples from each supplier is required prior to authorization of part production.

2-8 Using the format shown in Figure P2-6, letter in the following information:*

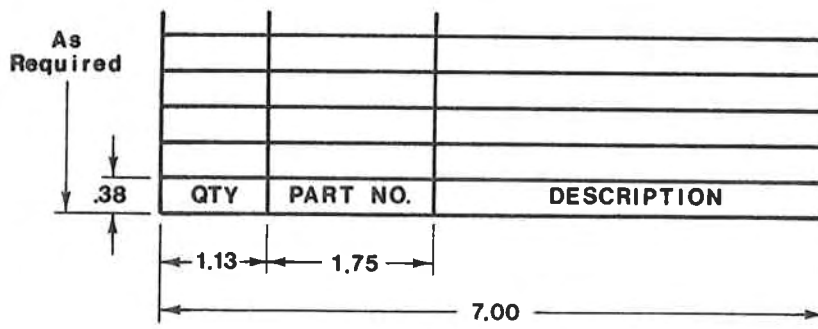
Drafting Checking Guide

The following check list should be used as a guide in checking drawings for compliance with related sections of Manufacturing Standard S, Drafting Standards.

1. Does the general appearance of the drawing conform to Ford Manufacturing Drafting Standards? Is the drawing clear, neat, and thorough?
2. Have the proper sheet sizes been used?
3. Has the title block been filled in completely and is the information correct? Are the title, scale, date, drawing and sheet numbers, etc., correct? Is the title complete and clear? Does the title include name of tools or equipment, operation or product part name?
4. Is the drawing number correct and according to the proper "Z" classification?
5. Are figures, letters, and lines correctly formed, uniform, and clean? Are they sharp and dense enough to assure good reproduction and legibility?
6. Are the necessary views and sections shown and are they positioned in proper relation to each other?
7. Do witness lines extend to the correct surface?
8. Do arrowheads extend to the correct witness lines?
9. Are all necessary dimensions shown?
10. Are drawings and dimensions to scale?
11. Are dimensions which are not to scale underlined with a wavy line, except those details with broken out sections?
12. Has duplication of dimensions and notes been avoided?
13. Are all components and included jobs shown in the stock list?
14. Has the assembly drawing been changed to agree with revised detail drawing?
15. Are related "Z" and "S" numbered tools properly listed on the main assembly drawings for reference?
16. On rework jobs are all changes fully and clearly listed?
17. Are cast details designed according to established practices?
See Group XB5.

2-9 Using the format shown in Figure P2-9, letter in the following information. Place the first line of information directly over the column headings and label each additional line *above* the previous line.

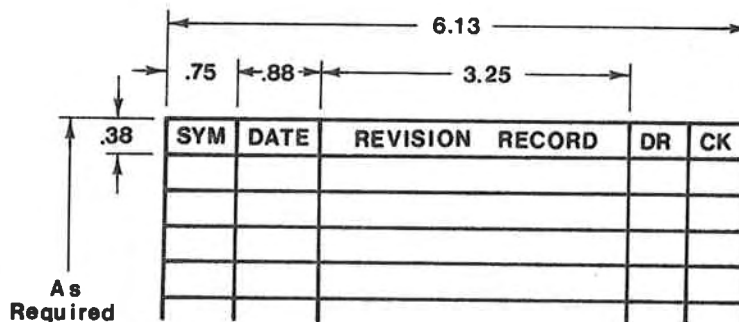
*Courtesy of Ford Motor Company.



QTY.	PART NO.	DESCRIPTION
1	564S72	Housing
1	564S75	Cover Plate
4	663A46	Clips
2	100T01	Bracket
12	XX	6-32 Screws
1	564S80	Side Support R.H.
1	564S85	Side Support L.H.
1	564S90	Base Plate
4	678Q99	Dowel Pins

Figure P2-9

2-10 Using the format shown in Figure P2-10, letter in the following information.* Use your own initials under the DR heading. Leave the CK column blank.



SYM.	DATE	REVISION RECORD	DR	CK
1	7/16/69	Optional Weight Revision		
2	7/16/69	1.742/1.729 was 1.747/1.734		
3	7/16/69	Note 8 Relocated		
	8/11/69	Issued		
	9/18/69	Released		
A	5/12/70	See SF3210686 Rev A		
B	10/21/70	Surface "J" Added		
C	10/21/70	Notes 8 & 9 Added		
D	10/21/70	Note Added		
E	11/17/71	4 was 3		
F	3/2/72	1.743/1.728 was 1.742/1.729		
G	3/28/72	Was .005 T.I.R.		

Figure P2-10

*Information Courtesy of American Motors.

GEOMETRIC CONSTRUCTIONS 3

3-1 INTRODUCTION

Geometric constructions are the building blocks of drafting. Every drawing, regardless of its difficulty, is a composite of geometric shapes. A rectangle is four straight lines and four right angles. A cam is a series of interconnected arcs of various radii. Every draftsman must have a fundamental knowledge of geometric constructions if he is to progress to the more difficult format and layout concepts required by most drawings.

This chapter is set up for easy reference. Each page contains one method of doing one geometric construction. Both classical methods and those requiring drafting equipment are presented. No attempt has been made to avoid redundancy, and each method is completely described within the page on which it is presented. A list of all constructions described in this chapter is given below:

SUBJECT	Page
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3-2 Points and Lines	38
3-3 Add and Subtract Lines	39
3-4 Parallel Lines—First Method	40
3-5 Parallel Lines—Two Triangle Method	41
3-6 Bisect a Line—First Method	42
3-7 Bisect a Line—Second Method	43
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3-9 Divide a Line into Proportional Parts	45
3-10 Fillets—Right Angles Only	46
3-11 Fillets—Any Angle	47
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3-13 Hexagon—First Method	49
3-14 Hexagon—Second Method	50
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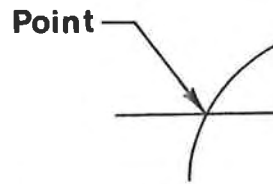
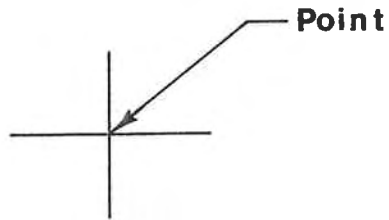
3-19	Pentagon—Definition	55
3-20	Octagon	56
3-21	Fillet—Two Circles	57
3-22	Round—Two Circles	58
3-23	Fillet—Concave Circle to a Line	59
3-24	Round—Convex Circle to a Line	60
3-25	S-curve (Reverse or Ogee Curve)	61
3-26	Approximate Ellipse	62
3-27	Bisect an Angle	63
3-28	Parabola	64

3-2 POINTS AND LINES

A point, to a draftsman, is defined by the intersection of two construction lines.

Note:

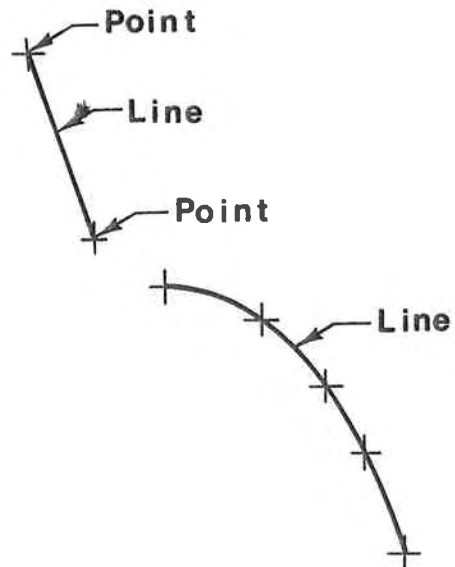
A dot should not be used to define a point because a dot may be easily confused with other marks on the drawing and thereby cause errors.



A line, to a draftsman, is an object line connecting two or more points.

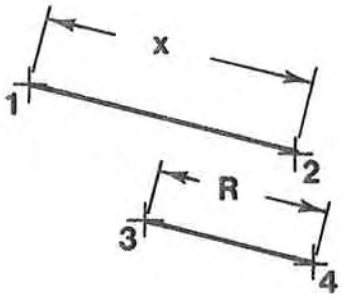
Note:

The accuracy of a curved line depends on the number points used to define it. The number of points used depends on the accuracy required for the particular curve.



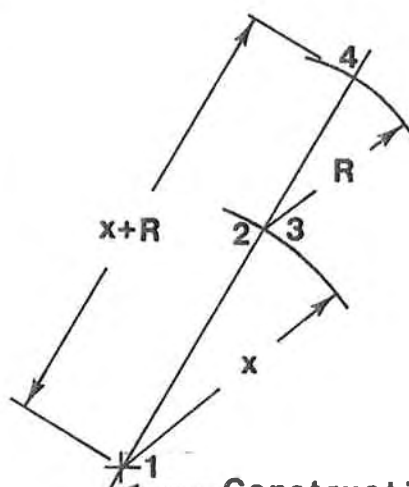
3-3 ADD AND SUBTRACT LINES

R. Given: Line 1-2 of length X and line 3-4 of length R .



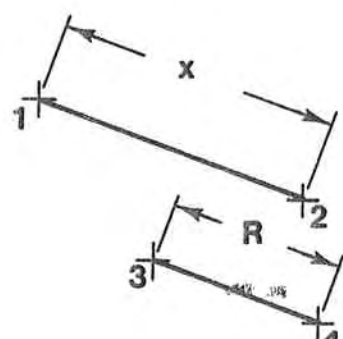
Problem: Add line 1-2 to 3-4.
 1. Construct a line and define point 1 anywhere along it.

2. Using a compass set on point 1, construct an arc of radius X .
 3. Using a compass set on the intersection of the arc constructed in step 2 and the line constructed in step 1, construct an arc of radius R as shown. Line 1-4 is equal to line 1-2 plus line 3-4.



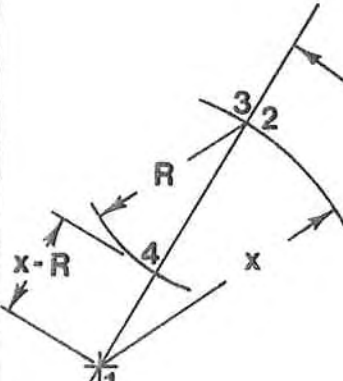
Construction Line

R. Given: Line 1-2 of length X and line 3-4 of length R .
 Problem: Subtract line 3-4 from line 1-2.



1. Construct a line and define point 1 anywhere along it.
 2. Using a compass set on point 1, construct an arc of radius X .

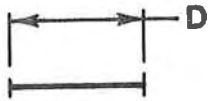
3. Using a compass set on the intersection of the arc constructed in step 2 and the line constructed in step 1, construct an arc of radius R as shown. Line 1-4 equals line 1-2 minus line 3-4.



Construction Line

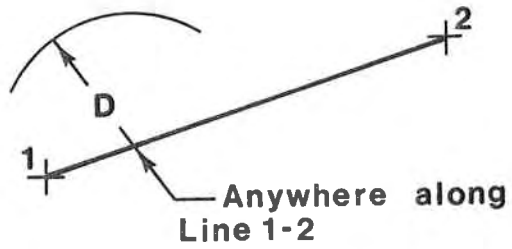
3-4 PARALLEL LINES—FIRST METHOD

Given: Line 1-2 and distance D .

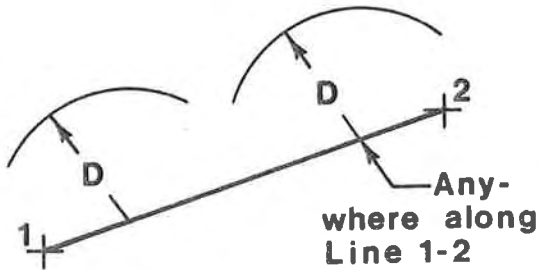


Problem: Construct a line parallel to line 1-2 at distance D .

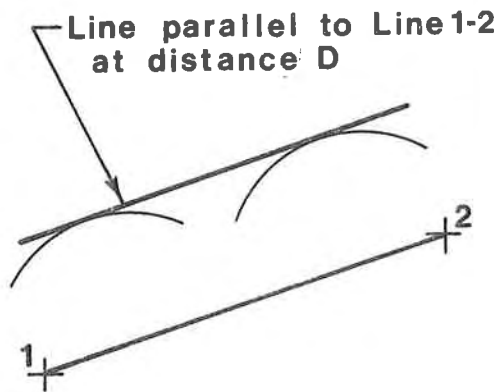
1. Using a compass set anywhere along line 1-2, construct an arc of radius D as shown.



2. Construct another arc of radius D as shown.

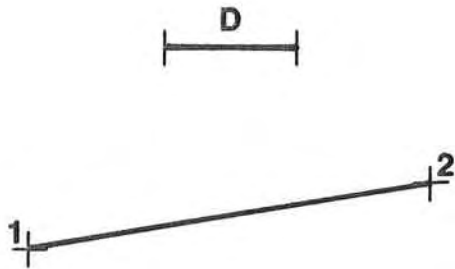


3. Construct a line tangent to both arcs.



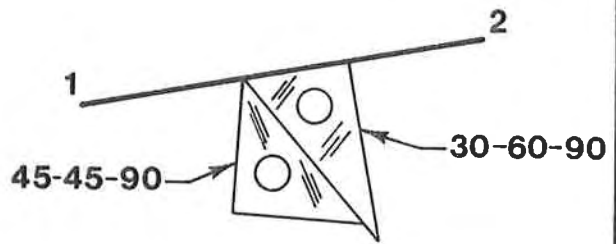
3-5 PARALLEL LINES—TWO TRIANGLE METHOD

Given: Line 1-2 and distance D .



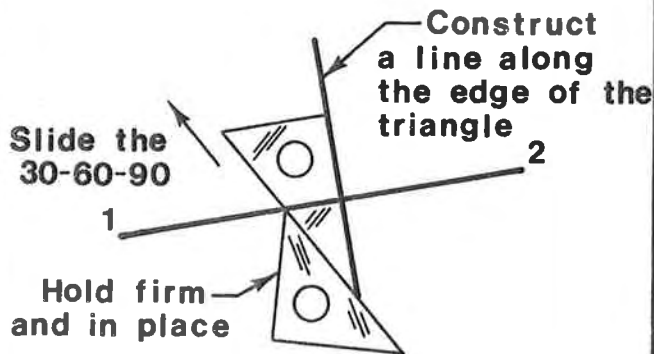
Problem: Construct a line parallel to line 1-2 at a distance D .

1. Align the shortest leg of a 30-60-90 triangle with line 1-2.
2. Place the hypotenuse of a 45-45-90 triangle against the hypotenuse of the 30-60-90 triangle.
3. Holding the 45-45-90 triangle firmly and in place, slide the 30-60-90 along the hypotenuse of the 45-45-90 as shown.



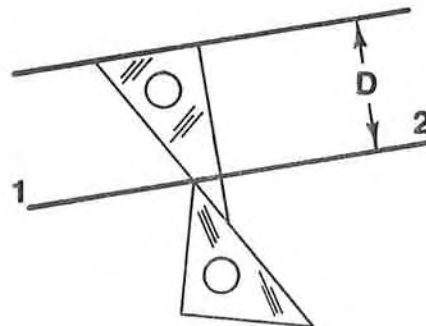
4. Construct a line along the edge of the 30-60-90 as shown.

5. Mark off a distance D from line 1-2 along the line constructed in step 4.



6. Realign the triangles to line 1-2 and slide the 30-60-90 until it is a distance D from line 1-2.

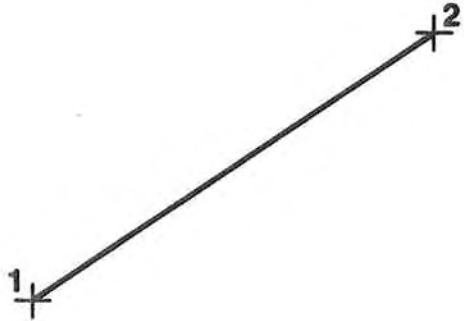
7. Construct a line along the shortest leg of the 30-60-90 through distance D parallel to line 1-2.



Note: ° A T-square may be used in lieu of a second triangle.
 ° The line used to locate distance D from line 1-2 in step 5 is perpendicular to line 1-2.

3-6 BISECT A LINE—FIRST METHOD

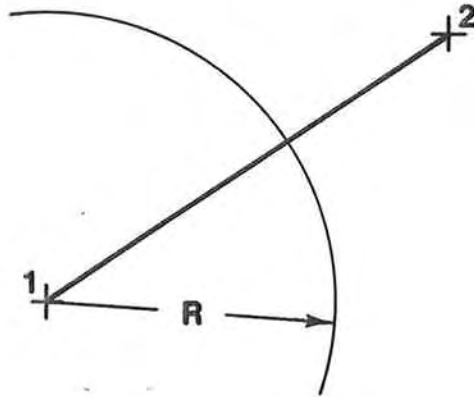
Given: Line 1-2.



Problem: Divide line 1-2 into two equal parts.

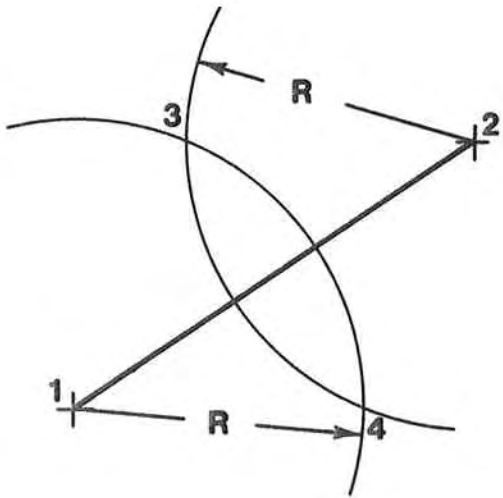
1. Construct an arc of radius R . Use point 1 as center.

$R =$ any radius of greater length than $\frac{1}{2}$ line 1-2.



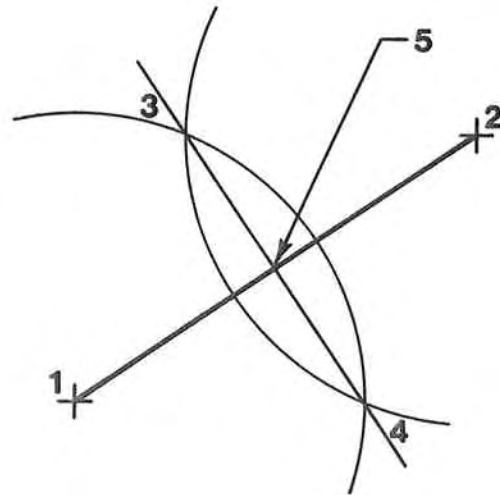
2. Construct an arc of radius R . Use point 2 as center.

3. Define the intersection of the arcs as points 3 and 4.



4. Connect points 3 and 4 with a construction line.

5. Define point 5 where line 3-4 intersects line 1-2. Line 1-5 = line 5-2.



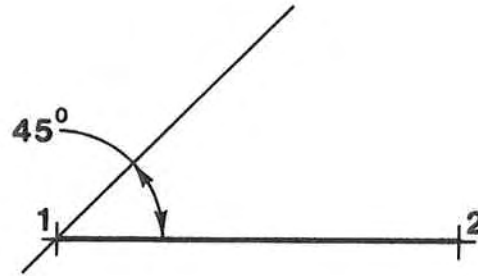
Note: This is the classical method as taught in plane geometry.

3-7 BISECT A LINE—SECOND METHOD

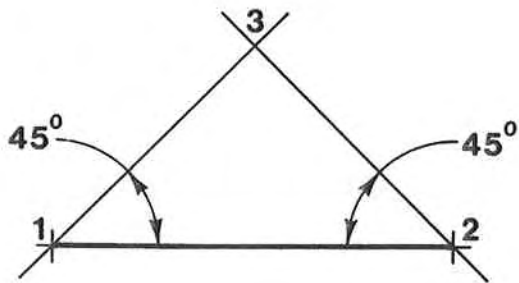
Given: line 1-2.



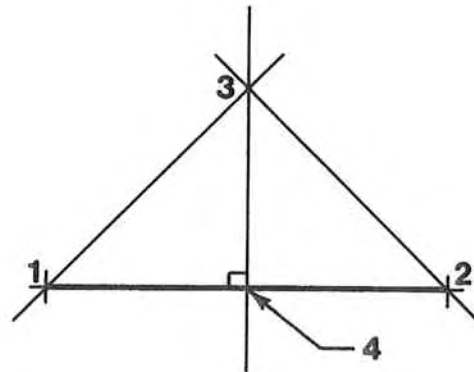
Problem: Divide line 1-2 into two equal parts.



1. Align the T-square with line 1-2 and using a 45-45-90 triangle as a guide, construct a line 45° to line 1-2 through point 1.



2. Repeat step 1 this time constructing the 45° line through point 2.
 3. Define the intersection of the construction lines as point 3.



4. Draw a line through point 3 perpendicular to line 1-2 which intersects line 1-2.
 5. Define point 4 as shown. Line 1-4 = line 4-2.

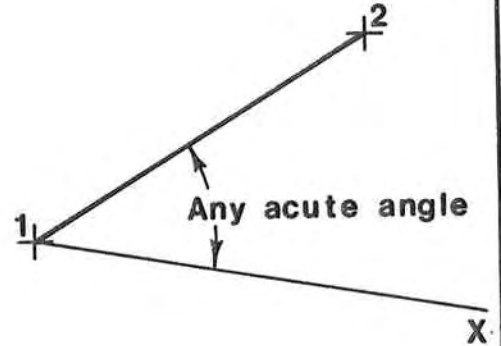
Note: This method relies on drafting equipment for completion. Any angle may be used in steps 1 and 2 as long as they are equal.

3-8 DIVIDE A LINE INTO ANY NUMBER OF EQUAL PARTS

Given: Line 1-2.

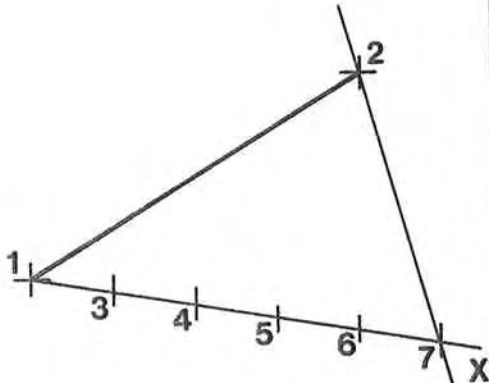


Problem: Divide line 1-2 into five equal parts.



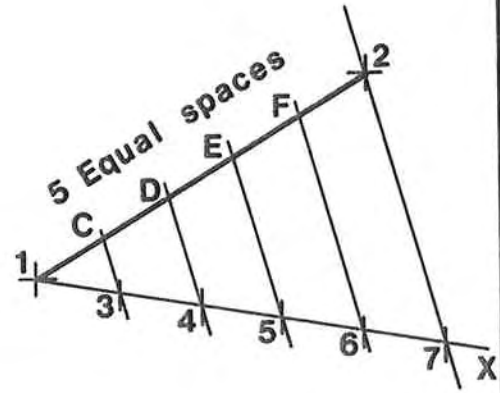
1. Construct a line A-X at any acute angle to line 1-2.

2. Mark off five equal spaces along line 1-X and construct a line 2-7.



Note: Any size space may be used as long as they are all equal in length.

3. Draw lines 6-F, 5-E, 4-D, and 3-C parallel to line 2-7.



$1-C = C-D = D-E = E-F = F-2.$

Note: This method is good for any number of equal parts, not just for the five shown. Once 1-X has been drawn, mark off as many spaces as needed. Remember that the spaces must be of equal length.

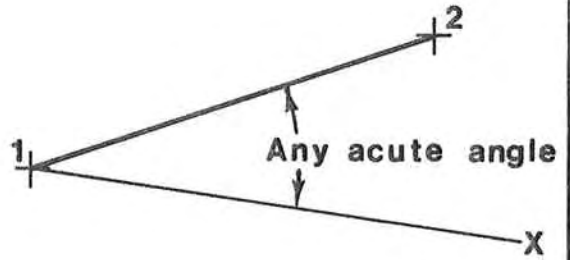
3-9 DIVIDE A LINE INTO PROPORTIONAL PARTS

Given: Line 1-2.



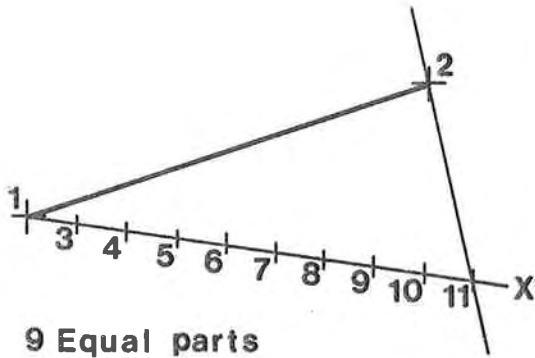
Problem: Divide line 1-2 into proportional parts of 1, 3, and 5.

1. Add up the total number of proportional parts required and use the total derived as if the problem were to divide the line into equal parts.

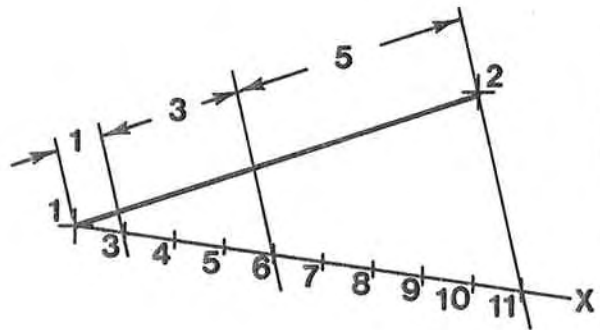


$$\begin{array}{r} 1 \\ 3 \\ 5 \\ \hline 9 \end{array}$$

See section 2. Divide a line into any number of equal parts.



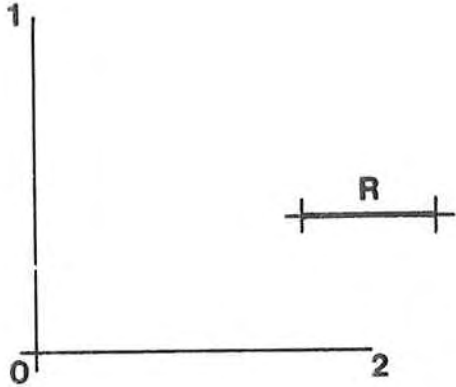
2. Mark off the required proportional parts.



Note: This method is good for any number of parts and any ratio, not just for the 1, 3, and 5 shown.

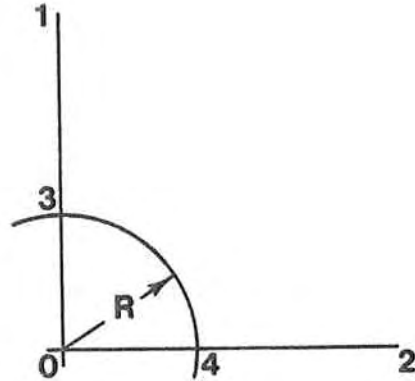
3-10 FILLETS—RIGHT ANGLES ONLY

Given: Right angle and radius R .



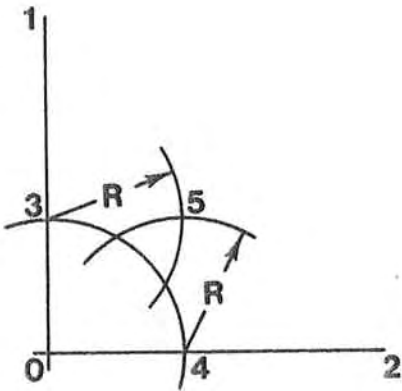
Problem: Draw a fillet of radius R tangent to angle 1-0-2.

1. Construct an arc of radius R . Use point 0 as center.



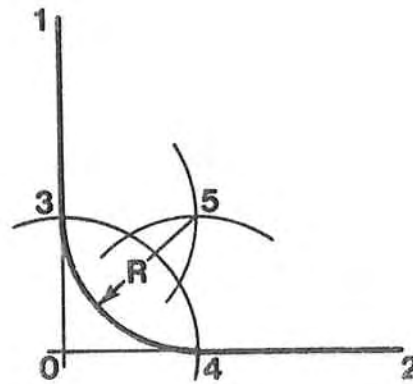
2. Define points 3 and 4 where the arc intersects lines 0-1 and 0-2.

3. Construct two more arcs of radius R . Use points 3 and 4 as centers.



4. Define point 5 where the arcs centered at points 3 and 4 intersect.

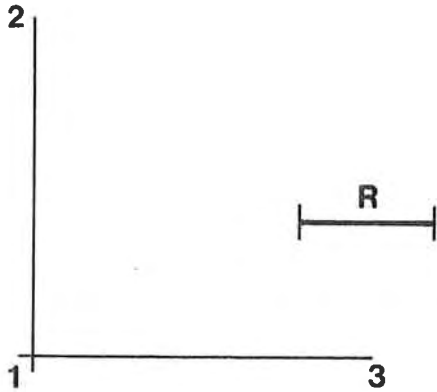
5. Draw a fillet of radius R . Use point 5 as center, tangent to lines 0-1 and 0-2.



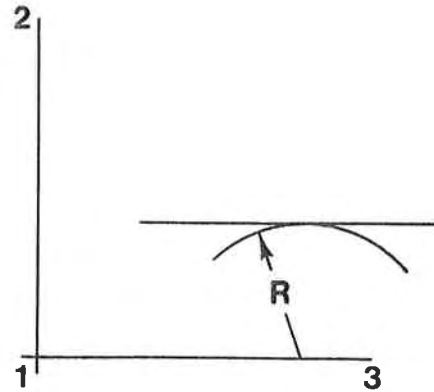
Note: • This method is good *only* for right angles.
• For small radii, use a circle template and draw fillet directly.

3-11 FILLETS—ANY ANGLE

Given: Angle 2-1-3 and radius R .

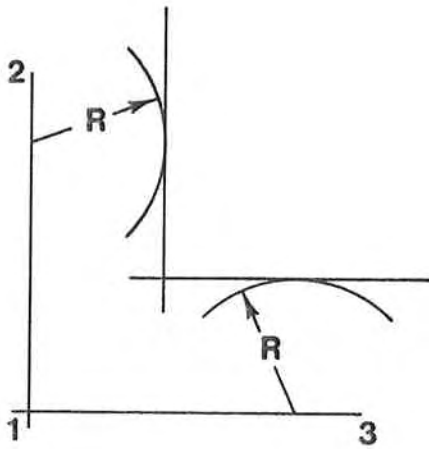


Problem: Draw a fillet of radius R tangent to angle 2-1-3.



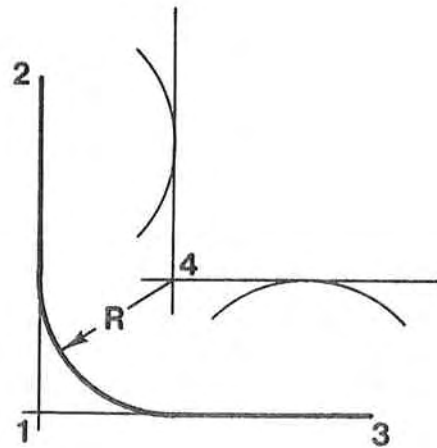
1. Construct a line parallel to line 1-3 at a distance R .

2. Construct a line parallel to line 1-2 at a distance R .



3. Define the intersection of the two constructed parallel lines as point 4.

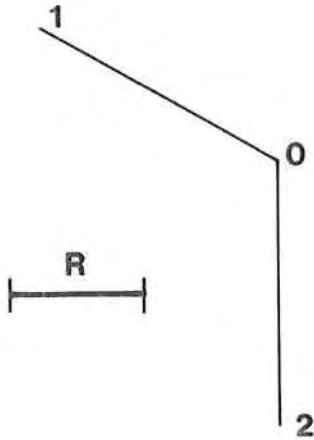
4. Draw a fillet of radius R tangent to angle 2-1-3.



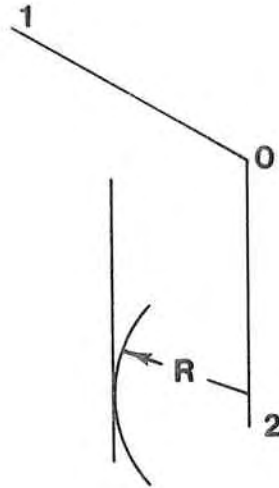
Note: This method is good, not only for the right angle as shown, but also for any angle, acute or obtuse.
For small radii, use a circle template and draw the fillet directly.

3-12 ROUNDS—ANY ANGLE

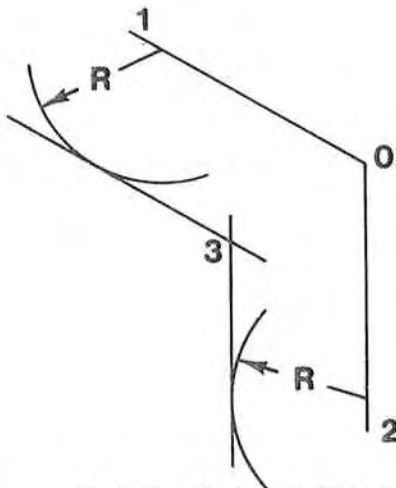
Given: Angle 1-0-2 and radius R .
 Problem: Draw a round of radius R tangent to angle 1-0-2.



1. Construct a line parallel to line 0-2 at a distance R .

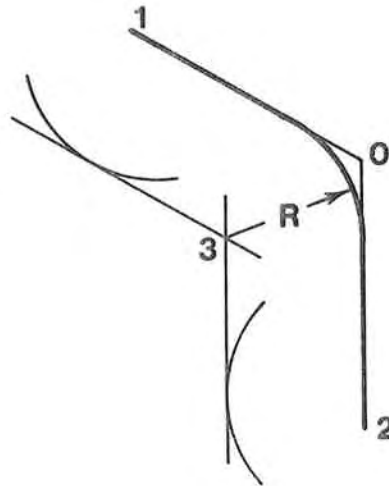


2. Construct a line parallel to line 0-1 at a distance R .



3. Define the intersection of the two constructed parallel lines as point 3.

4. Draw a round of radius R . Use point 3 as center, tangent to angle 1-0-2.

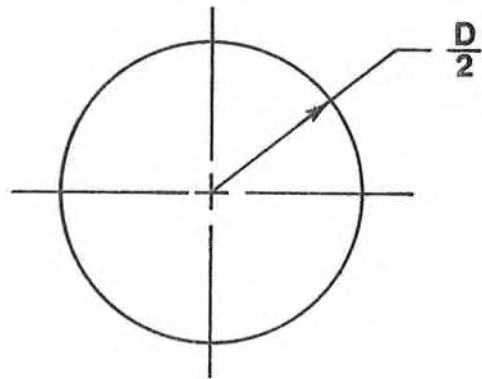


3-13 HEXAGON—FIRST METHOD

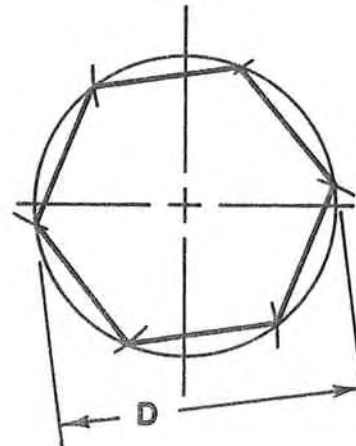
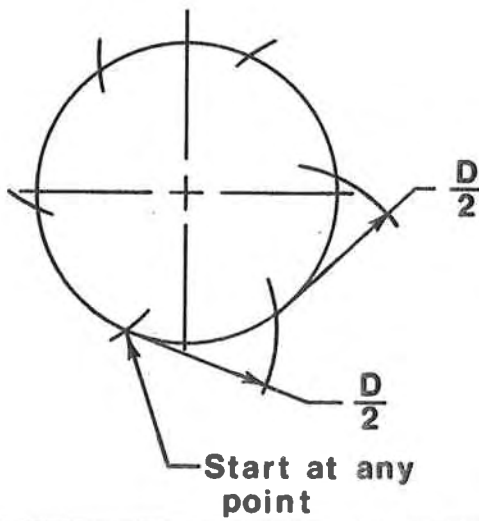
Problem: Draw a hexagon D across the corners.

1. Construct a circle of diameter D .

Note: $\frac{\text{Diameter}}{2} = \text{radius}$. Set compass to radius dimension.



2. Using a compass, mark off six distances $\frac{D}{2}$ as shown.



3. Draw in the hexagon.

Note: This is the classical geometric method and is not generally used by draftsmen because it makes positioning of the hexagon difficult.

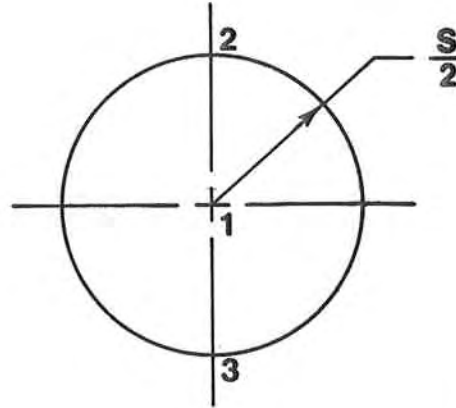
3-14 HEXAGON—SECOND METHOD

Problem: Draw a hexagon S across the corners.

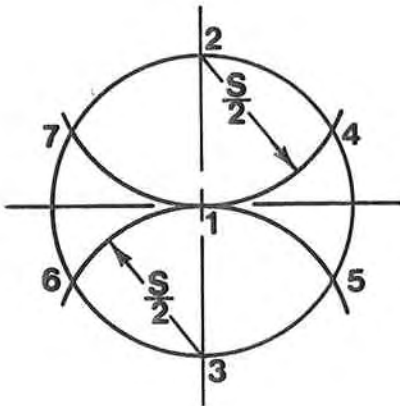
1. Construct a circle of diameter S .

Note: $\frac{\text{Diameter}}{2} = \text{radius}$. Set compass to radius dimension.

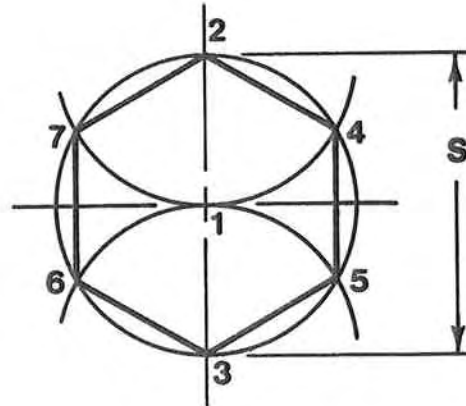
2. Define points 2 and 3 as shown:



3. Using points 2 and 3 as center, construct two arcs of radius $S/2$.



4. Define points 4, 5, 6, and 7 as shown.



5. Draw in the hexagon.

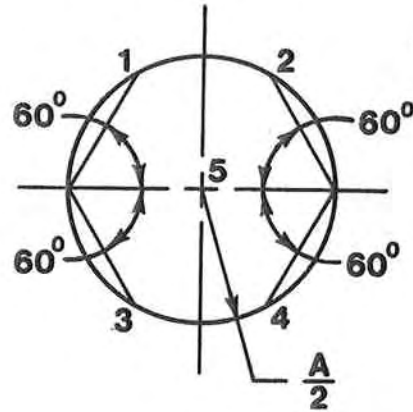
3-15 HEXAGON—THIRD METHOD

Problem: Construct a hexagon *A* across the corners.

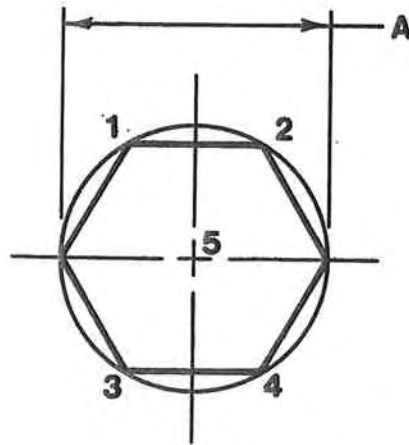
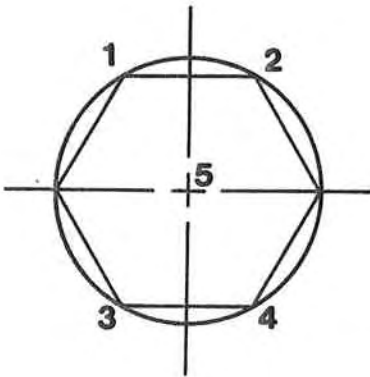
1. Construct a circle of diameter *A*.

2. Using a 60°-triangle, construct lines 60° to the horizontal as shown.

3. Define points 1, 2, 3, and 4.



4. Construct lines 1-2 and 3-4.



5. Draw in the hexagon.

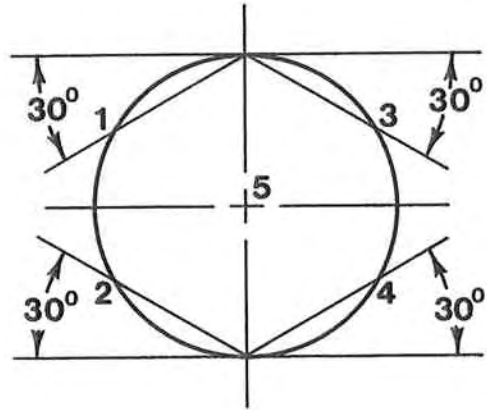
3-16 HEXAGON—FOURTH METHOD

Problem: Construct a hexagon B across the corners.

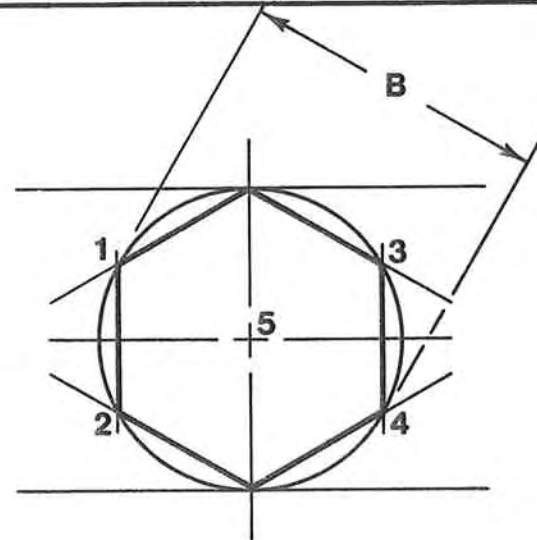
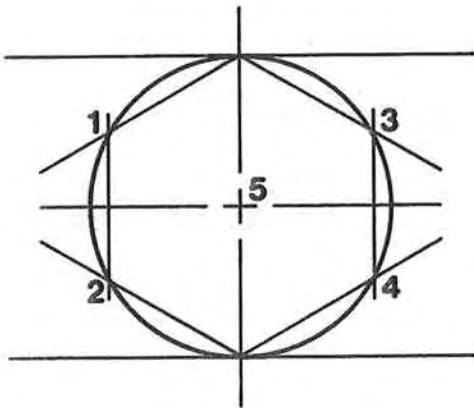
1. Construct a circle of diameter B .

2. Using a 30° -triangle, construct lines 30° to the horizontal as shown.

3. Define points 1, 2, 3, and 4.



4. Construct lines 1-2 and 3-4.



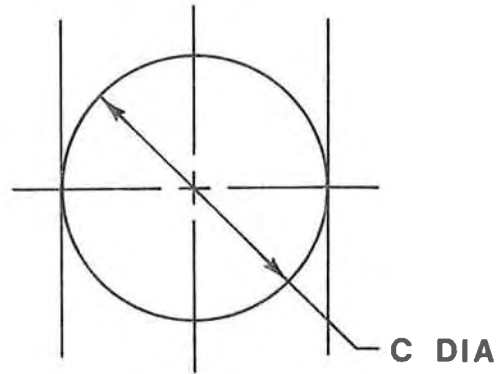
5. Draw in the hexagon.

3-17 HEXAGON—FIFTH METHOD

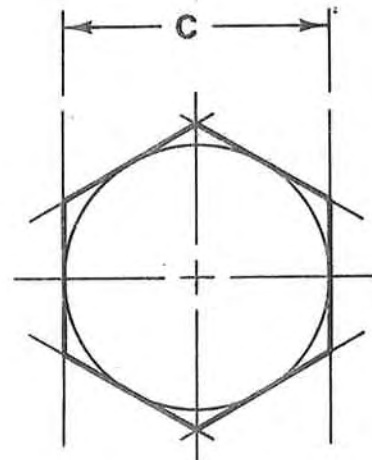
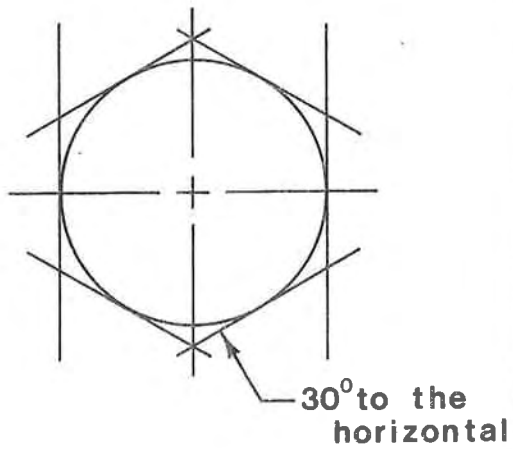
Problem: Construct a hexagon *C* across the flats.

1. Construct a circle of diameter *C*.

2. Construct two vertical lines tangent to the circle.



3. Using a 30°-triangle, construct lines tangent to the circle 30° to the horizontal as shown.

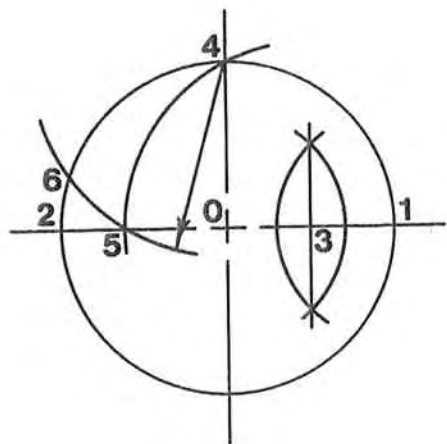
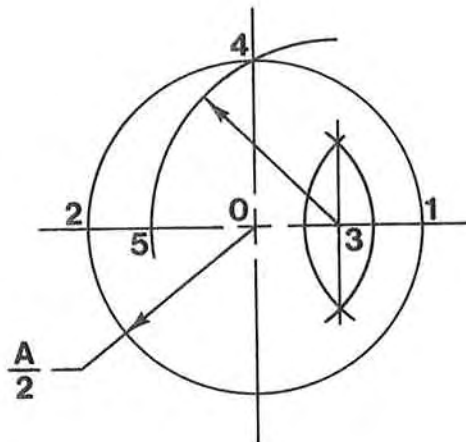


4. Draw in the hexagon.

3-18 PENTAGON—HOW TO DRAW

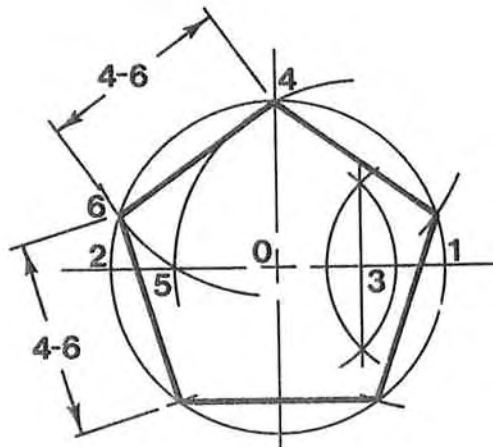
Problem: Draw a pentagon inscribed in a circle of diameter A .

1. Construct a circle of diameter A .
2. Define points 0, 1, and 2 as shown.
3. Bisect line 0-1 and define the midpoint as point 3.
4. Define point 4 as shown.
5. Using a compass set on point 3, construct an arc through point 4 and line 2-0.
6. Define the intersection of the arc constructed in step 5 and line 2-0 as point 5.



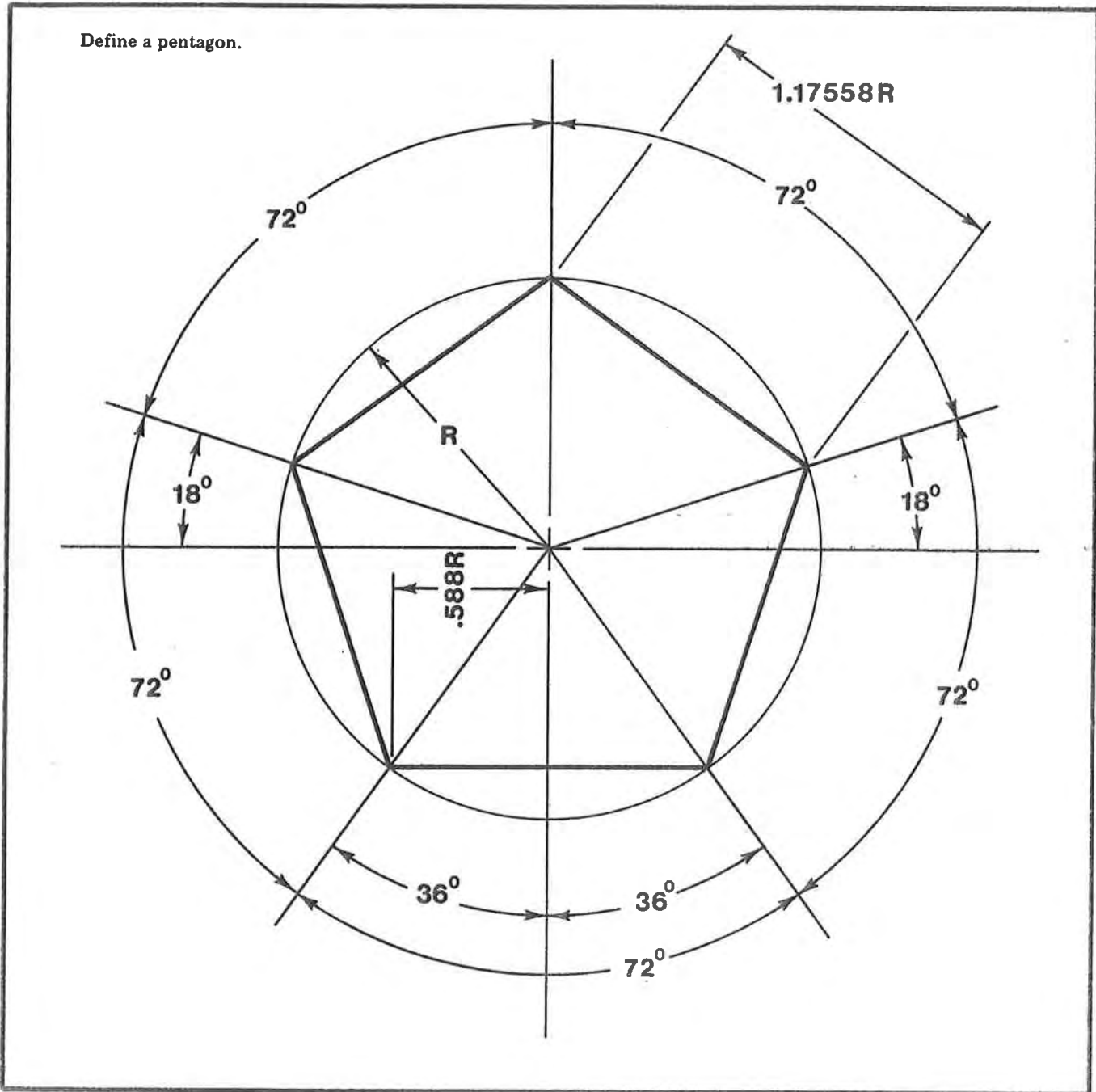
7. Using a compass set on point 4, construct an arc through point 5 and the edge of the circle.

8. Define the intersection of the arc constructed in step 7 and the circle as point 6.



9. Using a compass, mark off the distance 4-6 around the circumference of the circle as shown.
10. Draw in the pentagon.

3-19 PENTAGON—DEFINITION

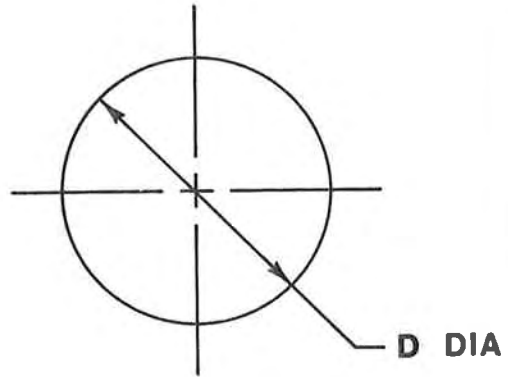


Note: This information has been included as a reference to help in drawing pentagons.

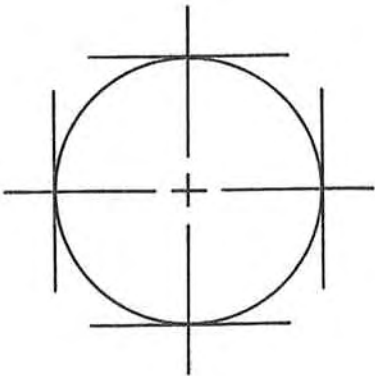
3-20 OCTAGON

Problem: Draw an octagon D across the flats.

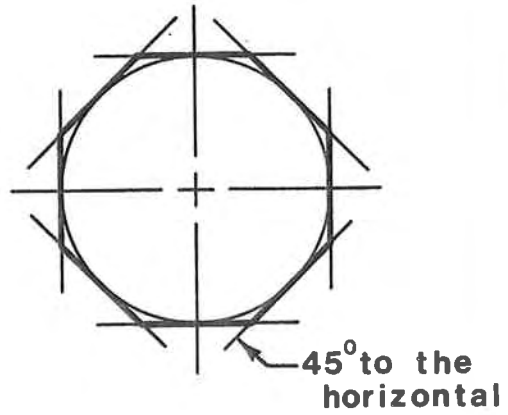
1. Draw a circle of diameter D .



3. Construct four lines, 45° to the horizontal, tangent to the circle as shown.



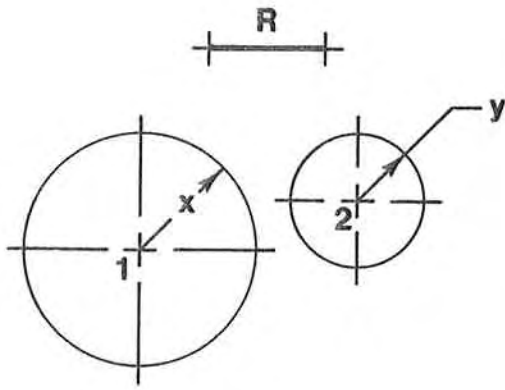
2. Construct four tangent lines as shown.



4. Draw in the octagon.

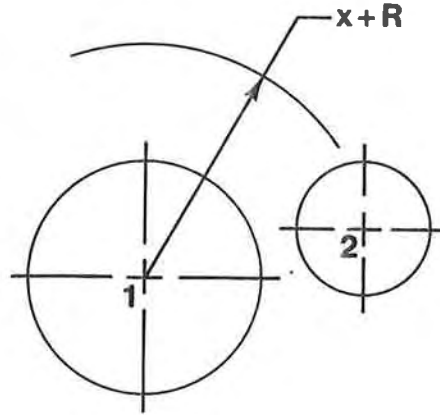
3-21 FILLET—TWO CIRCLES

Given: Circles X and Y and radius R .



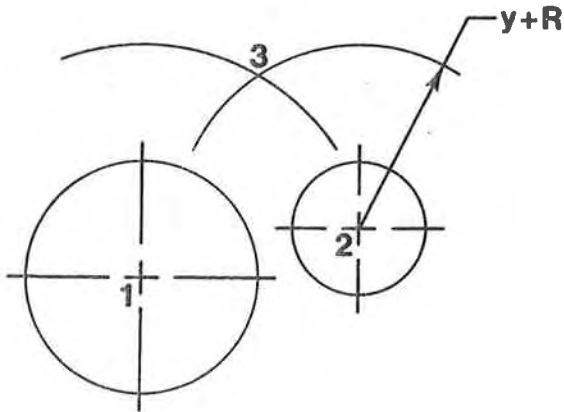
Problem: Draw a fillet of radius R tangent to circles X and Y .

1. Construct an arc of radius $X + R$. Use point 1 as center.



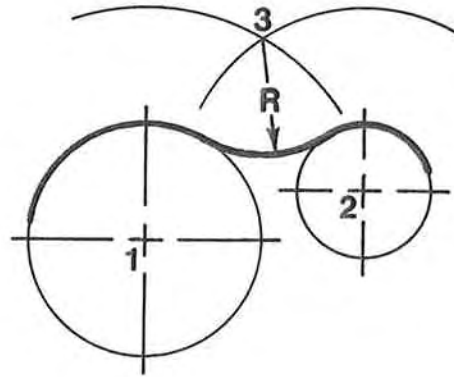
(See Section 3-3, Add and Subtract Lines.)

2. Construct an arc of radius $Y + R$. Use point 2 as center.



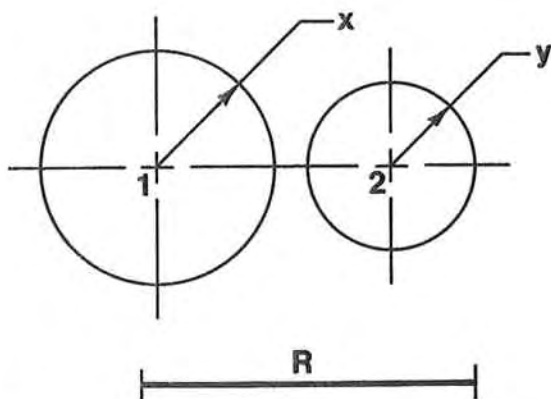
3. Define the intersection of the two arcs as point 3.

4. Using point 3 as center, draw a fillet of radius R tangent to the two circles.



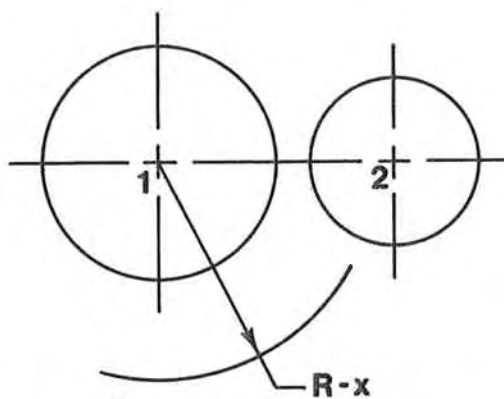
3-22 ROUND-TWO CIRCLES

Given: Circles x and y and radius R .
 Problem: Draw a round of radius R tangent to circles x and y .



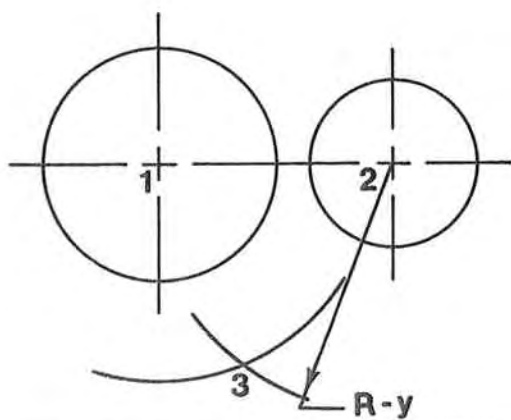
1. Construct an arc of radius $R-x$. Use point 1 as center.

(See Section 3-3, Add and Subtract Lines.)

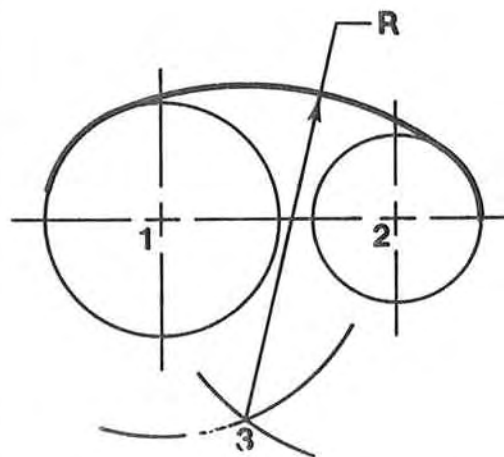


2. Construct an arc of radius $R-y$. Use point 2 as center.

3. Define the intersection of the two arcs as point 3.



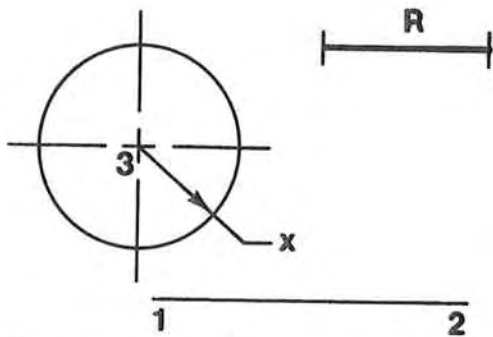
4. Using point 3 as center, draw an arc of radius R tangent to the two circles.



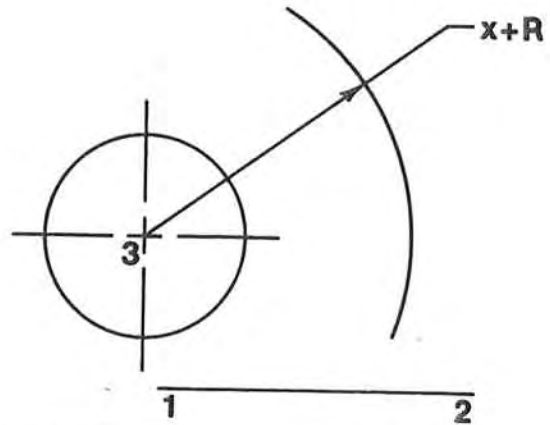
3-23 FILLET—CONCAVE CIRCLE TO A LINE

Given: A circle of radius X , line 1-2, and a radius R .

Problem: Draw a fillet of radius R tangent to a circle and a line.

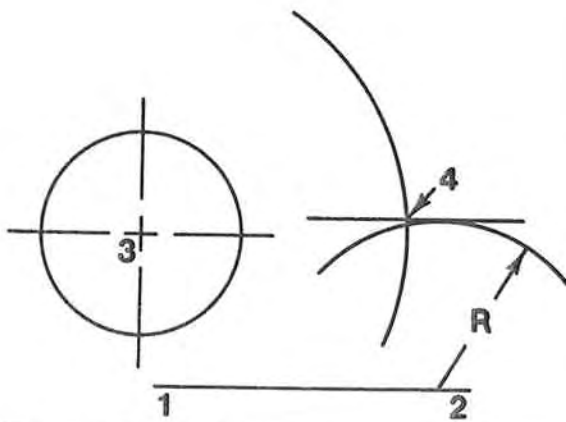


1. Construct an arc of radius $X + R$. Use point 1 as center.

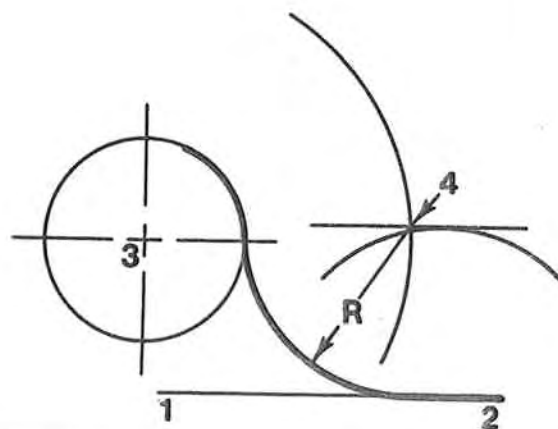


2. Construct a line parallel to line 1-2 at a distance R .

3. Define the intersection of the arc ($X + R$) and the line parallel to line 1-2 as point 4.

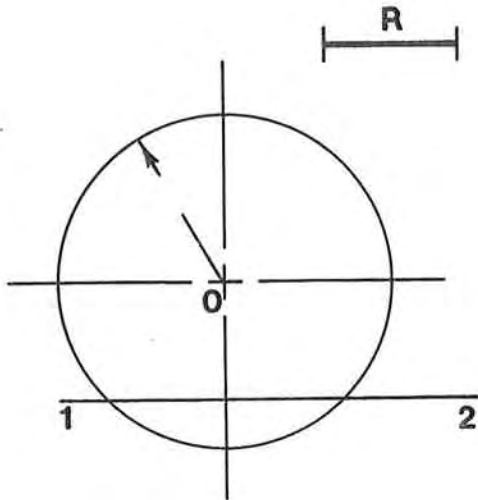


4. Using point 4 as center, draw in a fillet of radius R .



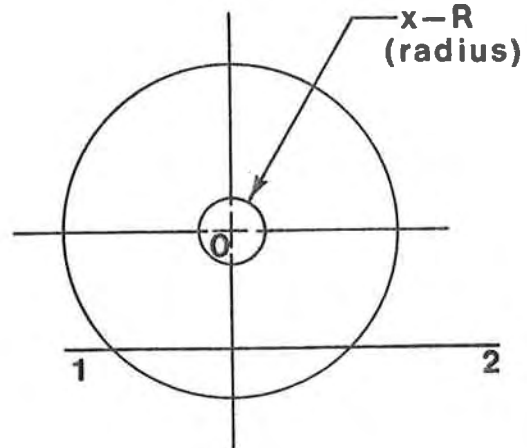
3-24 ROUND-CONVEX CIRCLE TO A LINE

Given: Circle x , line 1-2, and fillet radius R .



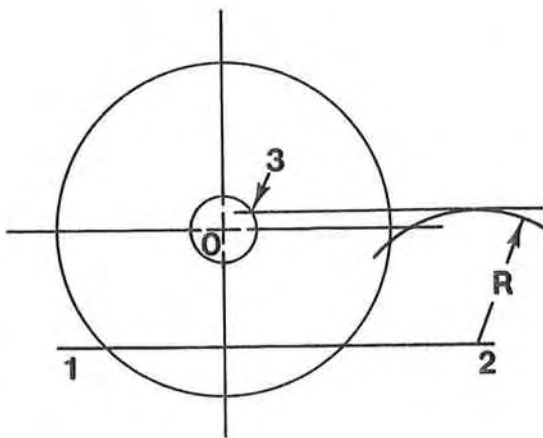
Problem: Draw a round tangent to a circle of radius x and line 1-2.

1. Construct a circle of radius $x - R$.



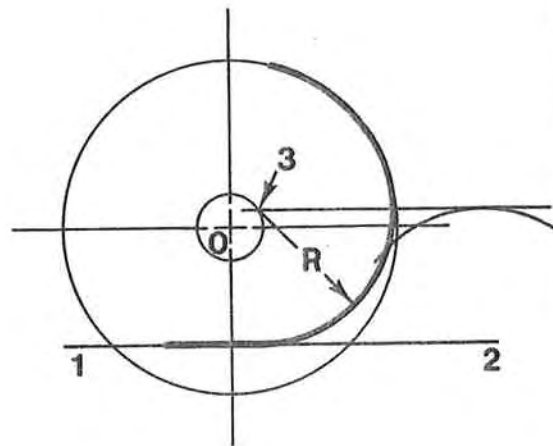
(See Section 3-3, Subtracting Lines)

2. Construct a line parallel to line 1-2 at a distance R .

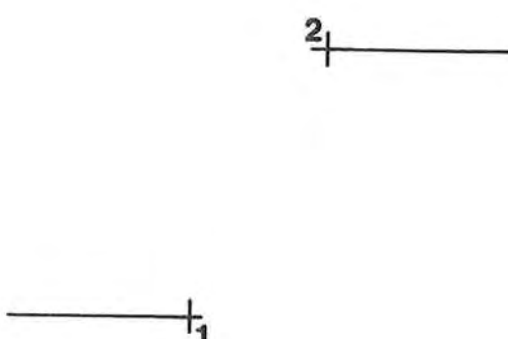


3. Define the intersection of the circle $(x - R)$ and the line parallel to line 1-2 as point 3.

4. Draw a round of radius R . Use point 3 as center.

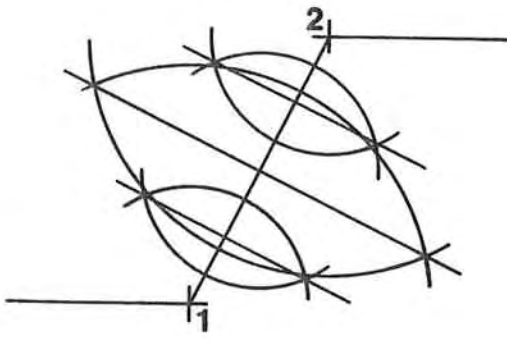


3-25 S-CURVE (REVERSE OR OGEE CURVE)

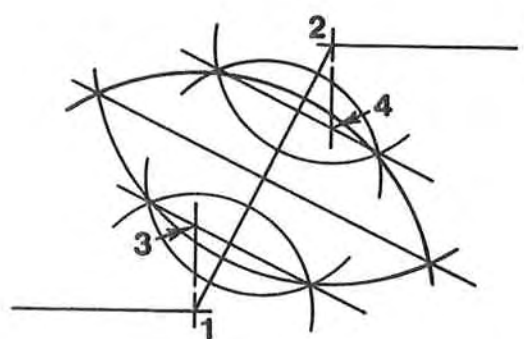


Problem: Draw an S-curve between points 1 and 2.

1. Construct line 1-2.
2. Divide line 1-2 into four equal parts.

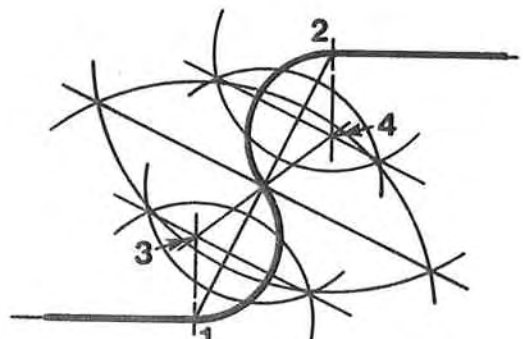


3. Construct perpendiculars from points 1 and 2 such that they intersect the quarter bisect lines as shown.



4. Define the intersects of step 3 as points 3 and 4.

5. Using points 3 and 4 as centers, draw in curves of radii 3-1 and 4-2.

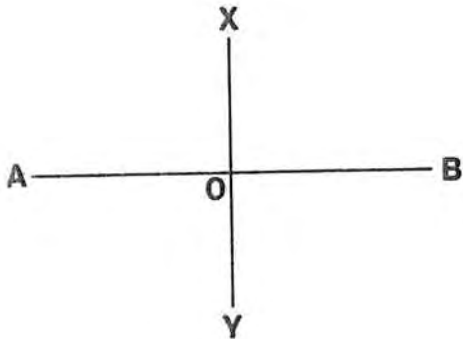


Note: The S-curve need not be symmetrical. Asymmetrical curves may be constructed, but the method is not covered in this book.

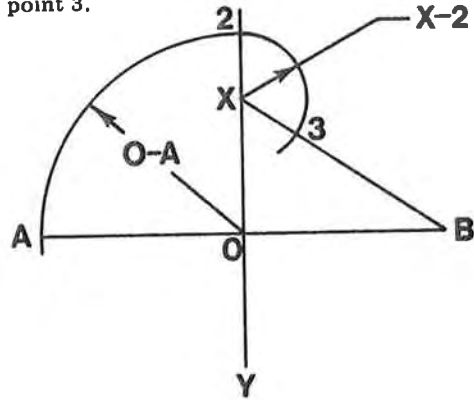
3-26 APPROXIMATE ELLIPSE

Given: A major axis of $A-O-B$ and a minor axis of $X-O-Y$

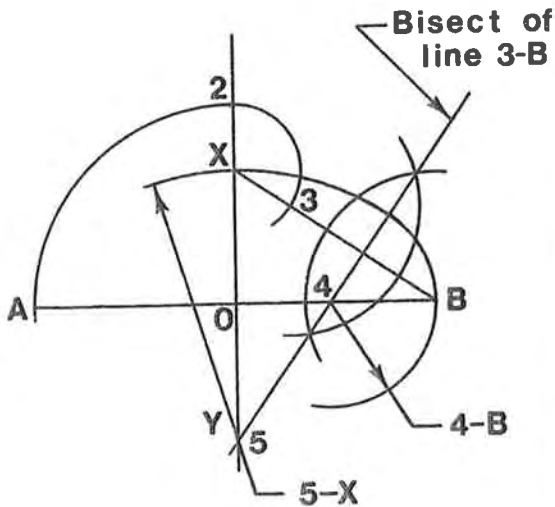
Problem: Construct an approximate ellipse.



1. Draw an arc of radius $O-A$. Use point O as a center such that it intersects point A and an extension of line $Y-O-X$.
2. Draw a straight line between points X and B .
3. Draw arc $X-2$ as shown.
4. Define the intersection of arc $(X-2)$ and line $X-B$ as point 3 .

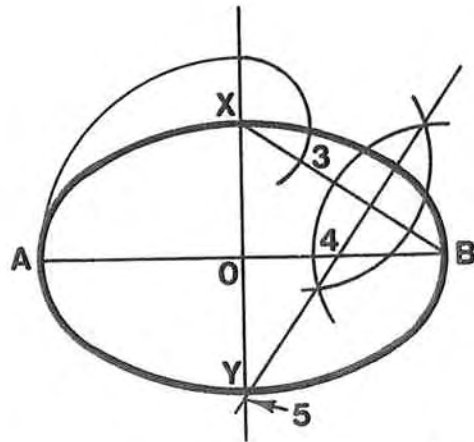


5. Bisect line $3-B$ and draw the bisect line so that it intersects an extension of the line $X-O-Y$. Define this intersection as point 5 .



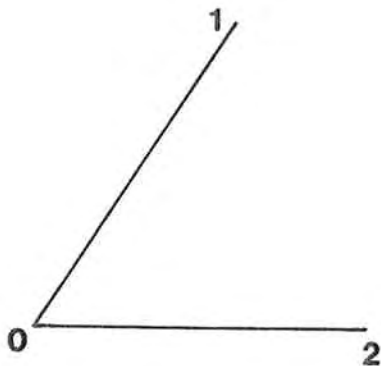
6. Define the intersection of the bisect line and line $O-B$ as point 4 .

7. Using point 5 as center, draw an arc of radius $5-X$ as shown. Also draw an arc of radius $4-B$ as shown. These two arcs will generate half of ellipse. Draw the half by symmetry.



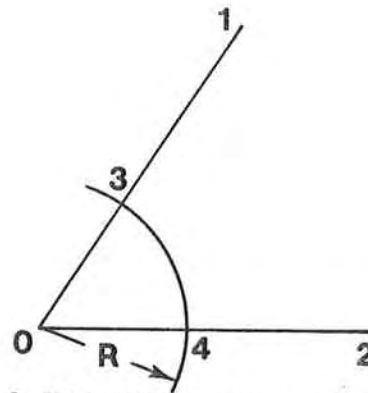
3-27 BISECT AN ANGLE

Given: Angle 1-0-2



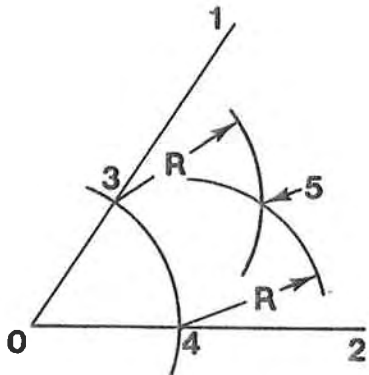
Problem: Bisect angle 1-0-2.

1. Construct an arc of radius R . Use point 0 as center.



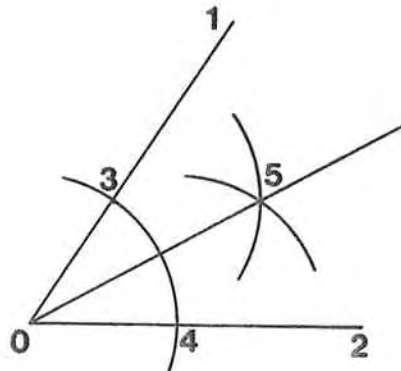
3. Using points 3 and 4 as centers, construct two more arcs of radius R as shown.

2. Define points 3 and 4 where the arc intersects lines 0-1 and 0-2.



4. Define the intersection of the two arcs as point 5.

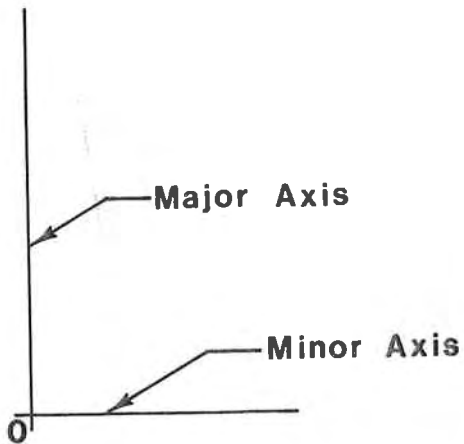
5. Construct a line 0-5.



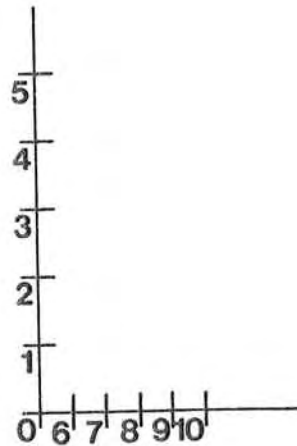
Angle 1-0-5 = Angle 5-0-2.

3-28 PARABOLA

Problem: Draw a parabola whose major axis is twice the minor axis.

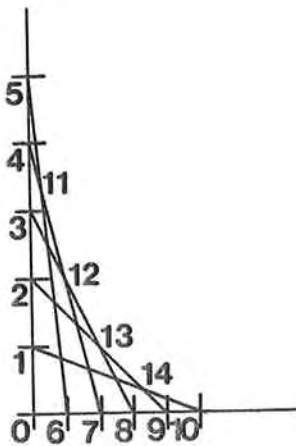


1. Lay out points making those on the major axis twice as far apart as those on the minor axis.



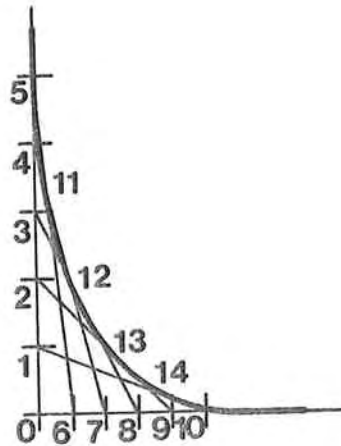
The number of points on each axis must be equal.

2. Construct lines from the first point on the major axis to the last point on the minor axis, etc. (1-10, 2-9, 3-8, 4-7, 5-6)



3. Define points 11, 12, 13, and 14 as shown.

4. Draw a parabola by using a French curve and connecting points 5-11-12-13-14-10.



Note: • In this example the major axis points are $\frac{1}{2}$ apart and the minor axis points are $\frac{1}{4}$ apart.
 • The accuracy of the parabola depends on the number of points used to define it. The more points, the greater the accuracy.

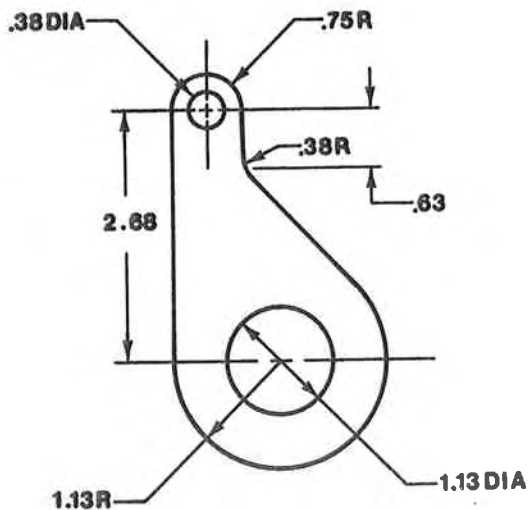
PROBLEMS

- 3-1 You are given a line $1\frac{15}{16}$ long. Bisect it.
- 3-2 You are given a line 2.36 long. Bisect it.
- 3-3 Draw two parallel lines $\frac{15}{16}$ apart.
- 3-4 Draw two parallel lines $1\frac{1}{4}$ apart.
- 3-5 Draw two parallel lines 2.063 apart.
- 3-6 You are given a line $2\frac{1}{8}$ long. Divide it into 7 equal parts.
- 3-7 You are given a line $3\frac{1}{4}$ long. Divide it into 15 equal parts.
- 3-8 You are given a line 1.68 long. Divide it into 3 equal parts.
- 3-9 You are given a line $1\frac{7}{8}$ long. Divide it into proportional parts of 2, 4, and 7.
- 3-10 You are given a line $2\frac{9}{16}$ long. Divide it into proportional parts of 1, 4, 3, and 5.
- 3-11 You are given a line 2.78 long. Divide it into proportional parts of 3, 4, and 9.
- 3-12 You are given lines of $1\frac{1}{16}$ and $\frac{5}{8}$ long. Graphically add them.
- 3-13 You are given lines of 1.75 and 0.625 long. Graphically add them.
- 3-14 You are given a line $2\frac{3}{8}$ long. Subtract a line $1\frac{3}{16}$ long from it.
- 3-15 You are given a line $1\frac{7}{8}$ long. Subtract a line $\frac{15}{16}$ long from it.
- 3-16 You are given a line 1.28 long. Subtract a line 0.80 long from it.
- 3-17 You are given a 37° angle. Draw a fillet of radius $\frac{3}{4}$.
- 3-18 You are given a 123° angle. Draw a fillet of radius $1\frac{3}{8}$.
- 3-19 You are given a 90° angle. Draw a round of radius $\frac{7}{8}$.
- 3-20 You are given a 60° angle. Draw a round of radius 1.20.
- 3-21 Draw a hexagon $1\frac{1}{4}$ across the corners.
- 3-22 Draw a hexagon $2\frac{3}{16}$ across the corners.
- 3-23 Draw a hexagon 1.80 across the corners.
- 3-24 Draw a hexagon 80 mm across the corners.
- 3-25 Draw a hexagon 2 across the flats.
- 3-26 Draw a hexagon $2\frac{9}{16}$ across the flats.
- 3-27 Draw a pentagon inscribed within a $2\frac{1}{4}$ diameter circle.
- 3-28 Draw an octagon inscribed within a $1\frac{7}{8}$ diameter circle.
- 3-29 You are given two circles of $1\frac{1}{2}$ and $\frac{7}{8}$ in diameter and located $1\frac{1}{2}$ apart. Draw a fillet between them of radius $\frac{3}{4}$.
- 3-30 You are given two circles of 1.75 and 1.10 in diameter and located 1.60 apart. Draw a fillet between them of radius .90.

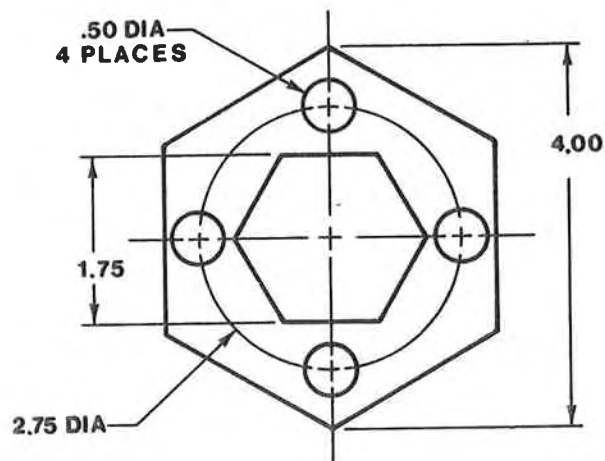
- 3-31 You are given two circles of $1\frac{1}{4}$ and $1\frac{1}{2}$ in diameter and located $2\frac{1}{4}$ apart. Draw a round between them of radius $2\frac{1}{2}$.
- 3-32 You are given a circle $1\frac{7}{16}$ in diameter located $2\frac{1}{8}$ above a line. Draw a fillet between them of radius $1\frac{1}{16}$.
- 3-33 You are given a circle $2\frac{1}{4}$ in diameter located $\frac{9}{16}$ above a line. Draw a round between them of radius $\frac{7}{8}$.
- 3-34 Draw an approximate ellipse with a minor axis of 1 and a major axis of $1\frac{1}{2}$.
- 3-35 Draw an approximate ellipse with a minor axis of 2.25 and a major axis of 3.80.
- 3-36 Draw a parabola whose major axis is $1\frac{1}{2}$ times the minor axis.
- 3-37 Draw a parabola whose major axis is two times the minor axis.
- 3-38 You are given an angle of 60° . Bisect it.
- 3-39 You are given an angle of 50° . Bisect it.
- 3-40 You are given an angle of 108° . Bisect it.
- 3-41 You are given an angle of 42.5° . Bisect it.

Redraw the following shapes:

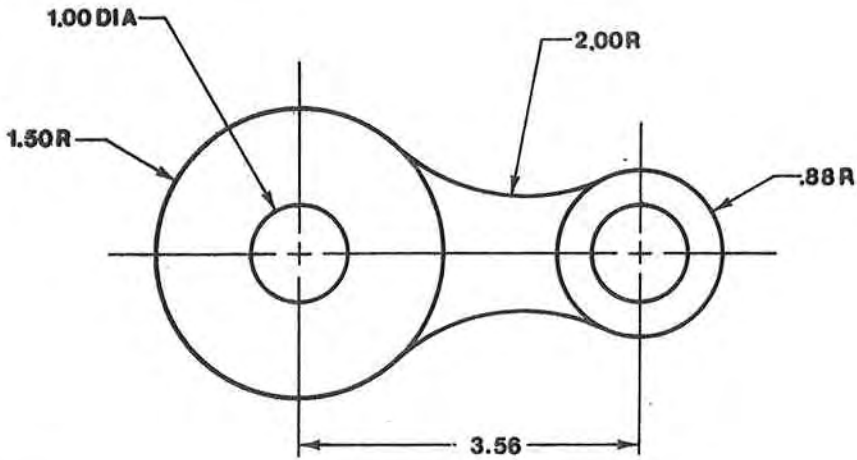
3-42



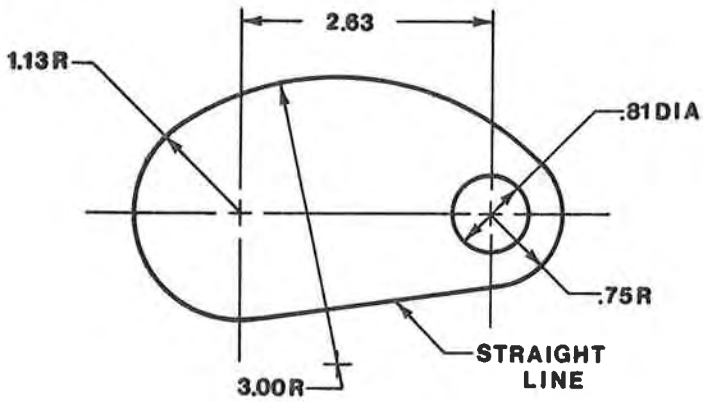
3-43



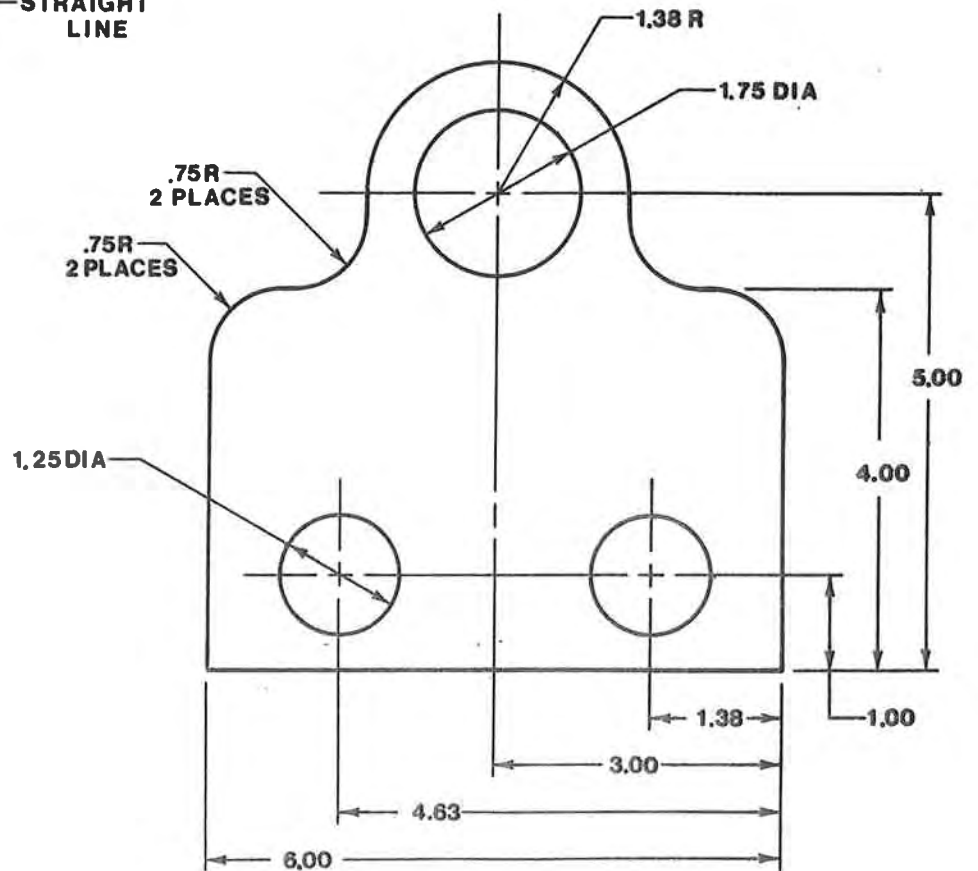
3-44



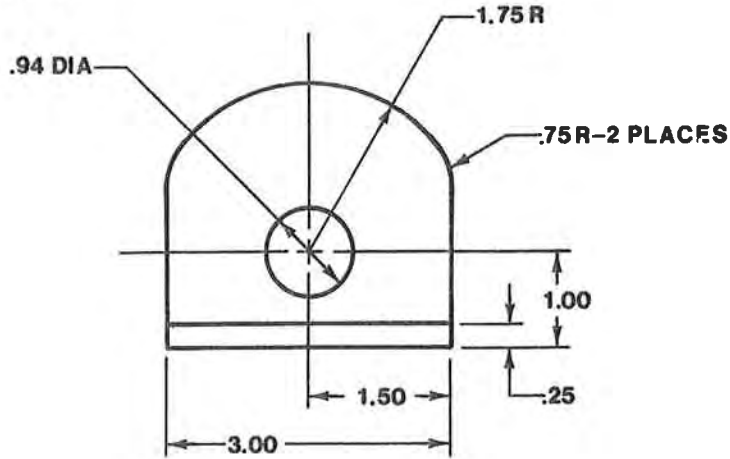
3-45



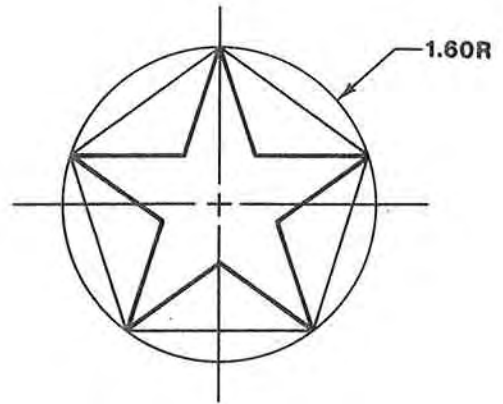
3-46 Use B size paper.



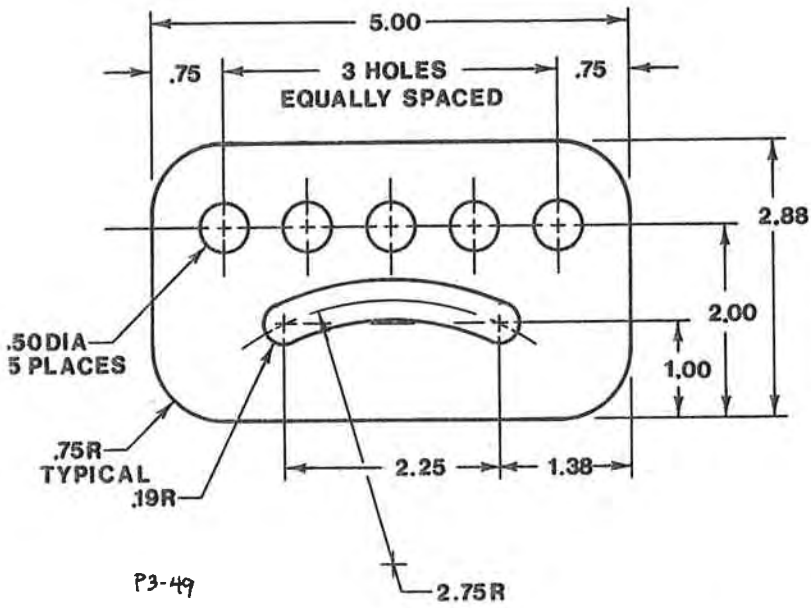
3-47



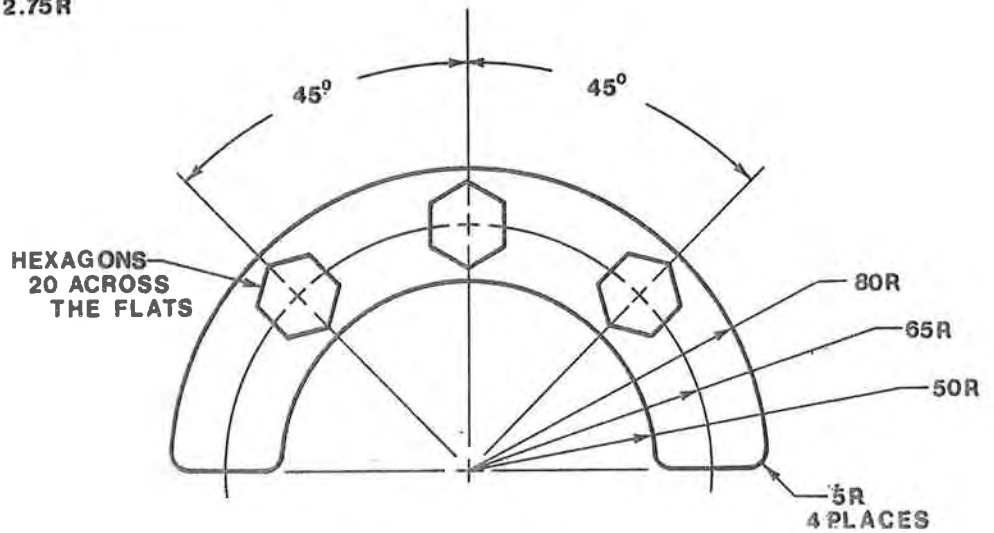
3-48



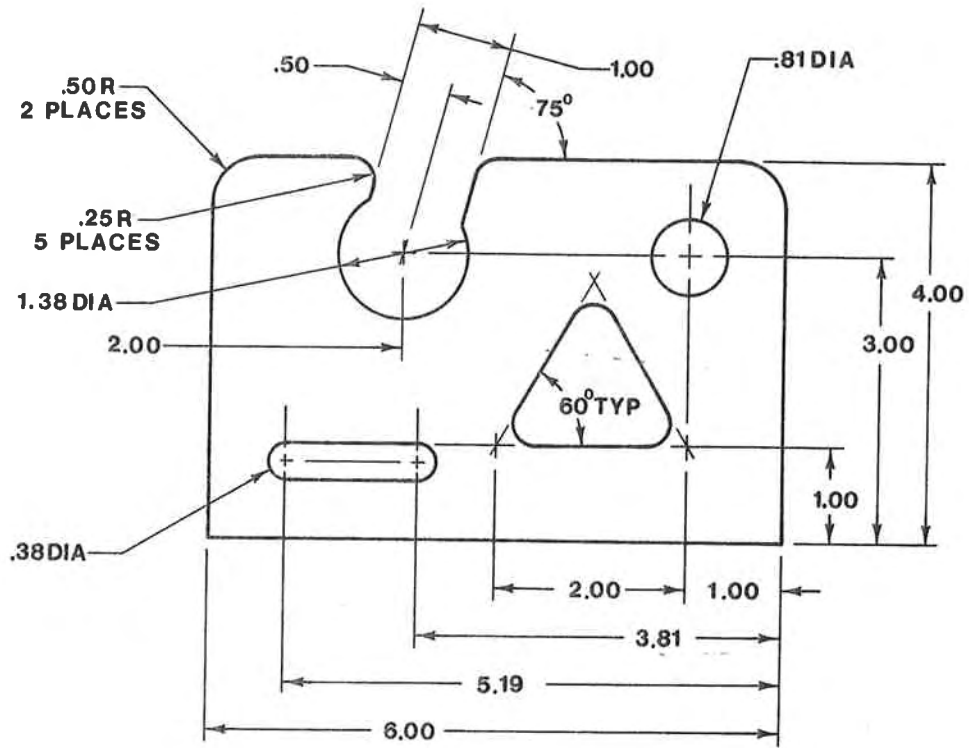
3-49



3-50 Millimeters.



3-51 Use B size paper.



PROJECTION THEORY 4

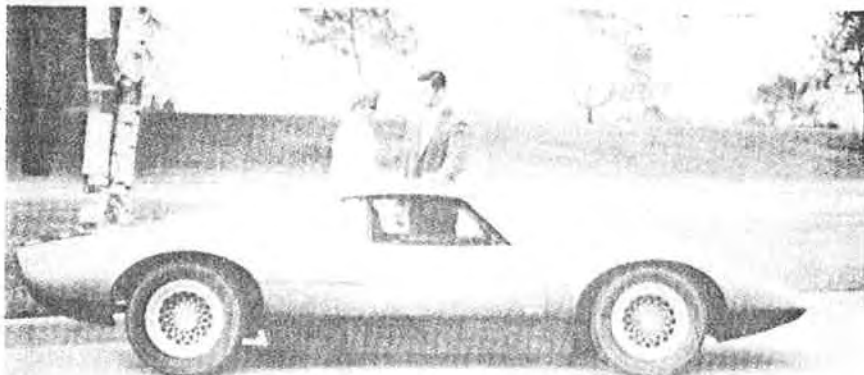


Figure 4-0 Many views of an object are needed to present a clear idea of the object's shape. Photograph courtesy of General Motors Corp.

4-1 INTRODUCTION

The purpose of a technical drawing is to communicate information. As in any kind of communication, it is easy to know what you want to say but sometimes very difficult to make yourself understood.

From the time a customer places his initial order until the finished product is delivered, many people of varying technical skills and backgrounds will contribute to help satisfy the demands of the order. An engineer and draftsman design the product and prepare the necessary drawings. The drawings are then used progressively by a planner to price and time the job, by a buyer to order necessary manufacturing stock, by a shop foreman to schedule and assign the work, by a machinist to actually make the parts, by an inspector to make sure that the work has been done properly, by an assembler to put the pieces together, by another inspector, and so on. Each member of this hypothetical chain takes from the drawings information that he needs for his particular function. It is, therefore, easy to see why the drawings must be accurate and clear, free from ambiguities or misleading representations. Just as the years of written communication have led to rules and conventions, so years of manufacturing and production experience have led to drafting rules and conventions that help prevent errors.

4-2 ORTHOGRAPHIC PROJECTIONS

One of the most useful systems used by draftsmen to help assure accurate communication is orthographic projection.

Orthographic projections are views of an object taken at right angles to the object and arranged in specific relative positions on the drawing.

There is an infinite number of possible orthographic projections—there is an infinite number of ways to look at an object—but the views most commonly used are front, top, bottom, right side, left side, and rear (see Figure 4-1).

Six views are not generally required, for most objects may be completely defined in three views: front, top, and right (corresponding to height, width, and depth). Drafting convention calls for these views to be specifically placed on a drawing, and any variance is an error. Figure 4-2 shows the three views in correct position. Figure 4-3 shows two examples of positioning errors.

Each orthographic view is taken at right angles to the object it is defining. It is not a picture, such as an artist would draw, but a two-dimensional representation which, for the sake of technical accuracy,

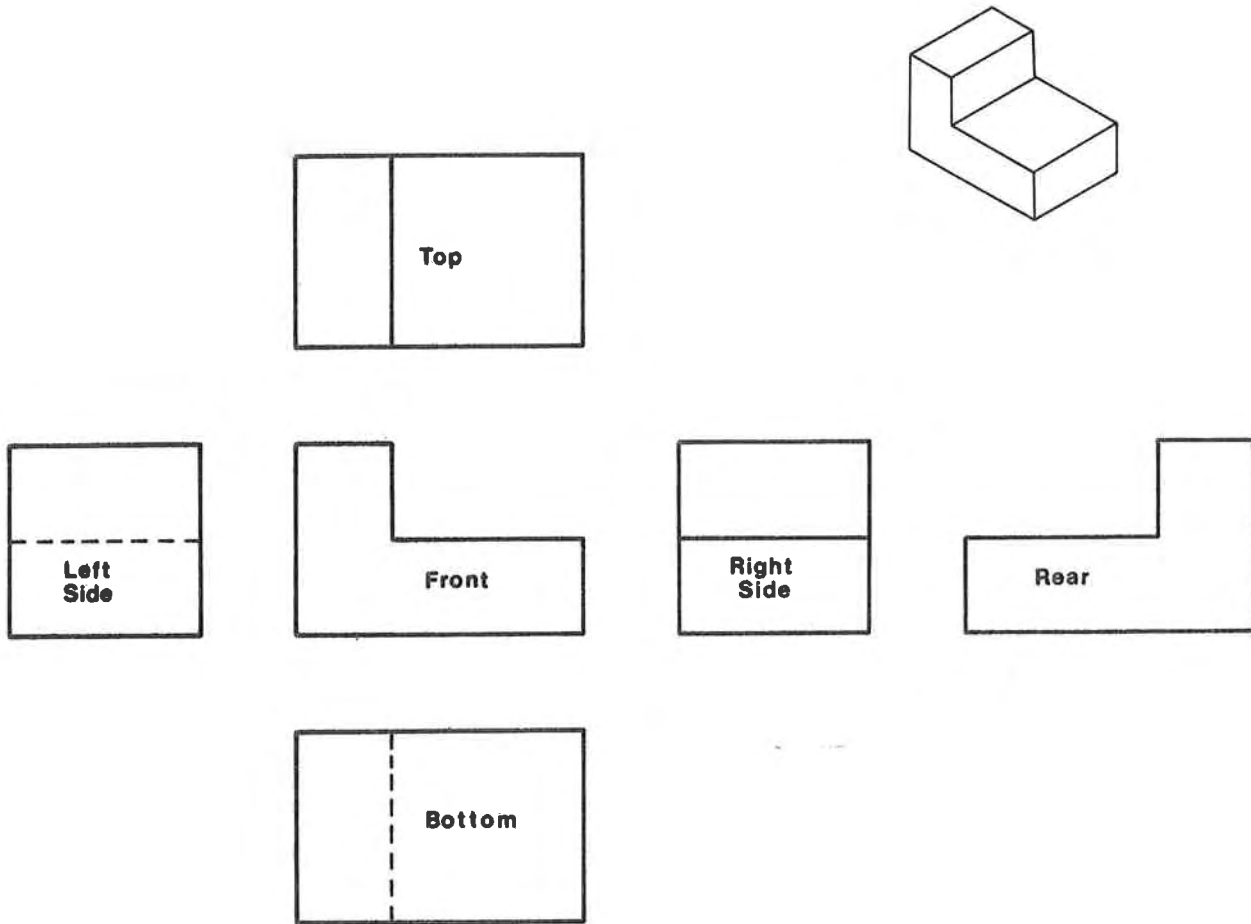


Figure 4-1 A front, top, bottom, right side, left side, and rear views of an object.

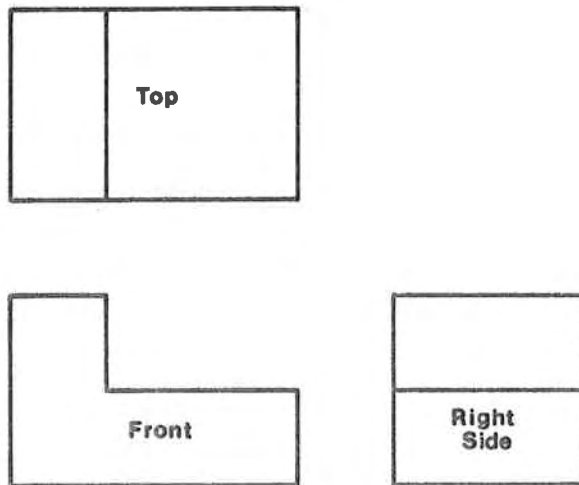


Figure 4-2 Three views of an object located in correct relative positions.

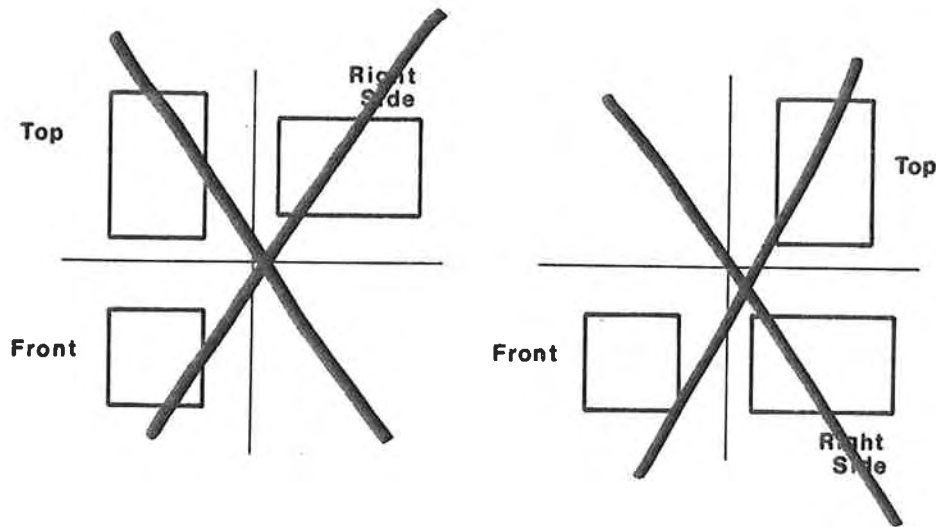


Figure 4-3 Orthographic views which are not positioned correctly.

has given up perspective. There is no shading and no attempt to “picture” the object. Each view presents only one face or one piece of the total information. Orthographic views are dependent on each other for a complete definition of the object. (There are objects that require fewer than three views, but these will be covered later.) In the top view in Figure 4-4, which surface is higher? There is no way to tell from this one orthographic view. Other views are needed before an answer may be given.

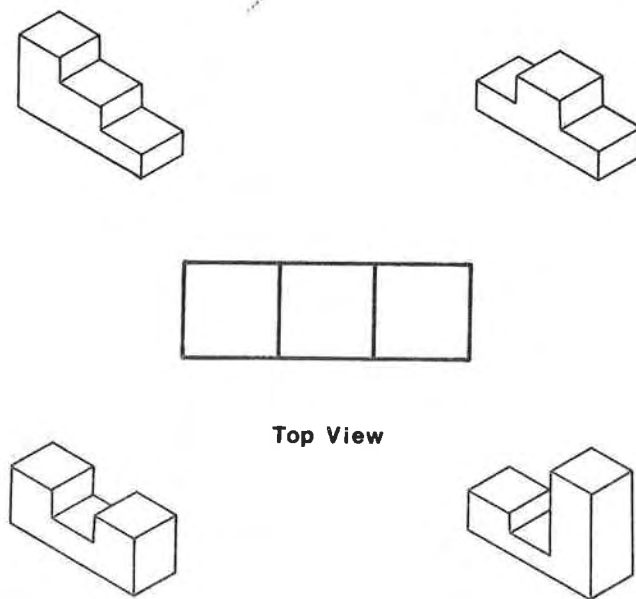


Figure 4-4 Given a top view of an object, which surface is higher? Other views are needed before an answer can be formulated.

4-3 PRINCIPAL PLANE LINE

Drawings are divided into zones. Each zone contains one orthographic view along with all information pertinent to that view. The zones are separated by crossed (at 90°) construction lines called *principal plane lines* which are similar to a mathematical coordinate system. They are omitted on most finished drawings, but their presence is tacit. They will be included for the first problems in order to help establish the importance of the separation and relative position of views.

Principal plane lines are defined in Figure 4-5(a). Figure 4-5(b) shows how principal planes lines were initially developed.

Figure 4-5(a) Principal plane lines.

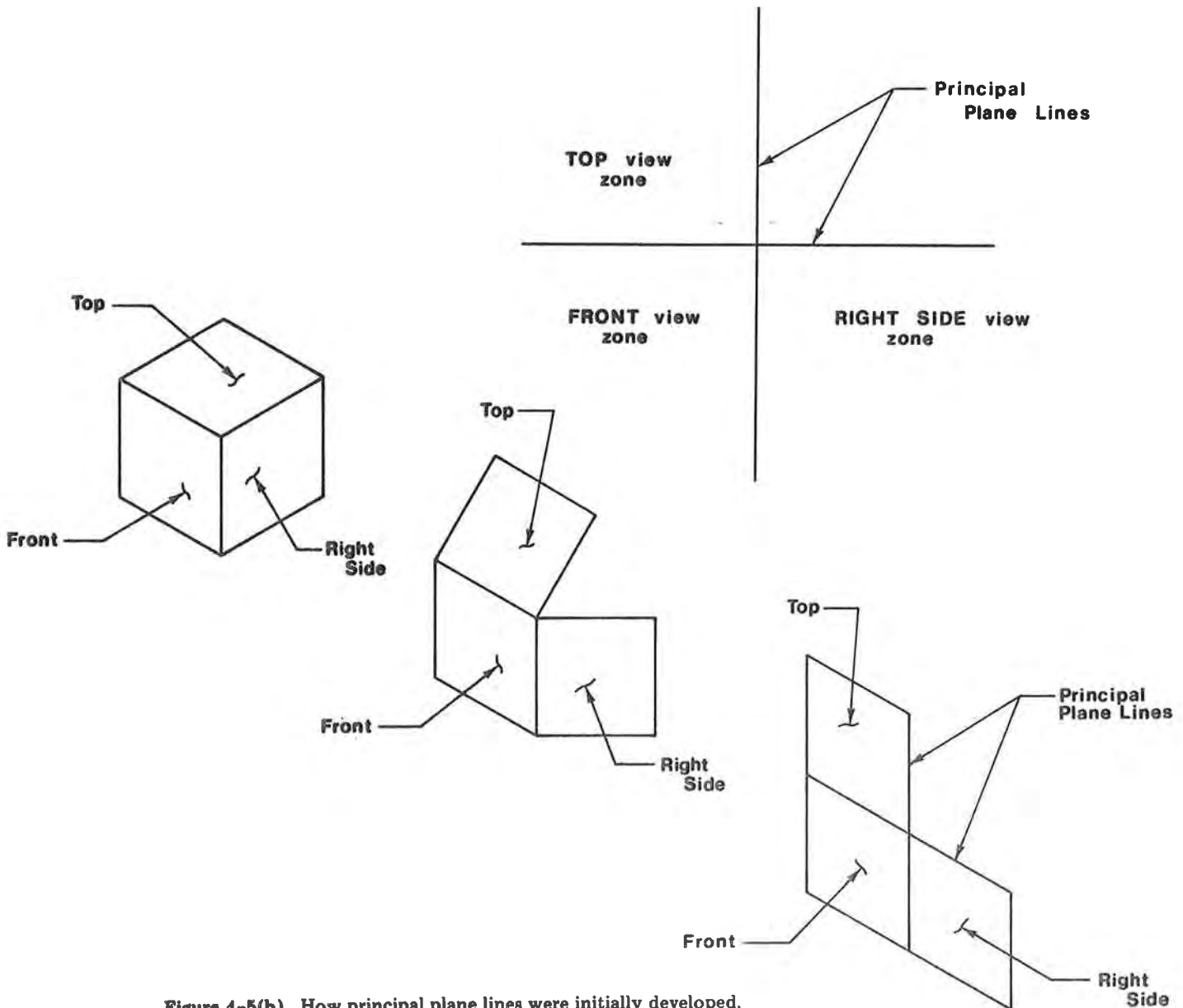


Figure 4-5(b) How principal plane lines were initially developed.

4.4 POINTS

Projection theory is the study of how to transfer information from one orthographic view to another. Often, two views of an object may be visualized, or parts of each view may be drawn, but the completed drawing remains clouded. Projection theory enables the bits and pieces to be used together to arrive at a finished drawing.

Reduced to its simplest form, projection theory may be used to transfer a single point from one view to another. Figure 4-6 presents the problem of finding the right side view of a point where the front and top views are given. Figure 4-7 shows the solution.

GIVEN: Front and top views of point 1.
PROBLEM: Draw the side view of point 1.

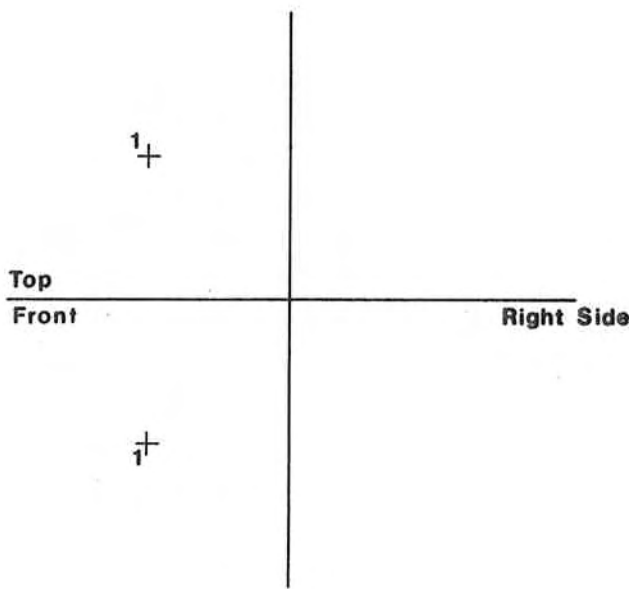


Figure 4-6 Top and front views of point 1.

SOLUTION:

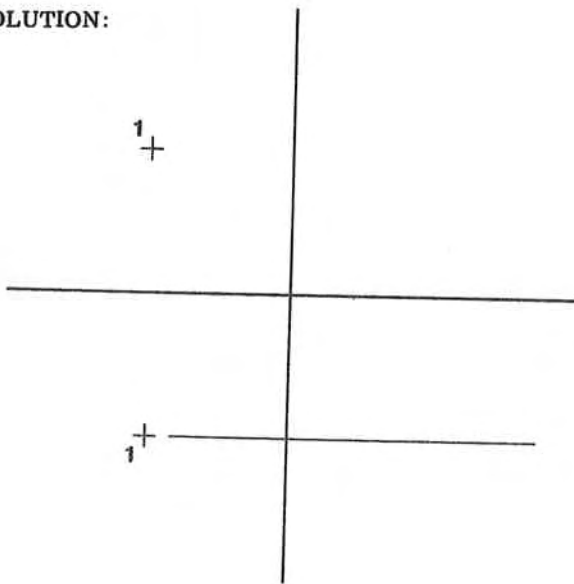


Figure 4-7(a)

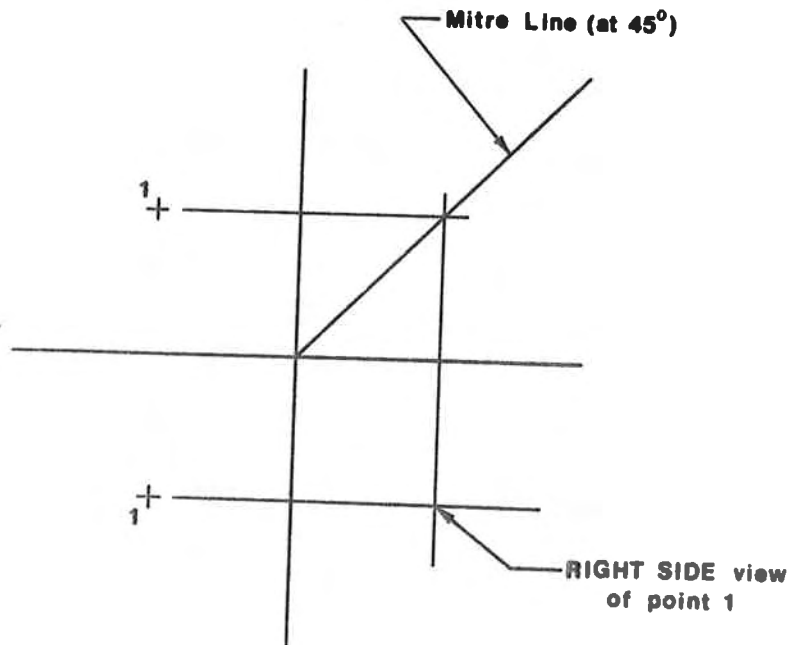


Figure 4-7(b)

1. Project the front view of point 1 into the right side view zone. This is done by drawing a horizontal construction line parallel to the horizontal principal plane line. The tendency here is to draw the projection line too short meaning extension may be required later on. All we know at this time is that the right side view is *somewhere* along the projection line.
2. Draw a line 45° up and to the right from the intersecting point of the principal plane lines. This is called a mitre line.
3. Project the top view of point 1 into the right side view zone. This is done by drawing a horizontal construction line to the right, parallel to the horizontal principle plane line until it touches the 45° -mitre line. When the projection line touches the mitre line, it turns the corner, i.e., it goes from horizontal to vertical. To continue the projection line, draw a vertical construction line, parallel to the vertical principal plane line, extending down into the right side view zone. As in step 1, don't be stingy with the lead; draw the projection line through and beyond the horizontal projection line.
4. The intersection of the two projection lines is the right side view of point 1. Label it.

Several additional points should be made before leaving this problem. The location of the front view of point 1 in relation to the top view is not random. The vertical line between the front and top views is parallel to the vertical principal plane line. Figure 4-8 shows three views of point 1 and the projection lines used to go from view to view. The point views and lines form a perfect rectangle (a four-sided figure with four right angles). This *projection rectangle* enables the draftsman to find any third view of a point when he is given the two other views. This means that if we consider only three principle views (top, front, and right side), there are only three possible projection problems.

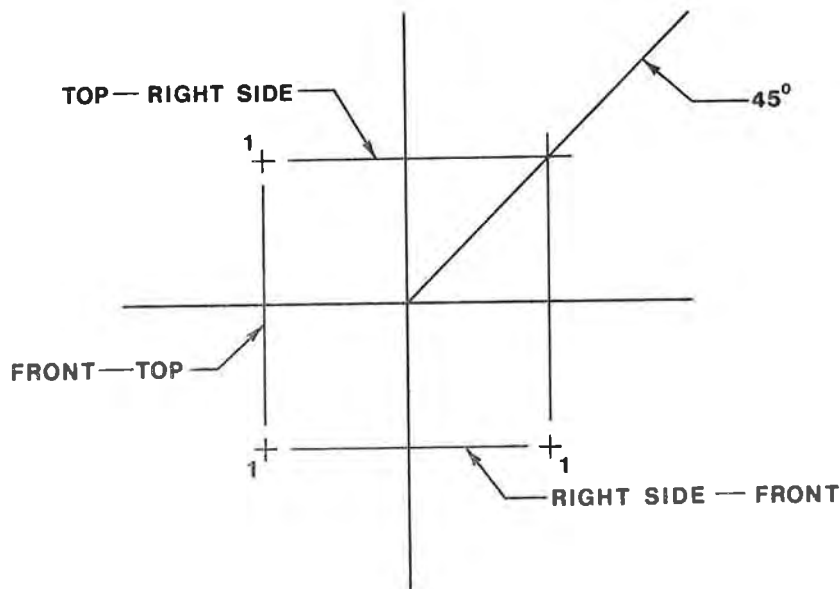
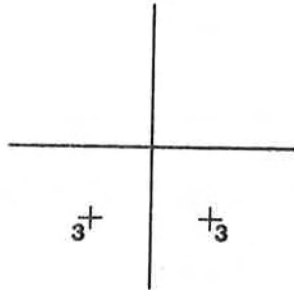


Figure 4-8 Projection rectangle.

1. When you are given the front and top, draw the right side.
2. When you are given the front and right side, draw the top.
3. When you are given the top and right side, draw the front.

The sample problems in Figures 4-9 and 4-10 are examples of the other two possible point projection problems. Study them before proceeding to the next section.

GIVEN: Top and right side views of point 2.
PROBLEM: Draw front view.



SOLUTION:

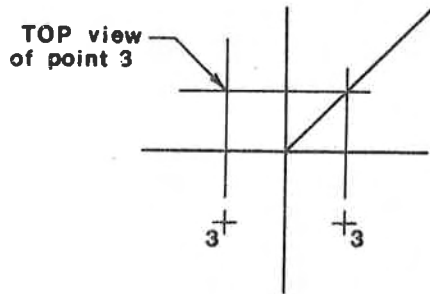
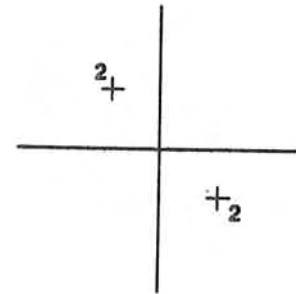


Figure 4-9

GIVEN: Front and right side views of point 3.
PROBLEM: Draw top view.



SOLUTION:

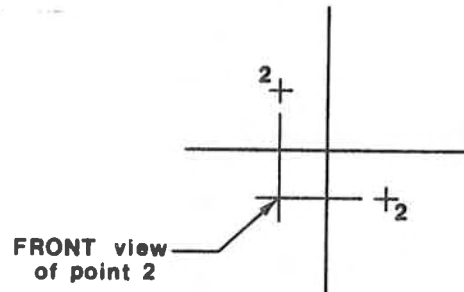


Figure 4-10

4-5 LINES

The projection of lines between views follows directly from point projection theory if we consider the axiom:

To a draftsman, a line is a visible line that connects two or more points.

Axiom 4-1

It follows then that lines may be projected by projecting the points that define them.

Figure 4-11 presents the problem of finding a right side view when the front and top views are given. Figure 4-12 is the solution and was arrived at by the following:

1. Projecting point 1 into the right side view (see Figure 4-1).

GIVEN: Front and top views of line 1-2.
PROBLEM: Draw side view.

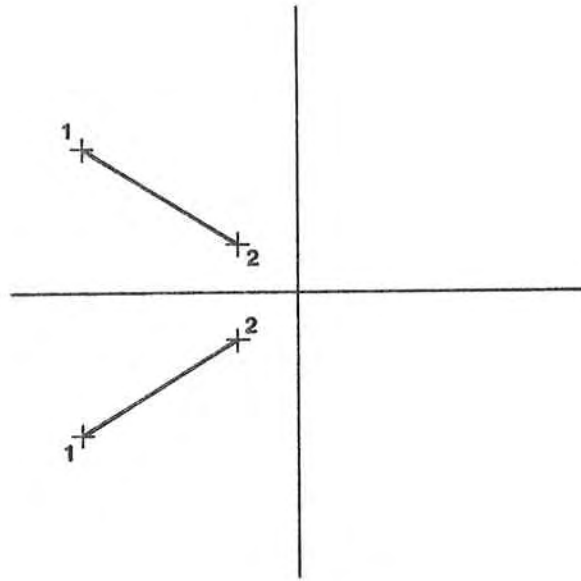


Figure 4-11

SOLUTION:

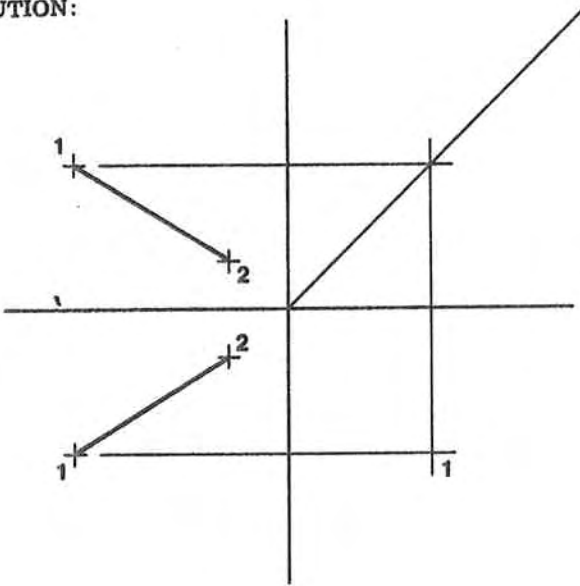


Figure 4-12(a)

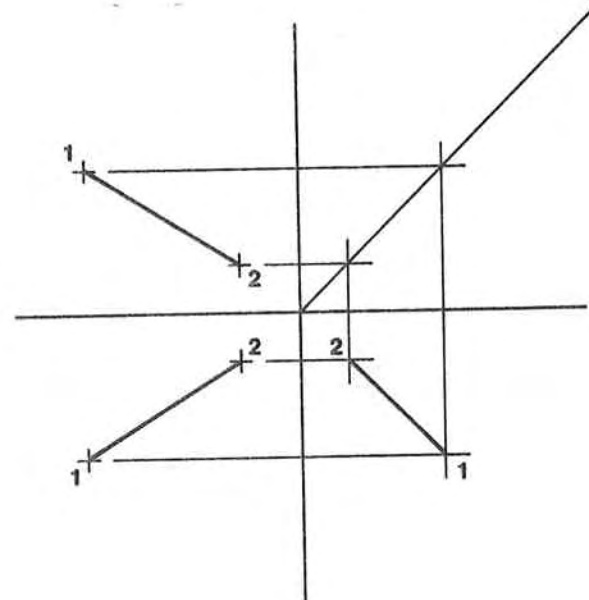


Figure 4-12(b)

2. Projecting point 2 into the right side view.
3. Connecting points 1 and 2 with an object line.

Step 3 is the right side view of line 1-2.

One aspect of line projection that could cause confusion is a double-point projection. This is clarified by the following axiom:

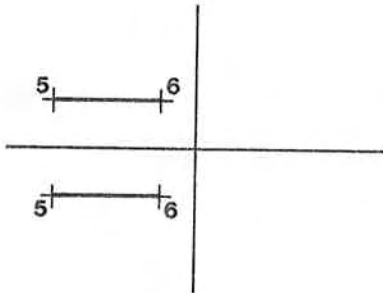
The end view of a straight line is a point (really a double point).

Axiom 4-2

Figure 4-13 is an example of a double-point projection. The solution is derived exactly as shown in Figure 4-11, except for step 3. Points 1 and 2 cannot be joined by an object line because the line extends into the paper and therefore appears as a double point. This may be visualized if you hold a pencil horizontal to the ground and rotate it until you are looking directly at the point with the eraser end directly behind the point. If the point represents point 1 and if the eraser represents point 2, you now have a model of the end view of a line.

Figures 4-14, 4-15, and 4-16 are samples of solved line projection problems. Study them before proceeding to the next section.

GIVEN: Front and top view of line 5-6.
PROBLEM: Draw right side view.



SOLUTION:

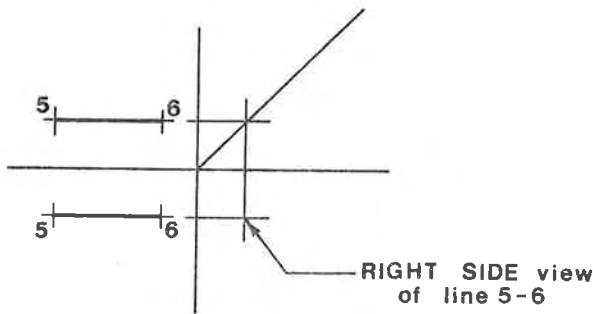
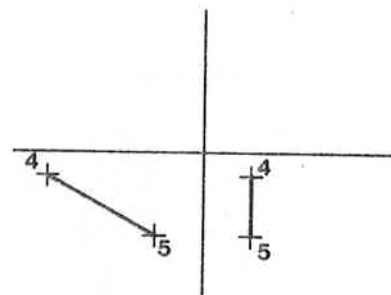


Figure 4-13 End view of a line.

GIVEN: Front and right side views of line 4-5.
PROBLEM: Draw top view.



SOLUTION:

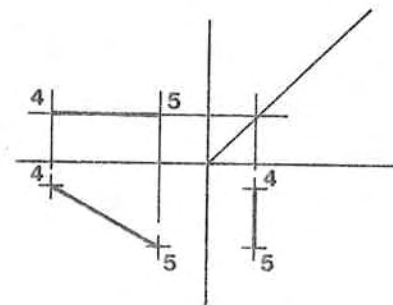
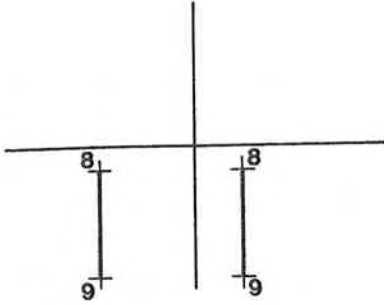


Figure 4-14

GIVEN: Front and right side view of line 8-9.
 PROBLEM: Draw top view.



SOLUTION:

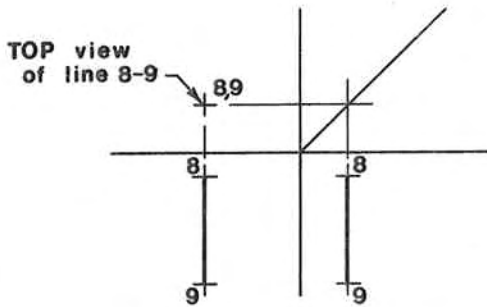
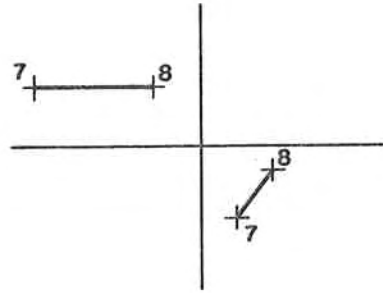


Figure 4-15

GIVEN: Top and right side views of line 7-8.
 PROBLEM: Draw front view.



SOLUTION:

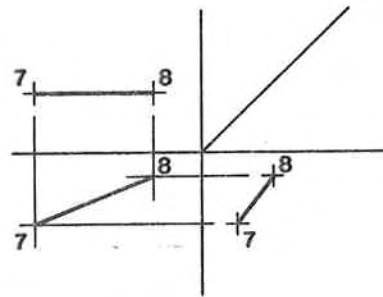


Figure 4-16

4-6 PLANES

As line projection theory was derived from point projection theory, so plane projection theory follows directly from line projection theory if we consider the following axiom:

To a draftsman, a plane is the area enclosed within a series of lines interconnected end to end.

Axiom 4-3

This differs from the geometric concept of planes in that it considers a plane a finite area, that is, an area with known boundaries.

Figure 4-17 gives the front and top views of plane 1-2-3-4 and asks for the right side view. Figure 4-18 shows the solution which was arrived at by the following:

1. Identify the lines that define the plane 1-2, 2-4, 4-3, and 3-1.
2. Project the individual points 1, 2, 3, and 4 into the right side view (see Figure 3-7).
3. Draw in with object lines the lines that define the plane.

The lines drawn in step 3 define the right side view of plane 1-2-3-4.

GIVEN: Front and top views of plane 1-2-3-4.
 PROBLEM: Draw right side view.

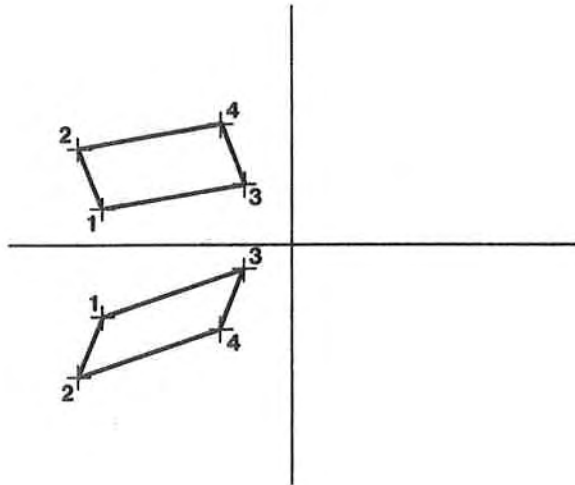


Figure 4-17

SOLUTION:

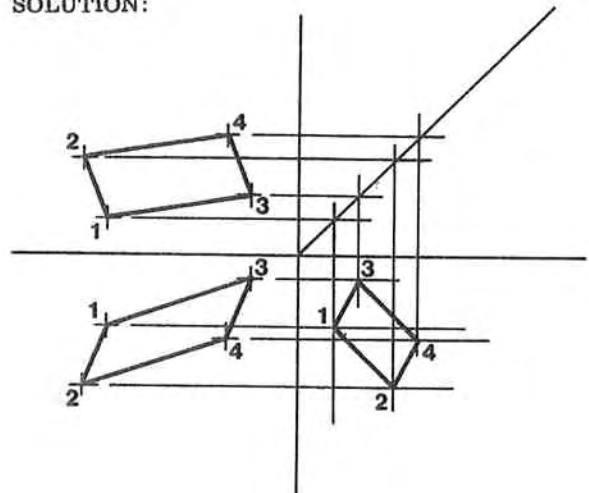


Figure 4-18

In line theory we found that the end view of a line was a double point. A similar situation appears in plane theory which is explained by the following axiom:

The end view of a plane is a line (really several lines directly behind each other).

Axiom 4-4

This may be verified by holding a sheet of paper horizontal to the ground and rotating it until you are looking directly at one edge. Although it is a plane, the sheet appears as a line.

Figure 4-19 is a sample problem involving the end view of a plane. Points 1, 2, 3, and 4 are double points or end views of lines. Line 1-3 is located directly behind line 2-4 and is therefore hidden from view. Figure 4-19 is a good example of why orthographic views are dependent on each other to present a complete picture of an object. By itself, the right side view is not only incomplete, it is also misleading.

GIVEN: Front and top views of plane 1-2-3-4.
 PROBLEM: Draw the right side view.

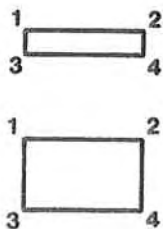
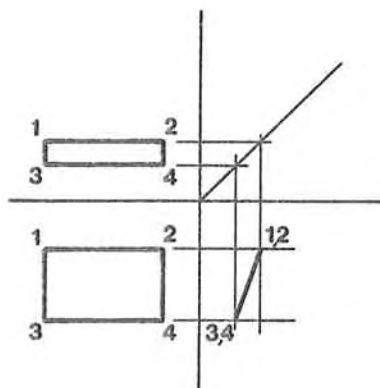


Figure 4-19

SOLUTION:



4-7 CURVES

So far we have considered only straight lines. Point, line, and plane projection theory may be extended to include curved lines if we consider the following axioms:

To a draftsman, a curved line is a visible line connecting three or more points which form a smooth, nonlinear line.

Axiom 4-5

To a draftsman, the accuracy of a curve is a function of the number of points used to define the curve.

Axiom 4-6

To draw a perfectly accurate curve would require an infinite number of points. To do this is not only impossible, it is also impractical. Most curves may be very closely approximated by a finite number of points, and it is up to the draftsman to determine which level of accuracy is required and how many points he needs to achieve this level. Circles and perfect arcs are exceptions to the axioms because they may be drawn with perfect accuracy by using a compass.

Figures 4-20 and 4-21 are examples of curved line projection problems and Figure 4-22 is an example of a plane with a curved edge. The solution to each of these problems is based on the concept of point project theory as shown in Figures 4-7, 4-9, and 4-10.

GIVEN: Front and right side views of curved line 1-2.

PROBLEM: Draw top view.

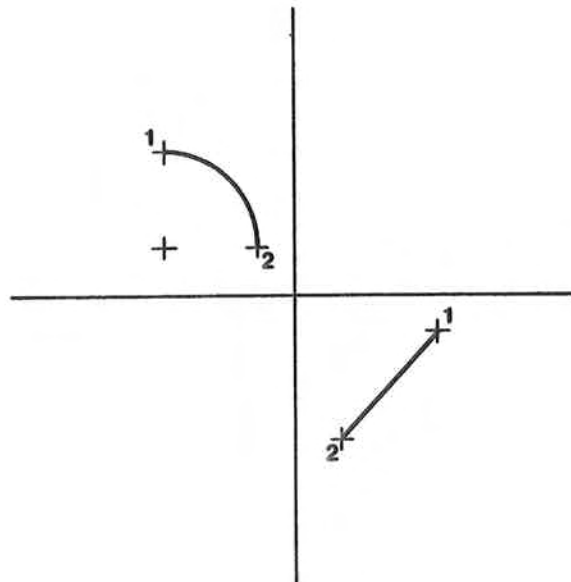


Figure 4-20

SOLUTION:

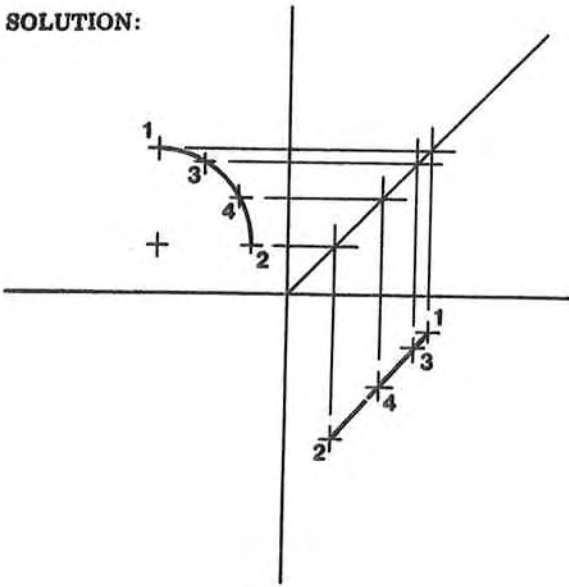


Figure 4-21(a)

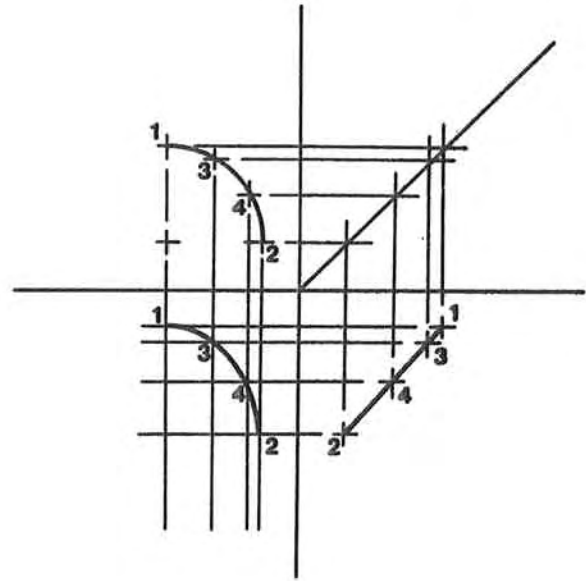
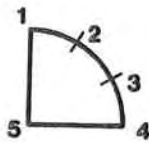
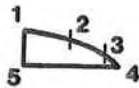


Figure 4-21(b)

GIVEN: Front and top views of plane 1-2-3-4-5.
PROBLEM: Draw the side view.



SOLUTION:

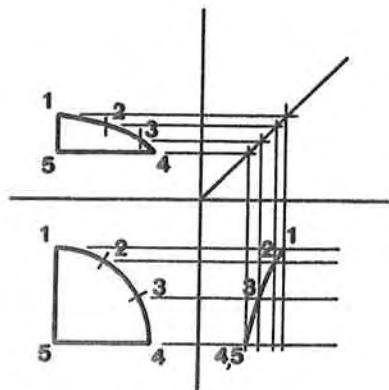
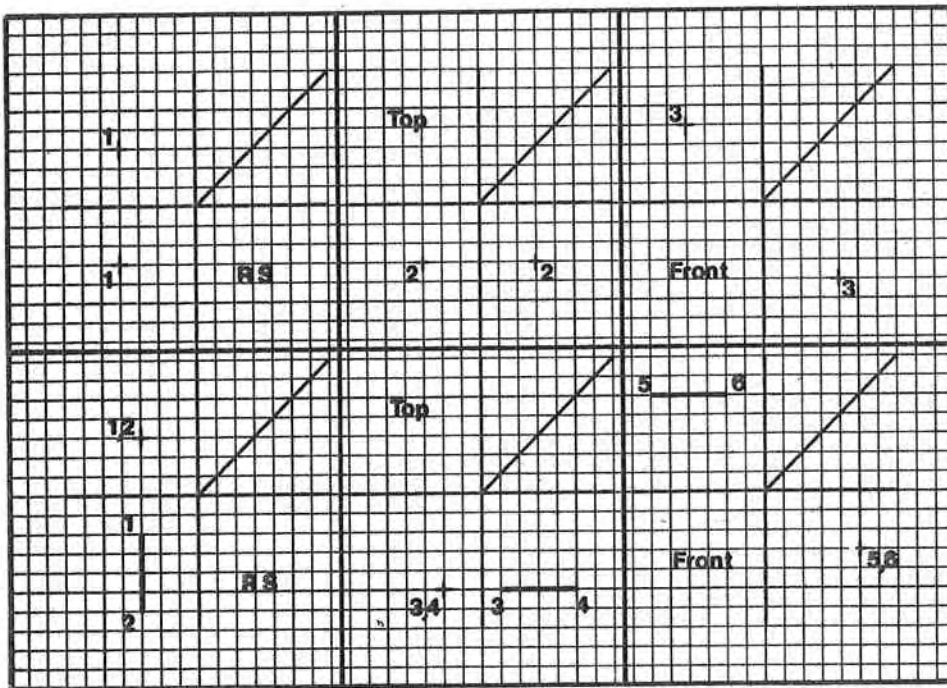


Figure 4-22

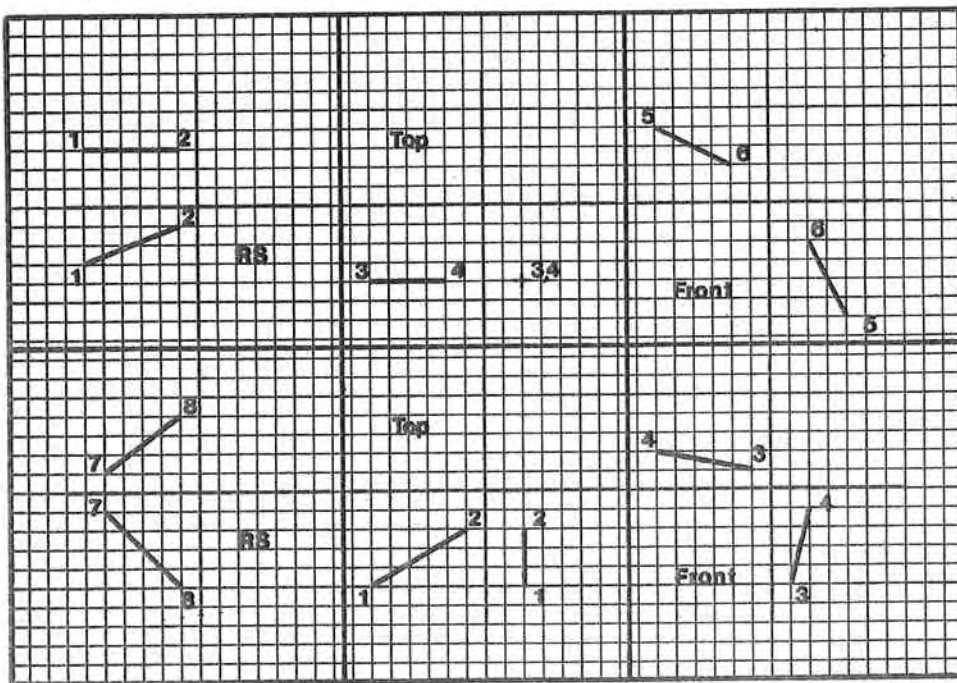
PROBLEMS

Draw three views (front, top, and side) of the following points, lines, and planes. Include principal plane lines, mitre lines, and projection lines for each problem. Each square on the grid is 0.20×0.20 .

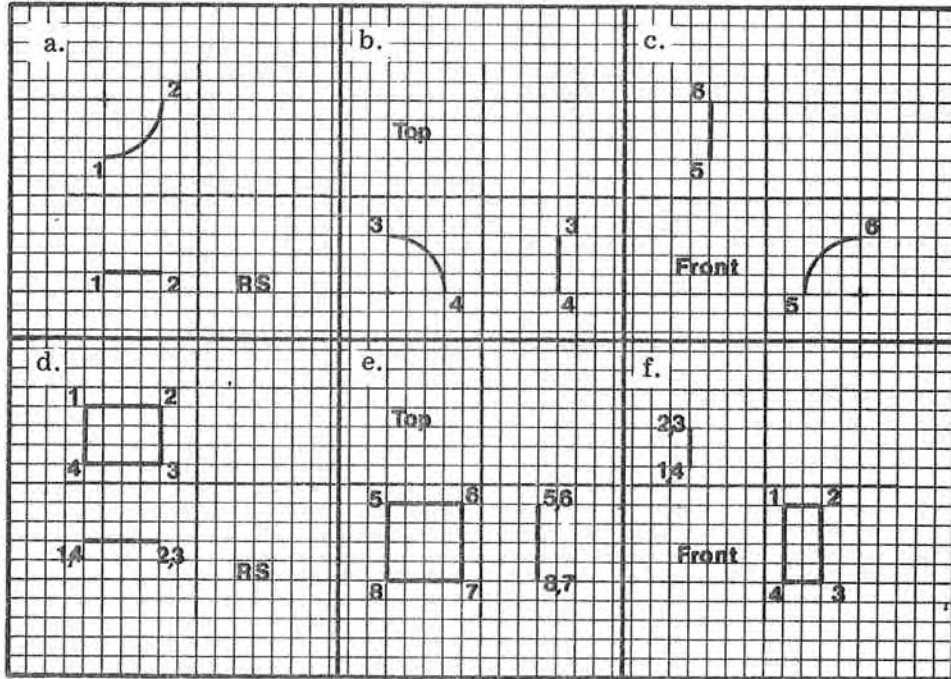
4-1



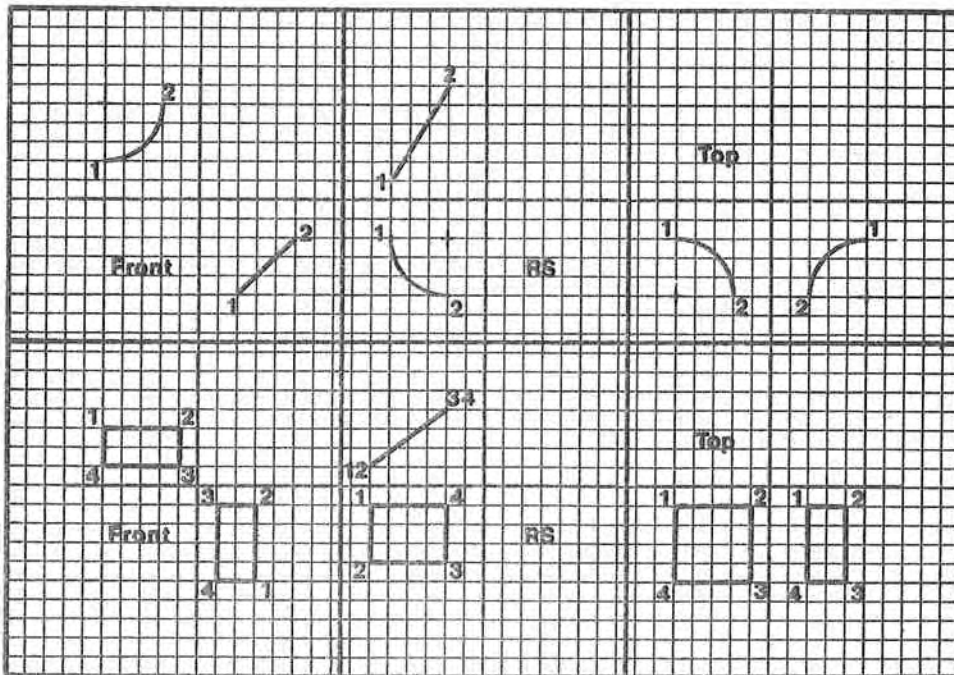
4-2



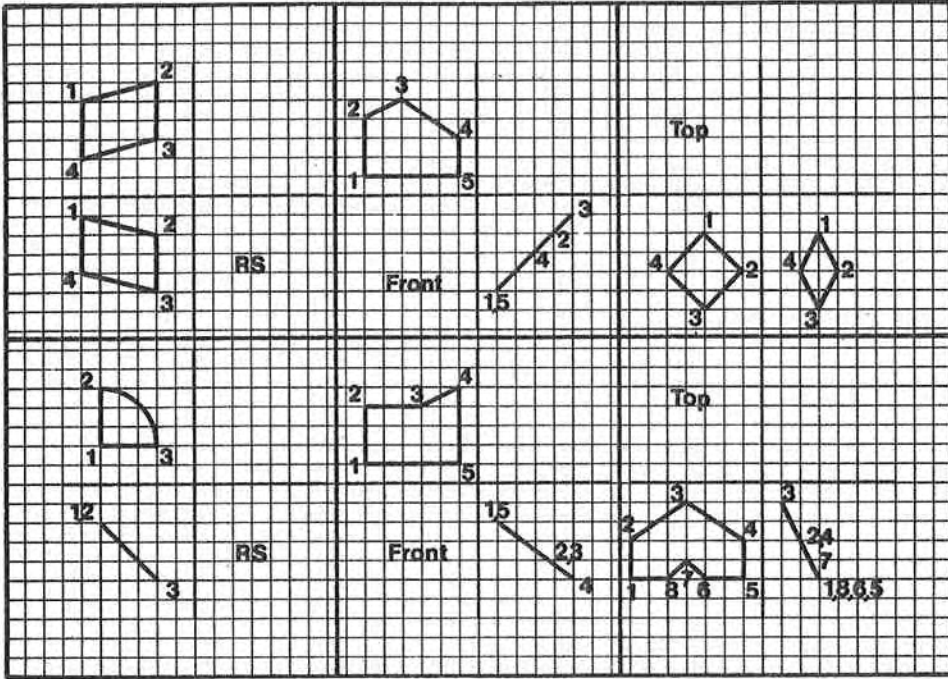
4-3



4-4



4-5



THREE VIEWS OF AN OBJECT

5

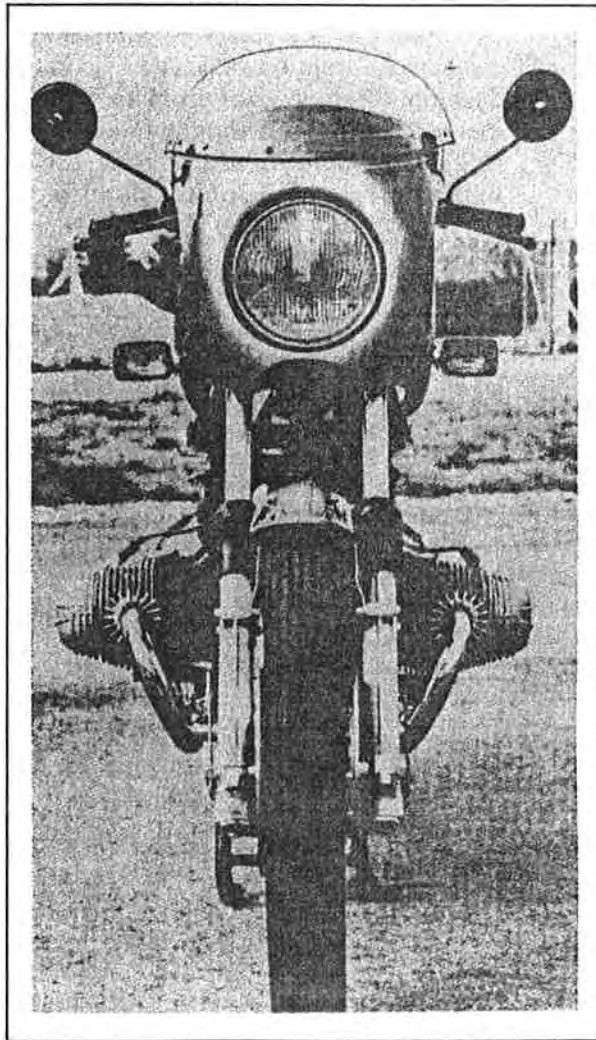


Figure 5-0 A front view of a BMW R90S. Photograph courtesy of Bob Braverman's Cycle Rider Publications, Inc.

5-1 INTRODUCTION

In this chapter we will extend the projection theory concepts of Chapter 4 to cover three-dimensional objects. The basic three views (front, top, and right side) and their relative locations on the drawing are the same for three-dimensional objects as they are for points, lines, and planes. Similarly, the techniques for projecting information from one view to another remain exactly the same. As we consider lines to be defined by points and we consider planes to be defined by lines, so we may consider three-dimensional objects to be defined by planes and, therefore, directly apply projection theory.

We also introduce in this chapter the concept of object visualization. *Object visualization* is the ability to mentally picture an object in three dimensions when only orthographic views are given and to mentally visualize the orthographic views of an object when only a three-dimensional picture is given. It is an important skill for a draftsman to develop. Each sample problem in this and the next six chapters will include both the orthographic views and a three-dimensional drawing, called an *isometric drawing*, of the objects to be studied so that an understanding of the object visualization may be developed.

5-2 NORMAL SURFACES

Figure 5-1 shows an object and a three-view orthographic drawing of that object. All surfaces in the object are normal, that is, at 90° to each other. The principal plane lines and the projection lines have been included, and points 1, 2, 3, 4, 5, and 6 have been defined.

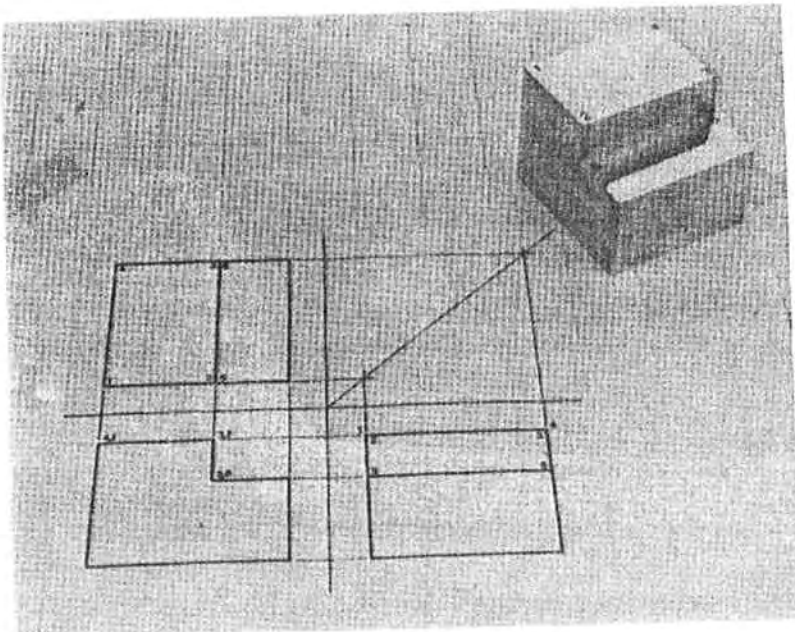


Figure 5-1 An object and a three view orthographic drawing of that object.

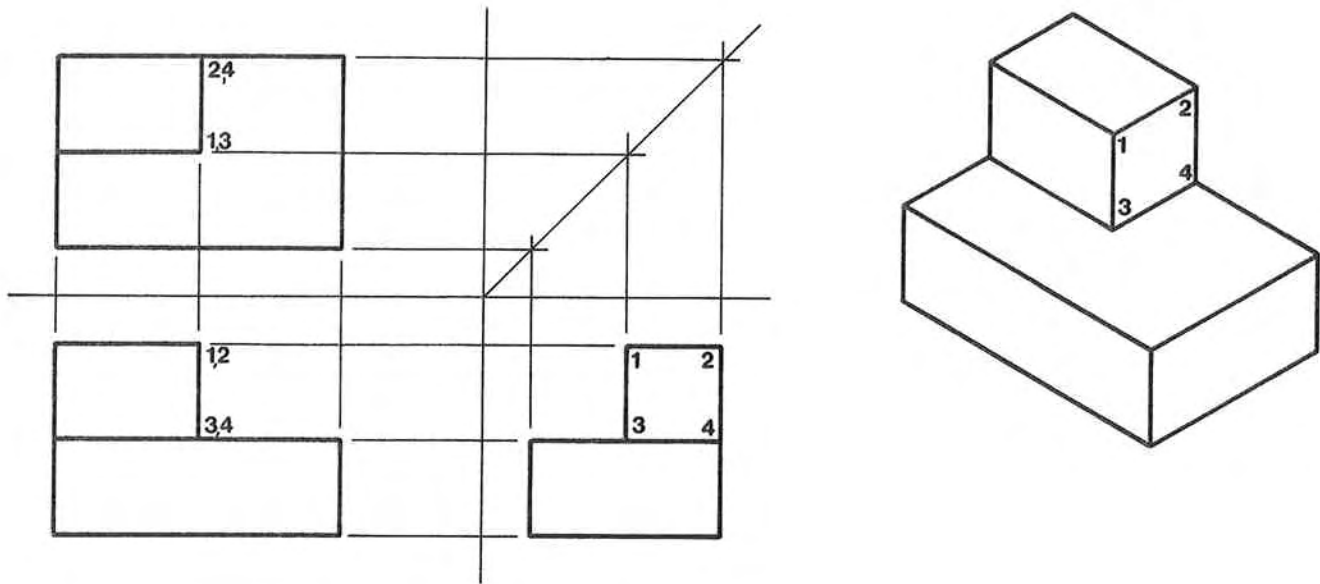


Figure 5-2 An object and a three view orthographic drawing of that object.

Planes 1-2-3-4 and 2-3-5-6 have been numbered to demonstrate the application of projection theory to objects. Projection theory is directly applicable to three-dimensional objects if we consider the following axiom:

To a draftsman, an object is a volume enclosed within a series of interconnected planes.

Axiom 5-1

As we are able to analyze lines from points and analyze planes from lines, so we are able to analyze objects from planes. Planes 1-2-3-4 and 2-3-5-6 are analyzed separately in Figure 5-2. All other surfaces that make up the object may be analyzed in the same way and then combined into a composite of planes which in turn form the three views of the object.

Normally, a draftsman does not number all points on an object because he mentally sees his finished drawing before he draws it. This is not always true, however, because not every object may be mentally solved. Thus, draftsmen often use projection theory to help them derive and check surfaces about which they are unsure. Let us assume, for example, that surface 1-2-3-4 in Figure 5-2 has caused confusion and that we have numbered what we feel are the correct three views. We now wish to check our work.

To check the proposed solution, start with point 1 and draw in the projection rectangle verifying the indicated locations of point 1. Do the same with line 1-2 and then with surface 1-2-3-4. All points, lines, and the plane check. Therefore, the drawn solution is correct.

Figure 5-3 is another example of an object containing all normal surfaces.

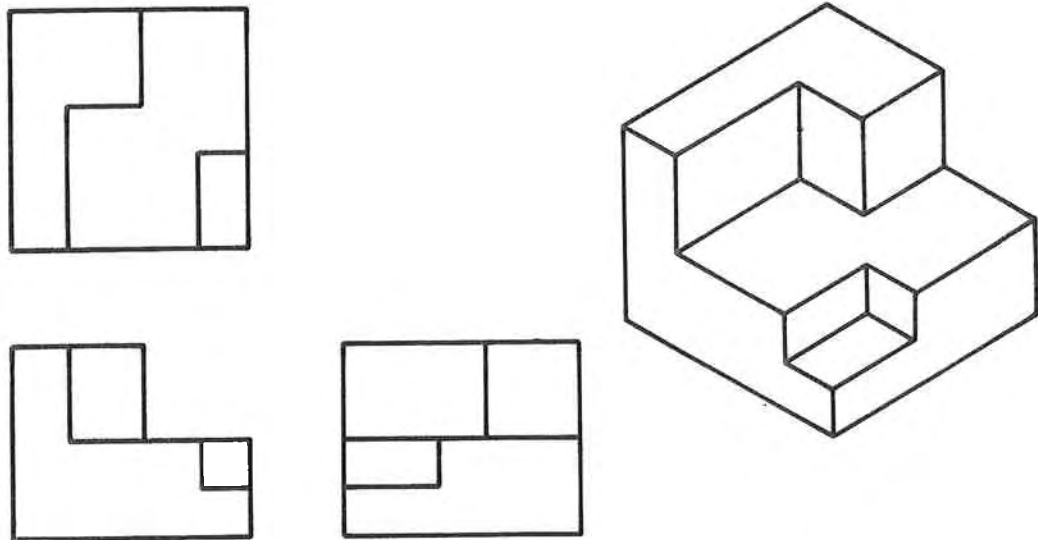


Figure 5-3 An object and a three view orthographic drawing of that object.

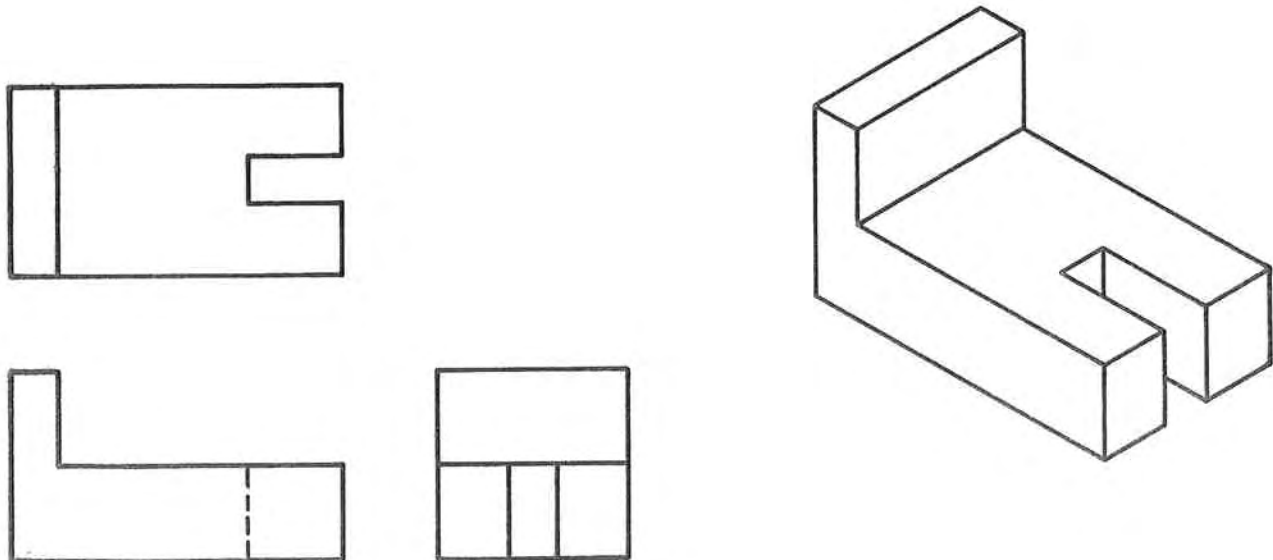
5-3 HIDDEN LINES

Most objects contain lines (edges) that cannot be seen in all three views. The slot in Figure 5-4 appears in the top and right side view, but it is hidden in the front view. We must somehow represent the slot in the front view to insure that all views are consistent in the information they present. We do this by using hidden lines.

Hidden lines are lines used to represent edges of an object that cannot be directly seen.

Axiom 5-2

Figure 5-4 An example of an object whose front view contains a hidden line.



The hidden lines in the front view of the object shown in Figure 5-4 represent the horizontal surface of the slot.

Hidden lines are drawn by using dashes as explained in Figure 5-5. The actual length of the dashes may vary according to the situation as long as a 4 to 1 ratio is maintained between the dashes and the intermittent spaces. Since hidden lines are not as dark or as thick as object lines, you should be careful to make sure that there is a noticeable difference between object lines and hidden lines. See Chapter 2 for further definition of kinds of lines.

There are three rules that must be followed when drawing hidden lines. They have been developed to prevent confusion and misunderstanding in the use and interpretation of hidden lines. Figure 5-6 illustrates the rules.



Figure 5-5 Hidden line configuration.

Rule 1: Do not continue an object line into a hidden line. Always allow a small (1/16) gap.

Axiom 5-3

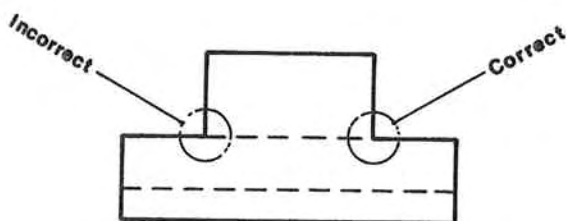


Figure 5-6(a) Do not continue a visible line into a hidden line; leave a gap.

Rule 2: Show hidden corners as an intersection of hidden lines, thereby specifically defining the location of the corner.

Axiom 5-4

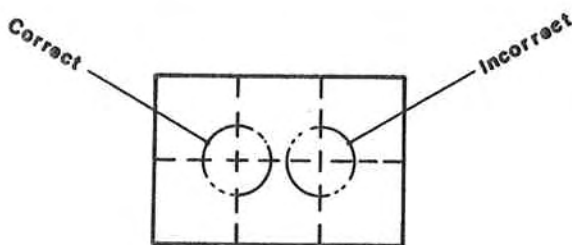


Figure 5-6(b) Show hidden intersections by crossed hidden lines.

Rule 3: Never draw parallel hidden lines with equal length dashes and spaces. Stagger the lengths so that each line is distinctive.

Axiom 5-5

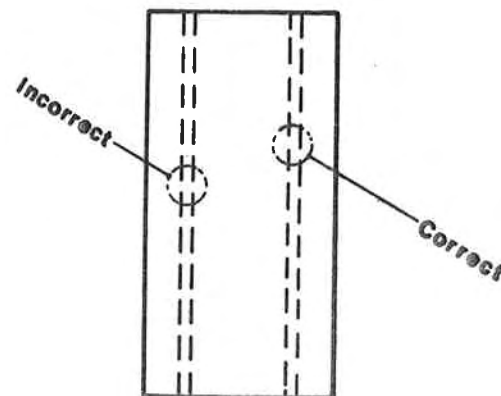


Figure 5-6(c) Stagger the spacing of close parallel hidden lines.

Figures 5-7, 5-8, 5-9, and 5-10 are further examples of hidden line problems.

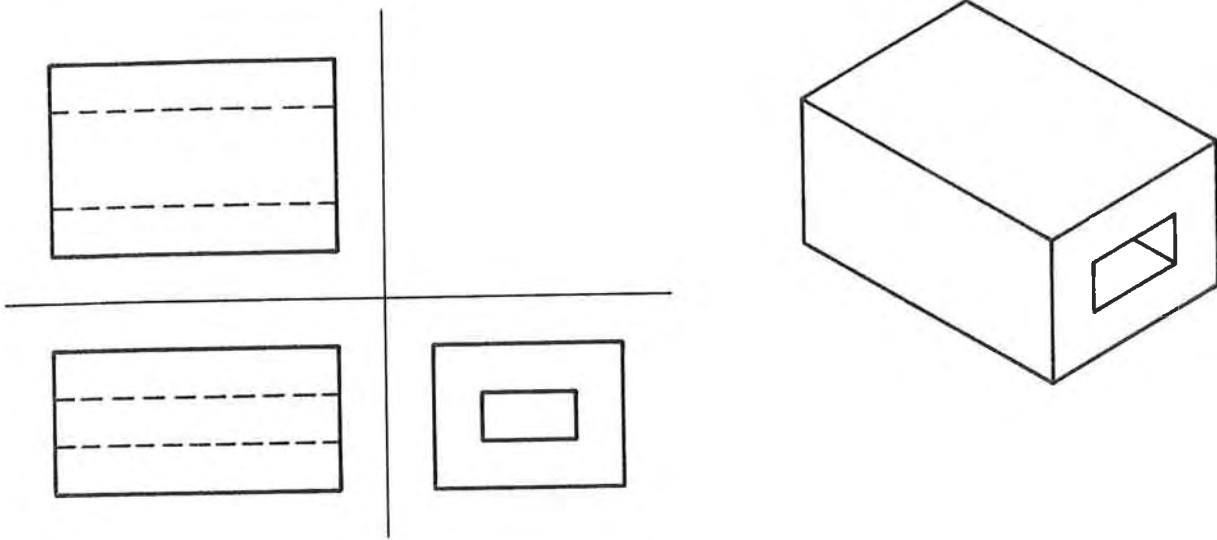


Figure 5-7 An example of an object whose orthographic views contain hidden lines.

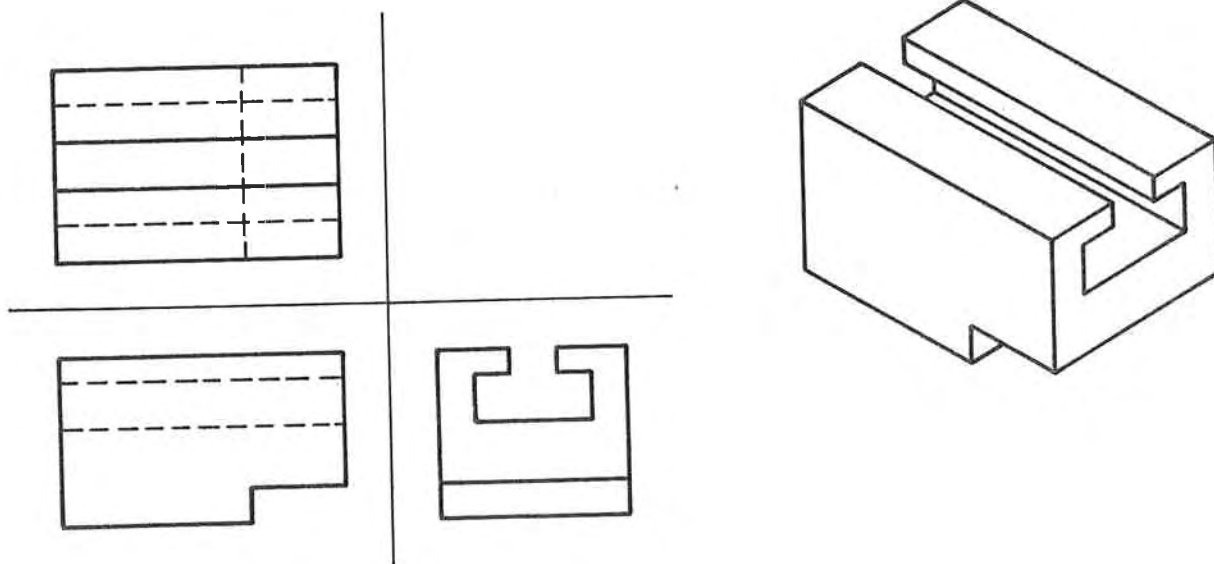


Figure 5-8 An example of an object whose orthographic views contain hidden lines.

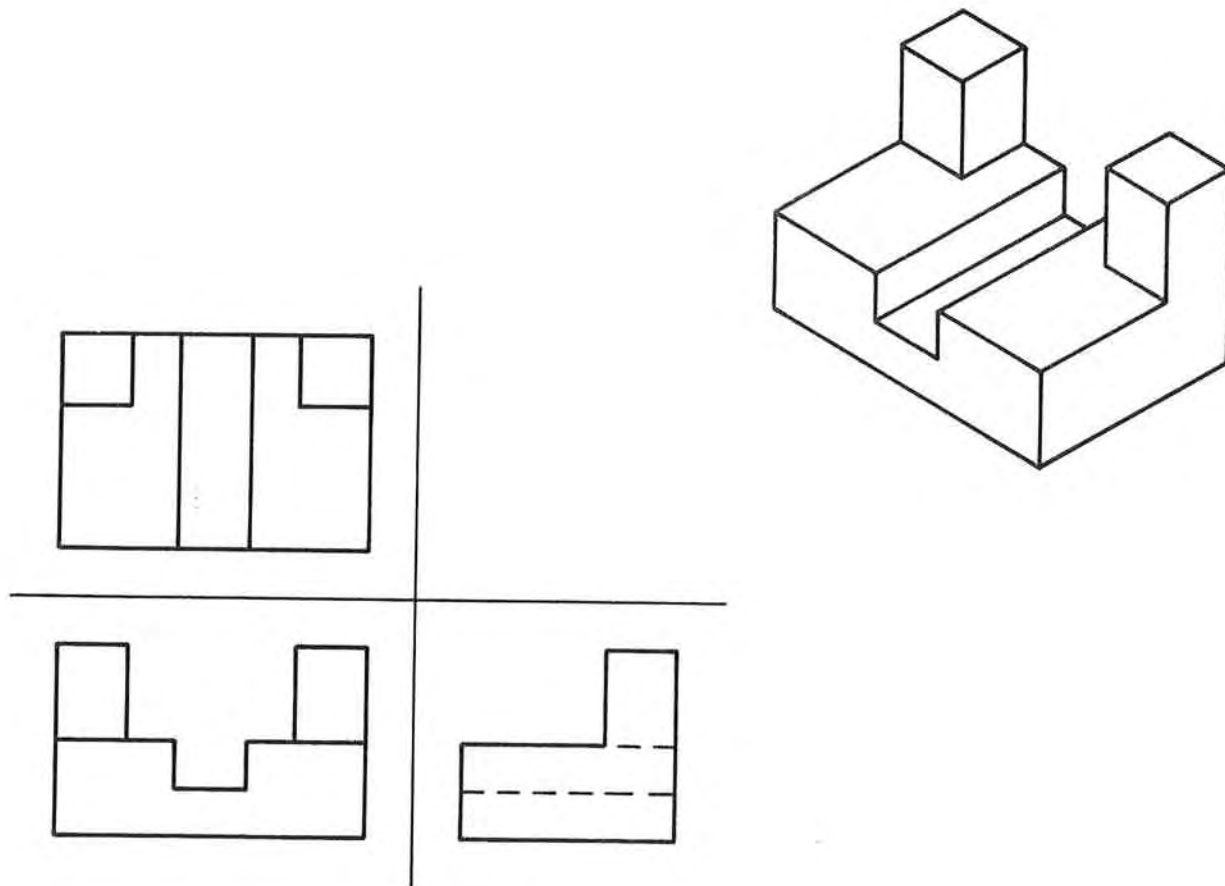


Figure 5-9 An example of an object whose orthographic views contain hidden lines.

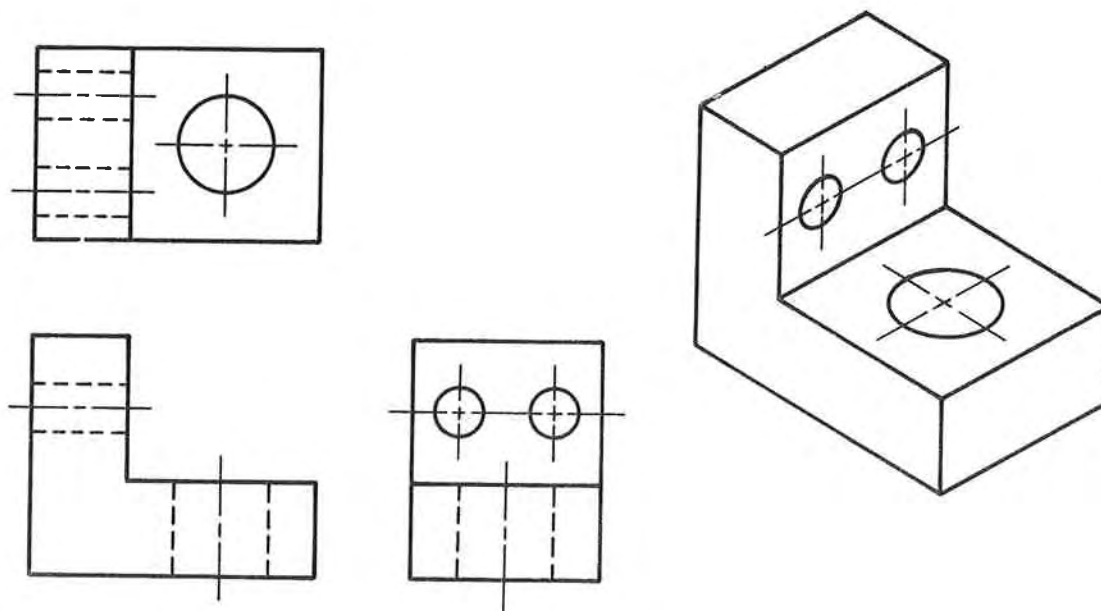


Figure 5-10 An example of an object whose orthographic views contain hidden lines.

5-4 INCLINED SURFACES

Figure 5-11 shows an object that has an inclined surface 1-2-3-4. An *inclined surface* is one that is parallel to one, but not both, principal plane lines. Note that the top and right side views are approximately the same as those shown for the example in Figure 5-1 and note the incline of plane 1-2-3-4 may only be seen in the front view. This kind of visual ambiguity is unavoidable in orthographic views, and as shown here it emphasizes the importance of using all orthographic views together to form a final solution to the problem.

Figures 5-12 and 5-13 are other sample problems which include inclined surfaces.

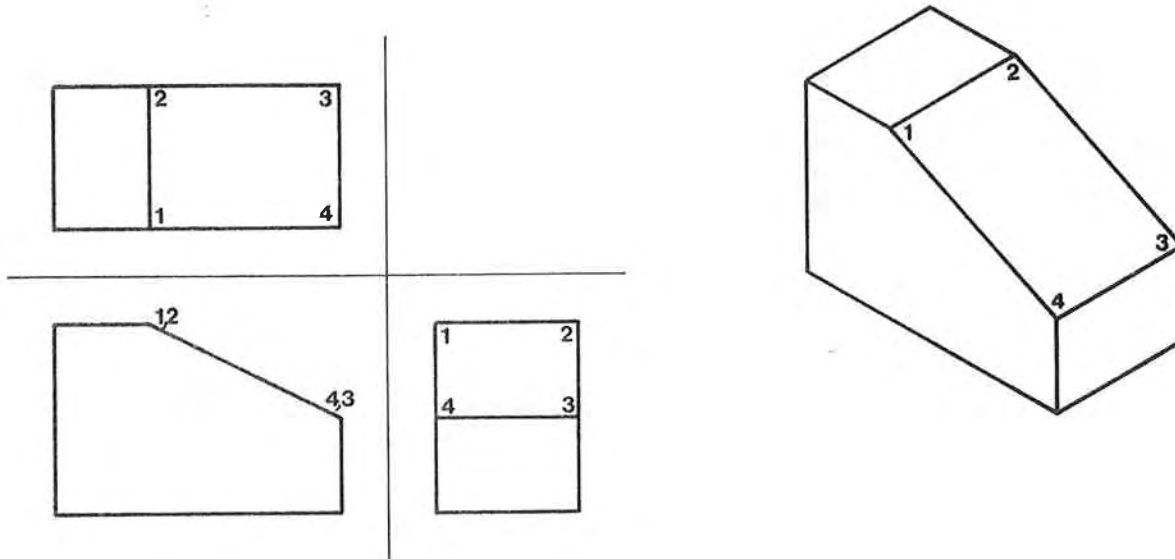


Figure 5-11 An object with an inclined surface 1-2-3-4.

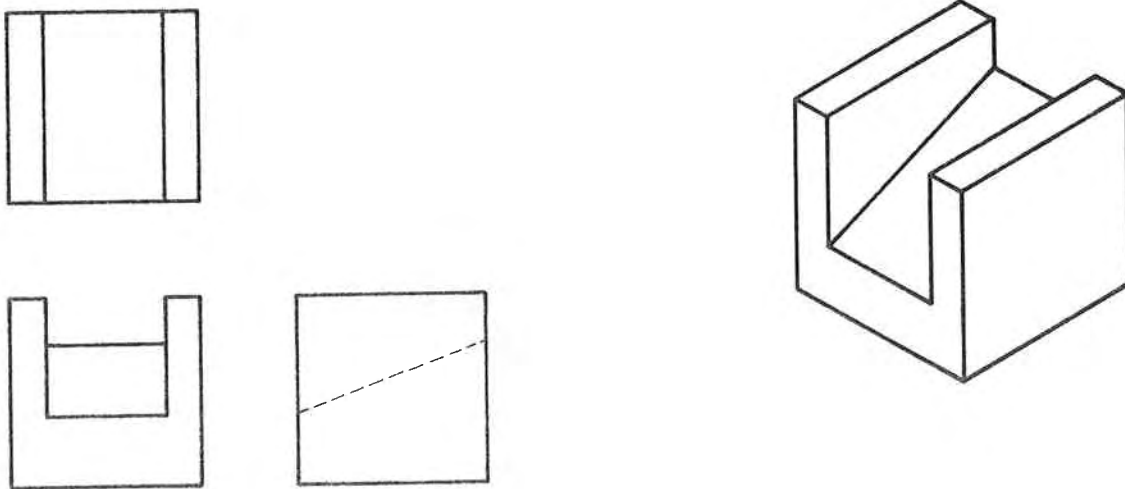


Figure 5-12 An object with an inclined surface.

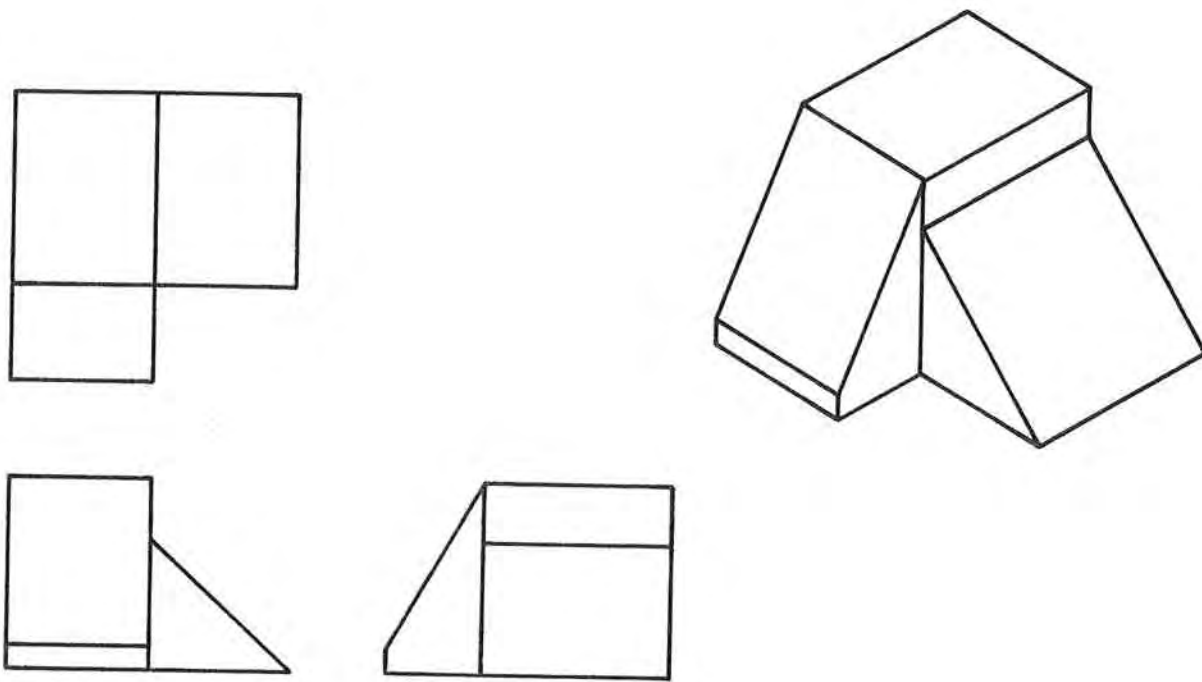


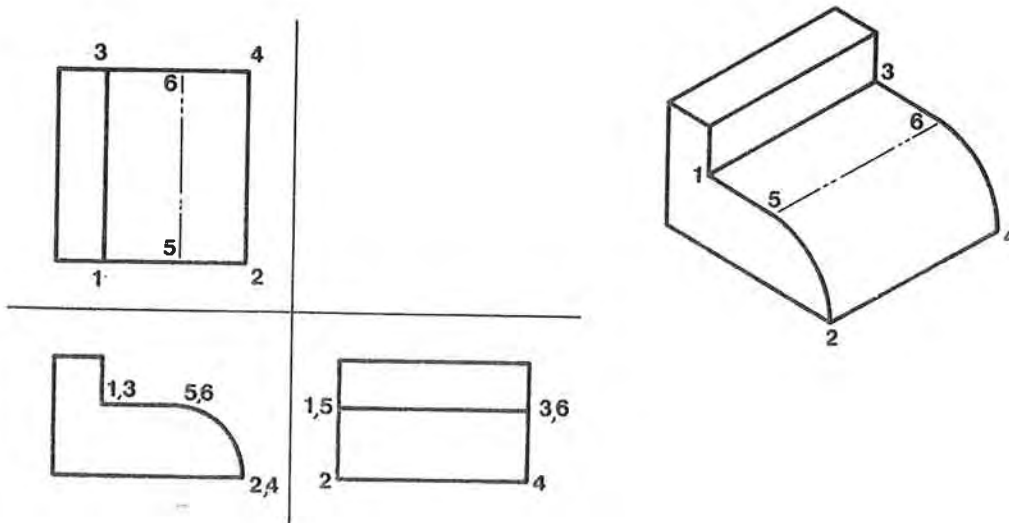
Figure 5-13 An object with inclined surfaces.

5-5 CURVED SURFACES

Figure 5-14 shows an object that has a curved surface. A *curved surface* is one that appears as a part of a circle (an arc of constant radius) in one of the orthographic views. Curved surfaces are similar to slanted surfaces in that they tend to generate ambiguous orthographic views.

A unique characteristic of curved surfaces is the tangency line. Surface 1-2-3-4 in Figure 5-14 contains a tangency line 5-6 represented by a phantom line. A tangency line represents the location at which the round portion of surface 1-2-3-4 flairs into (becomes tangent to) the flat horizontal portion. Because there is no edge here, a

Figure 5-14 An object with a curved surface.



line would not be drawn in any of the views. Figure 5-15 shows an object in which the curved surface does form an edge with the lines labeled 7-8 and 9-10; thus, it requires an object line. Without exception, you may always draw a visible line when the round surface forms an edge with the other surfaces.

You cannot, however, always omit a line if a physical edge does not appear. Figure 5-16 gives two examples of objects that require lines in their orthographic views even though no edges actually exist on the object. Figure 5-17 is another example of an object that does not require a line.

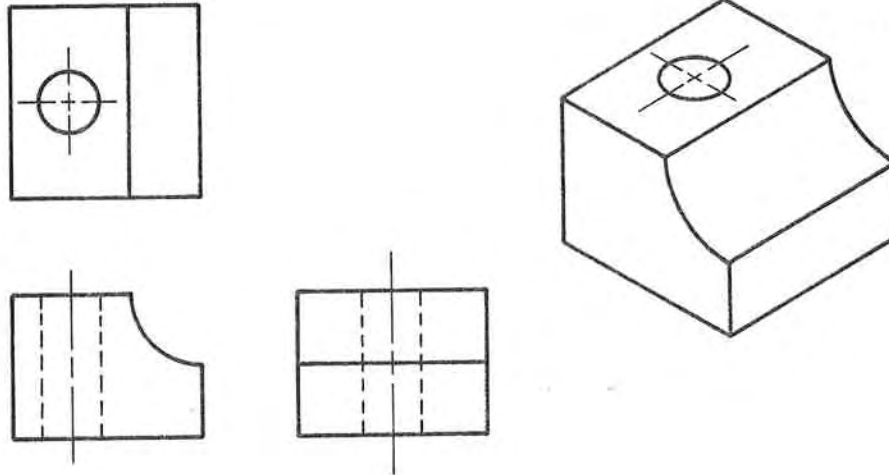
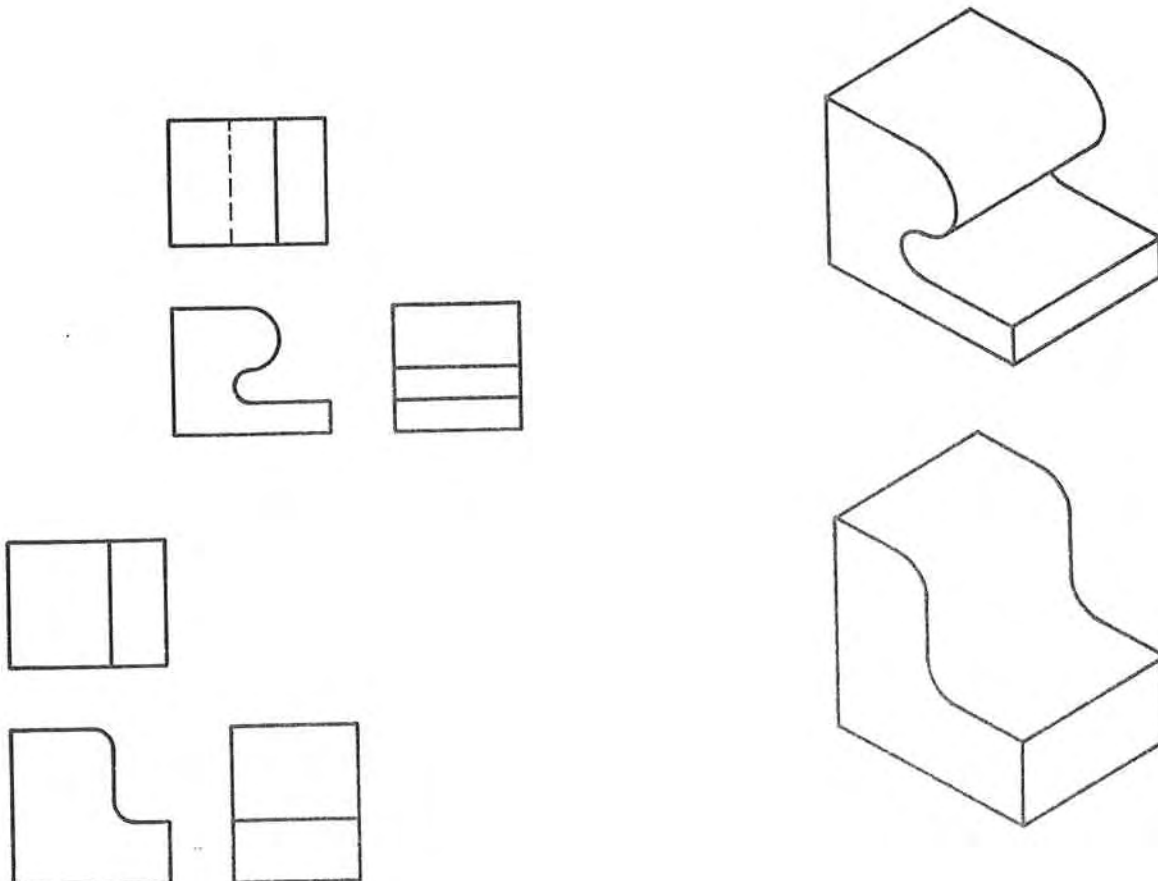


Figure 5-15 An object with a curved surface.

Figure 5-16 Two objects with curved surfaces.



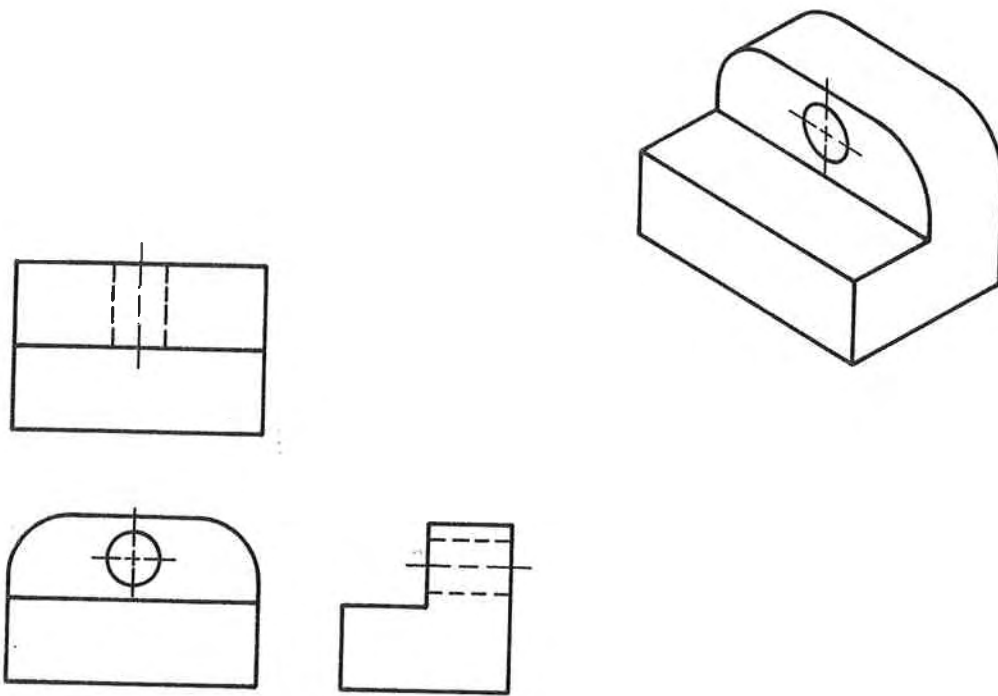


Figure 5-17 An object with curved surfaces.

As a rule, if a curve changes direction (goes from concave to convex, or vice versa) such that any part of it becomes parallel to one of the principal plane lines, a line is required.

5-6 SKETCHING

Before a draftsman begins the actual drawing of a new assignment, he will usually make a sketch of the object involved. He then studies the sketch and tries to identify any problems that could arise when he makes his drawing. If any problems are found, he reworks his sketch until the problems are solved and his sketch has become a clear, well-understood picture of his future drawing. A draftsman takes the time to create good sketches because it is much easier to correct freehand sketches than to correct finished drawings. The time he spends sketching is more than regained when he creates his drawing because he avoids the problems he found and corrected while he was making his sketches.

Of course, learning to sketch is easier for those who have artistic ability, but anyone can learn to sketch. The following hints are offered to make it easier for you to learn to sketch:

To make sketches of orthographic views (see Figure 5-18):

SOLUTION:

1. Use grid paper, graph paper, quadrapads, and so on. This kind of paper will help you to establish an approximate scale and thereby keep your sketches fairly proportioned. It will also help you to keep your lines straight.

GIVEN: An object.

PROBLEM: Sketch the front, top and right side views.

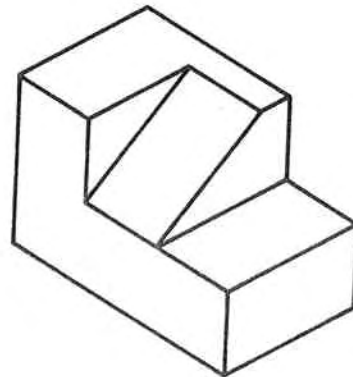


Figure 5-18(a)

2. Lightly sketch the overall shape of the object, as would be seen in the three basic orthographic views.

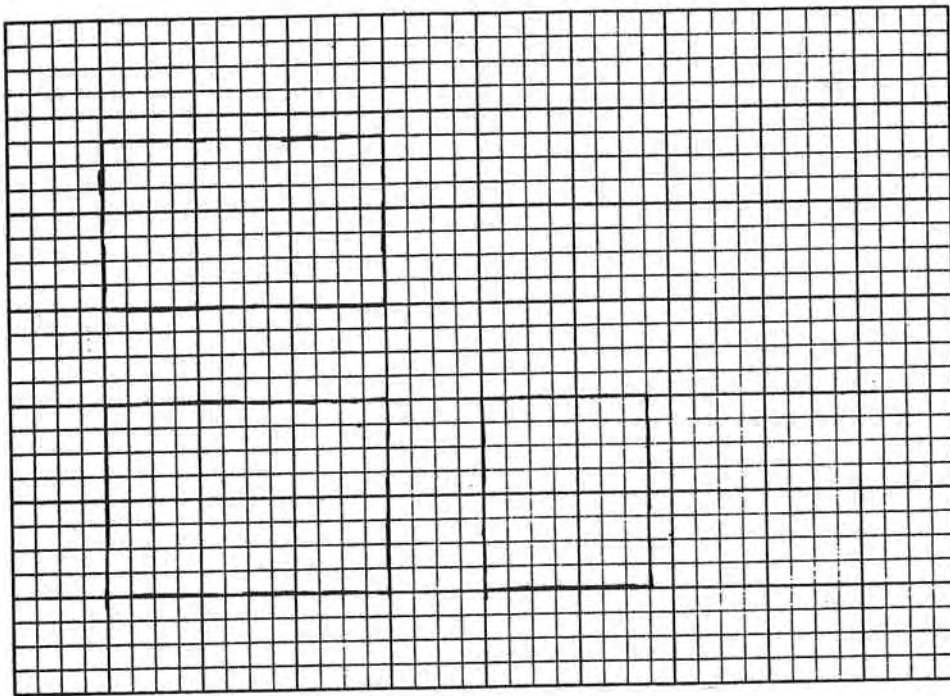


Figure 5-18(b)

3. Lightly sketch in the specific details of the object.

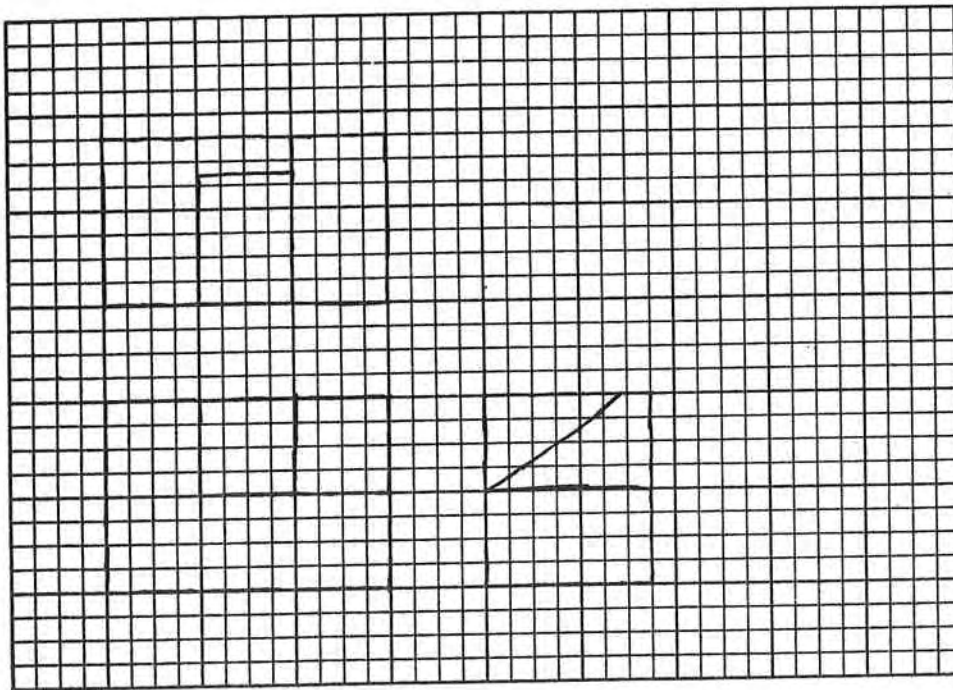


Figure 5-18(c)

- When the desired shape is completed, darken in the important lines by using heavy, bold strokes.

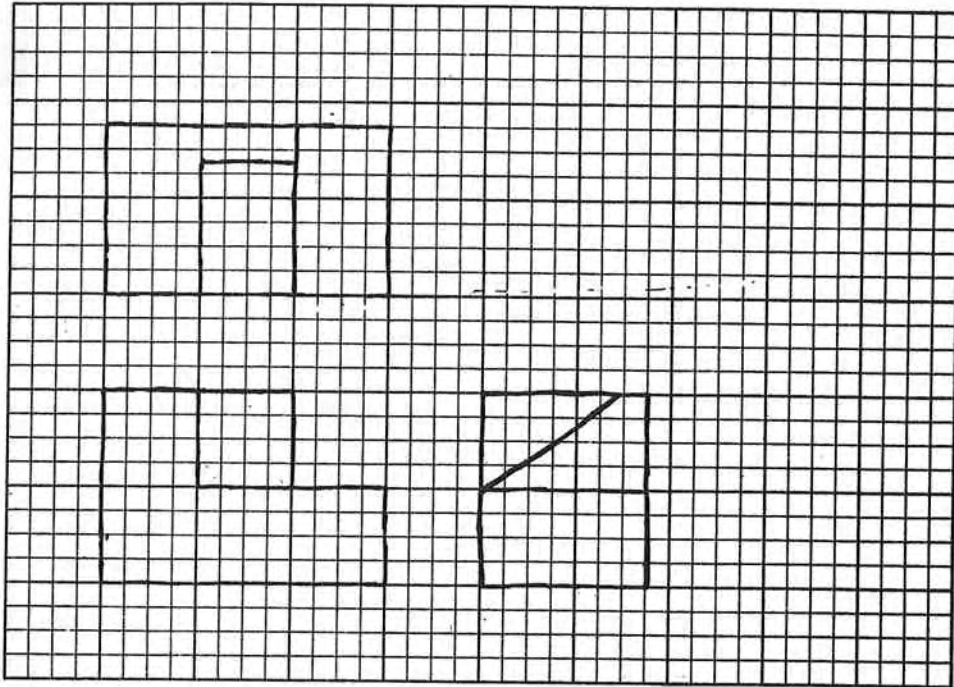


Figure 5-18(d)

To make a picture (isometric) sketch (see Figure 5-19):

GIVEN: Three views of an object.

PROBLEM: Sketch an isometric picture of the object.

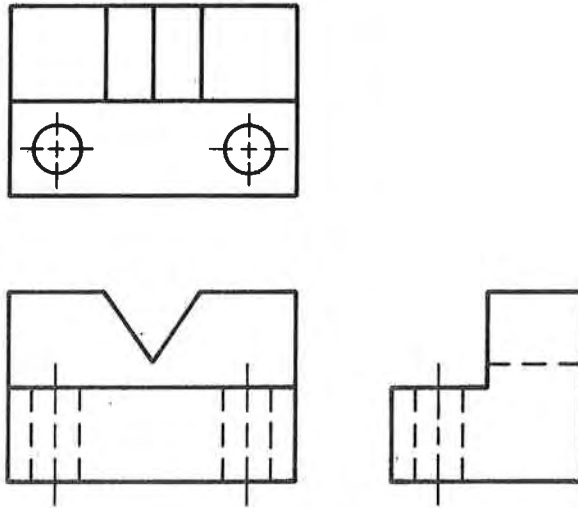
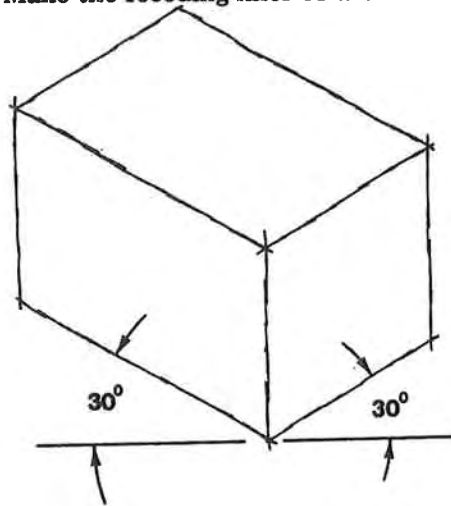


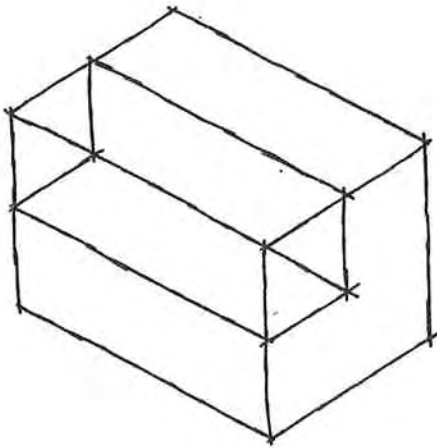
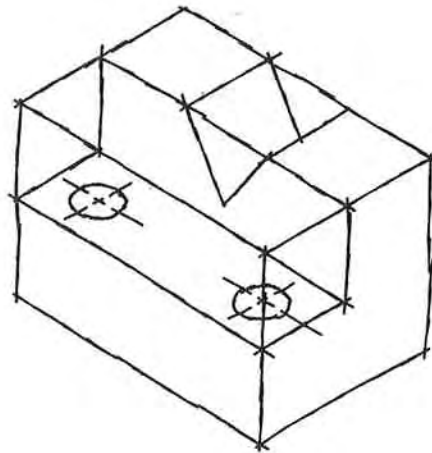
Figure 5-19(a)

SOLUTION:

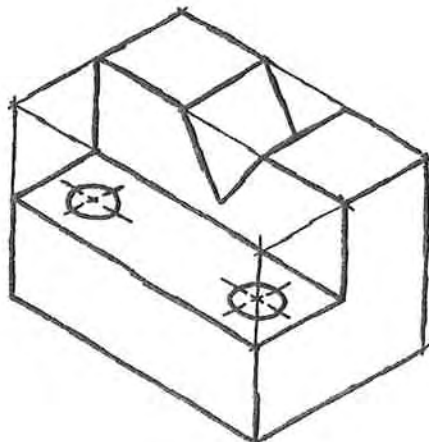
1. Draw a block whose length, width, and height are of approximately the same proportions as those of the object to be sketched. Make the receding lines of the box 30° .

**Figure 5-19(b)**

2. Lightly sketch in the specific details of the object.

**Figure 5-19(c)****Figure 5-19(d)**

3. When the desired shape is completed, darken in the important lines by using heavy, bold strokes.

**Figure 5-19(e)**

5-7 VISUALIZATION TECHNIQUES

Visualizing an object in three dimensions, given only the orthographic views, has always been a problem for draftsmen. Drawing and sketching experience and good depth perception help, but there are always those problems that just "can't be seen." Two techniques used by draftsmen to help visualize difficult problems are model building and surface coloring.

Models offer the best visualization aids because they themselves are three-dimensional objects, but models are usually expensive and time-consuming to build. Figure 5-20 shows examples of some well-constructed models. To overcome the expense and time constraints, some draftsmen make models out of children's modeling clay. Figure 5-20 shows an example. Clay models are not meant to be exact-scaled duplications, but rather approximate representations made to help a draftsman visualize the object being drawn; thus, the quality of clay models may vary according to personal requirements and situations.

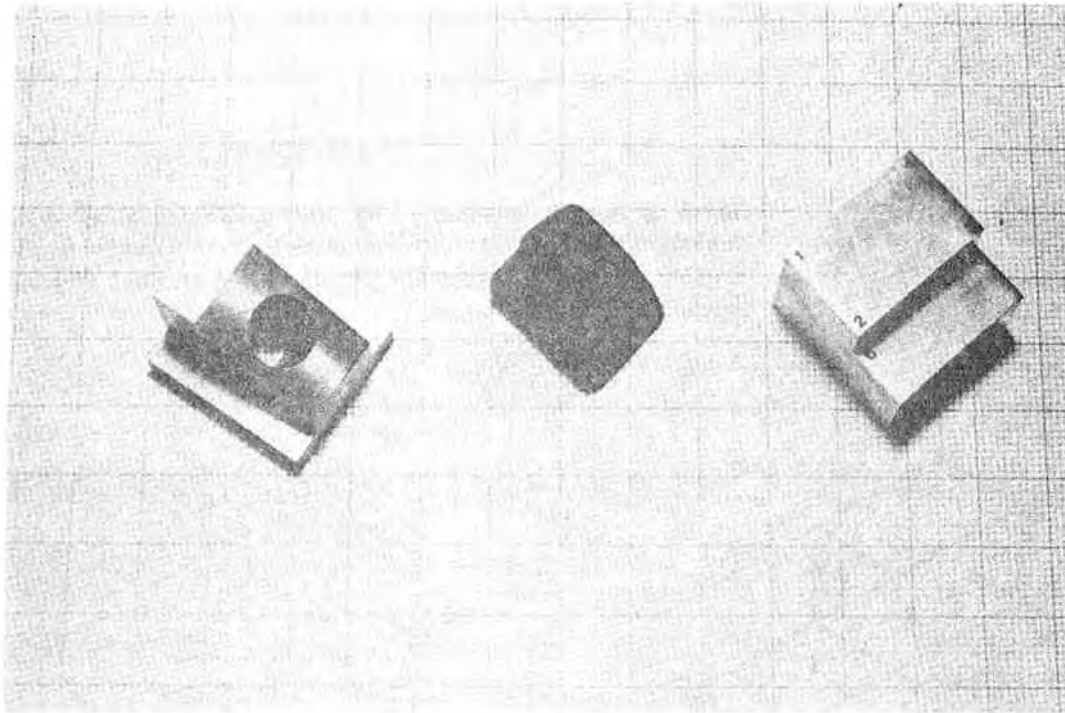


Figure 5-20 Models used to help visualize. The model in the center is made from children's modeling clay.

Figure 5-21 shows an example of surface coloring. Draftsmen generally color by using different colors (red, blue, etc.), but the example in Figure 5-21 was done by using various shades of gray. By coloring a surface with the same color in all the different views, the surface may be more easily identified in the various views and therefore more easily visualized.

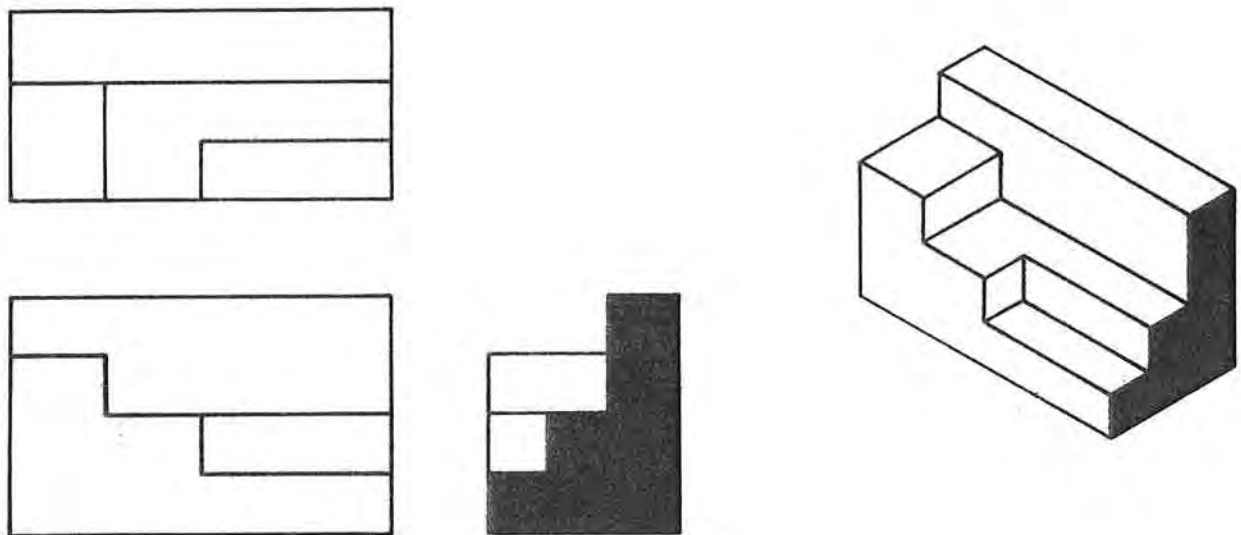
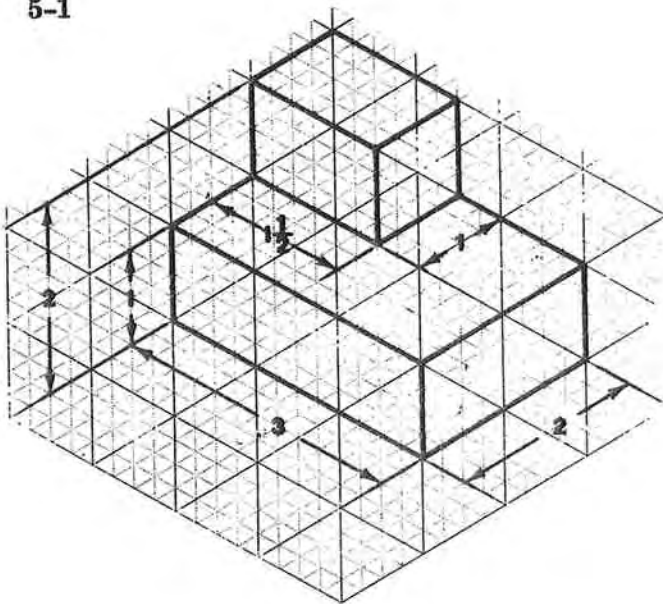


Figure 5-21 An example of surface shading.

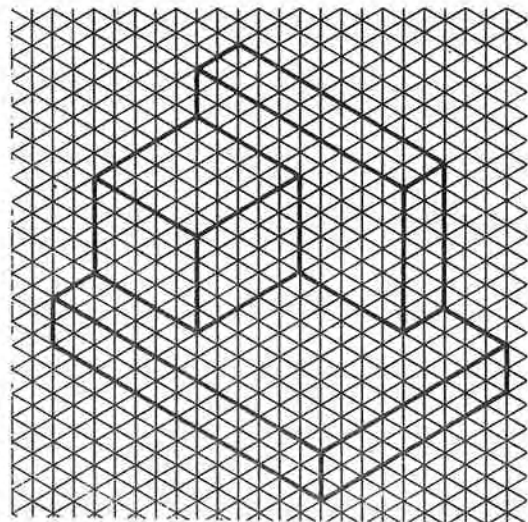
PROBLEMS

Draw or sketch, as assigned by your instructor, three views (front, top, and right side) of the following objects. Each triangle in the grid pattern is 0.20 on a side, except for problems 5-1 and 5-3 which-use a 0.25 on a side grid pattern.

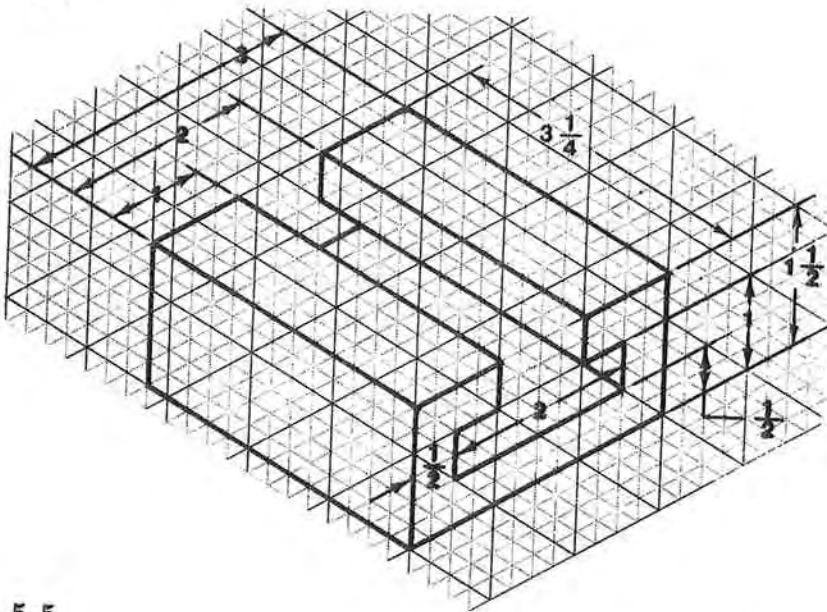
5-1



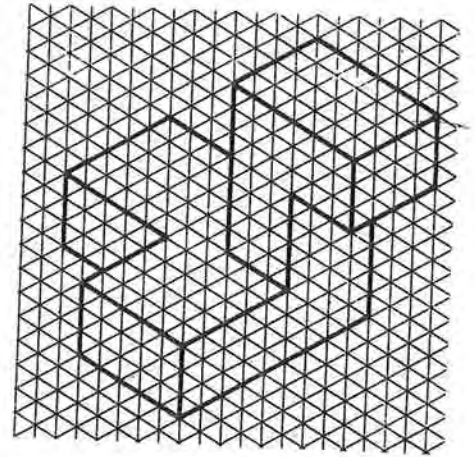
5-2



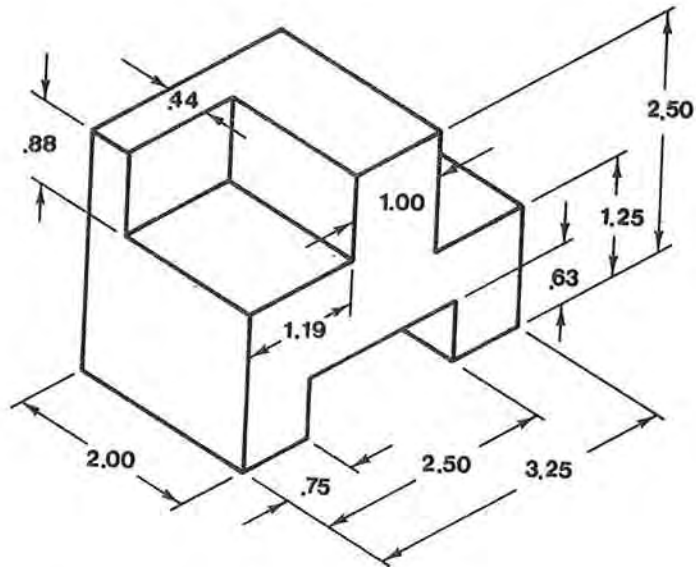
5-3



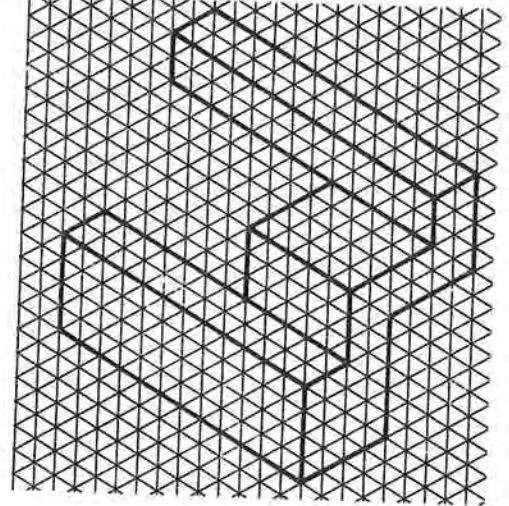
5-4



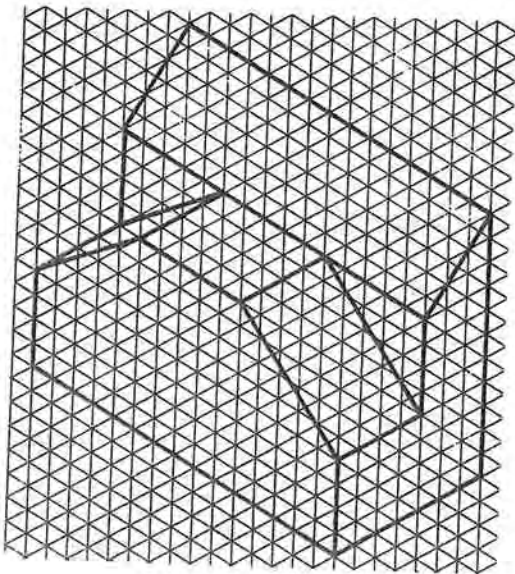
5-5



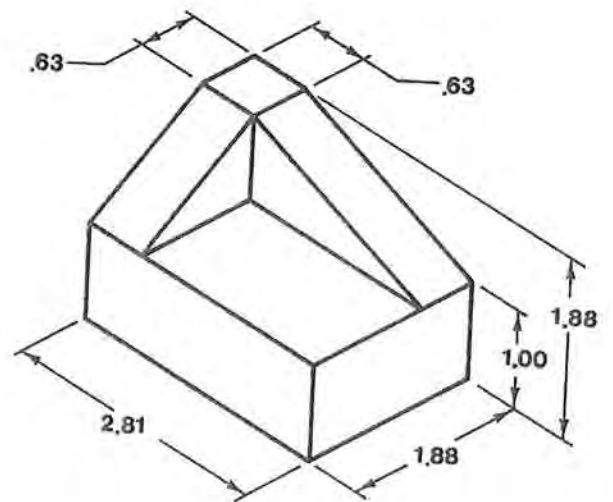
5-6



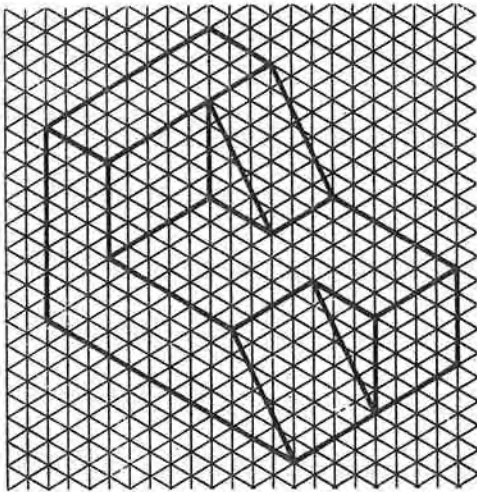
5-7



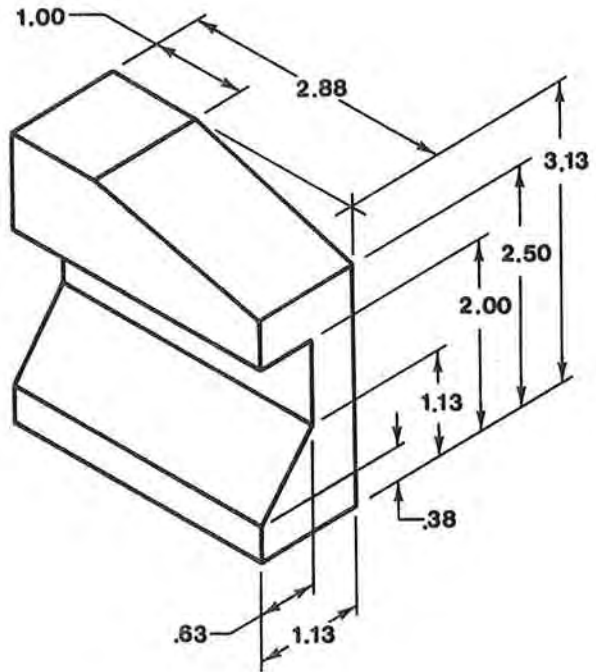
5-8



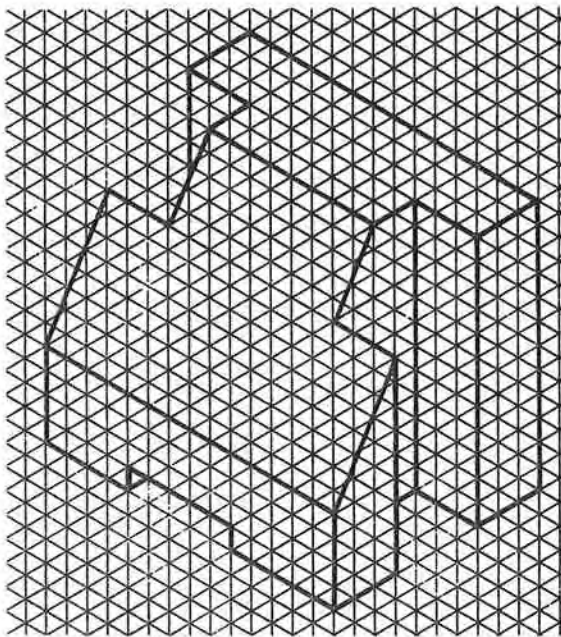
5-9



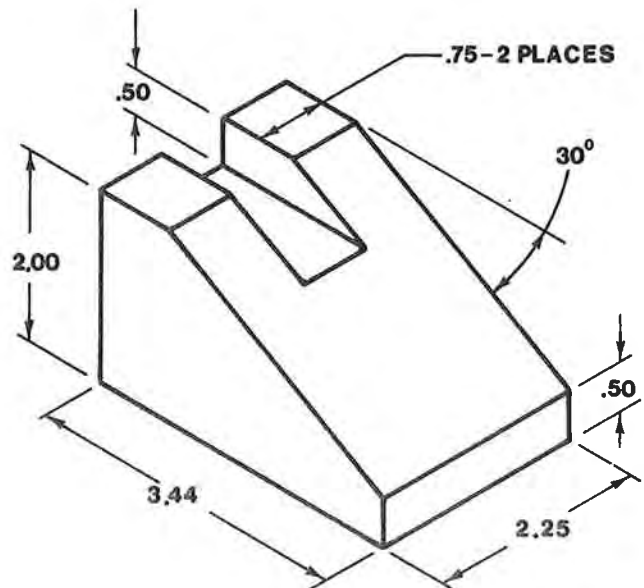
5-10



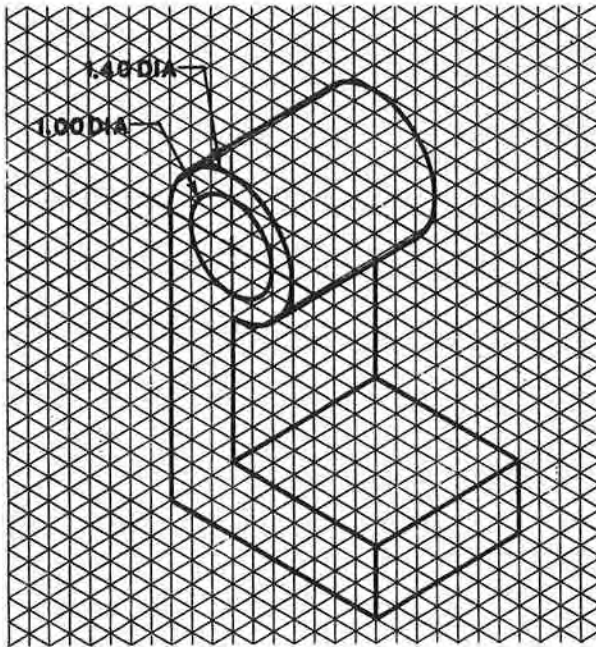
5-11



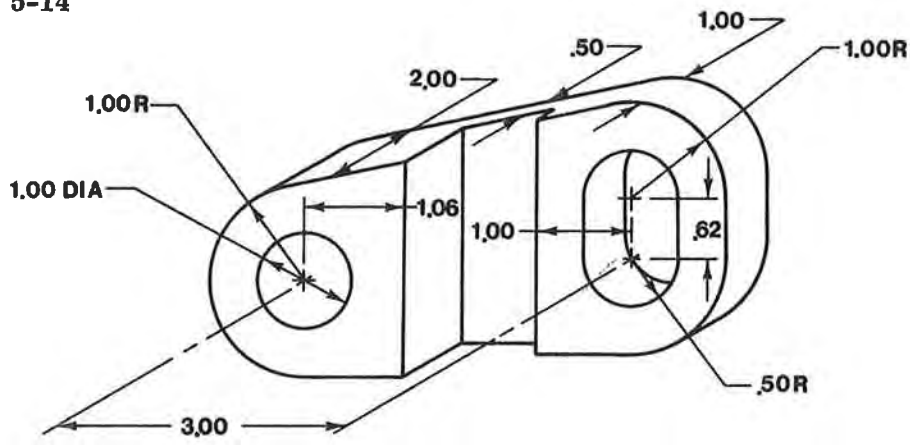
5-12



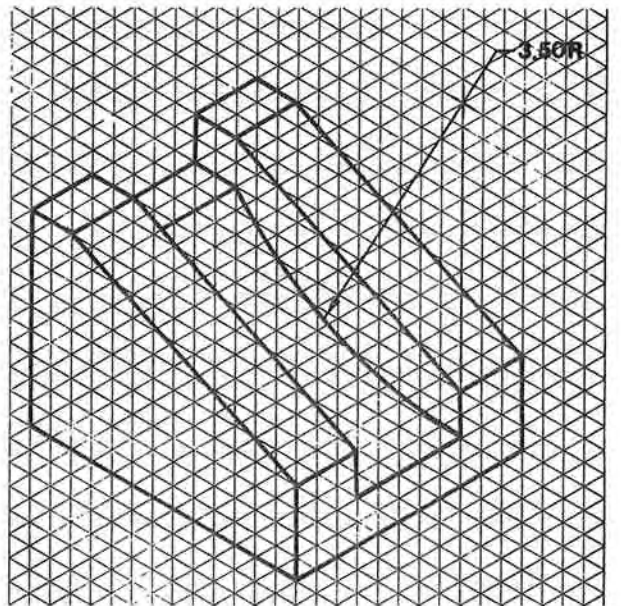
5-13



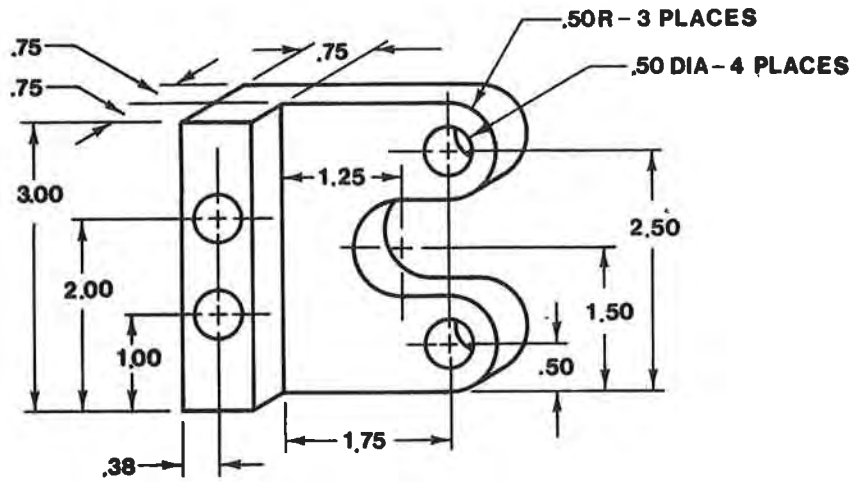
5-14



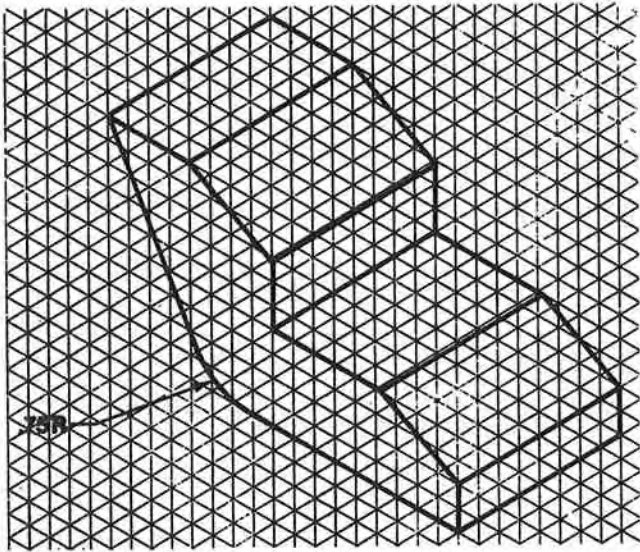
5-15



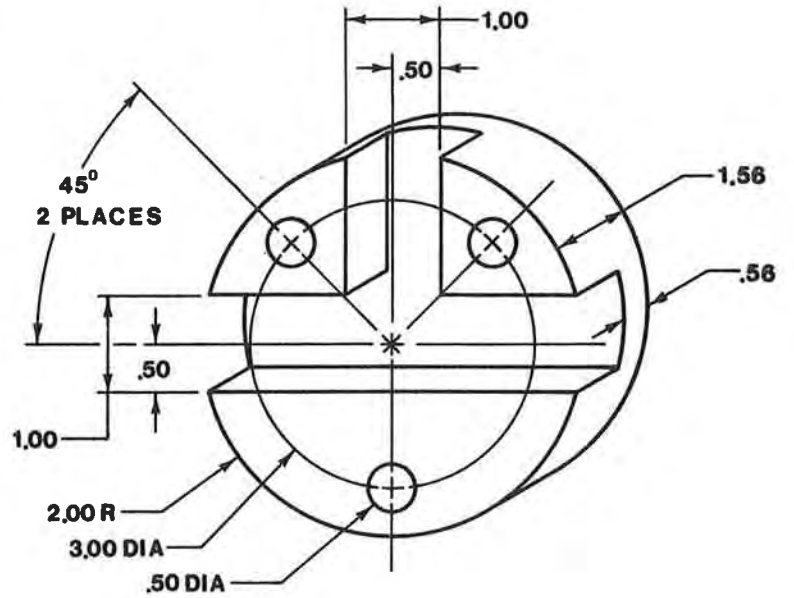
5-16



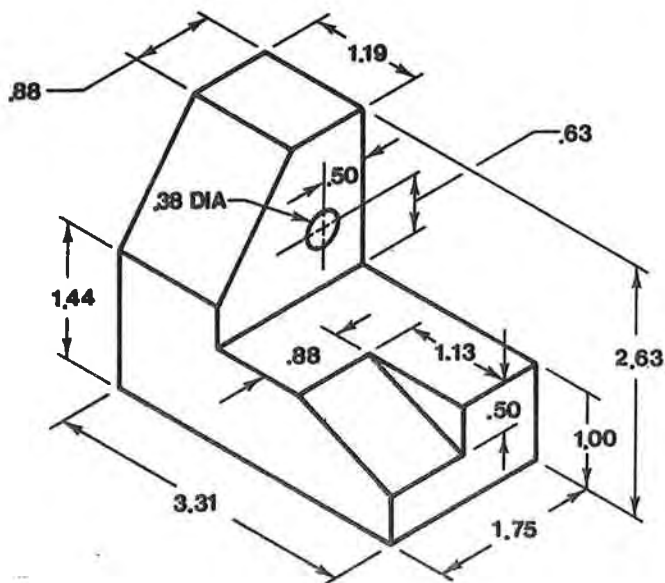
5-17



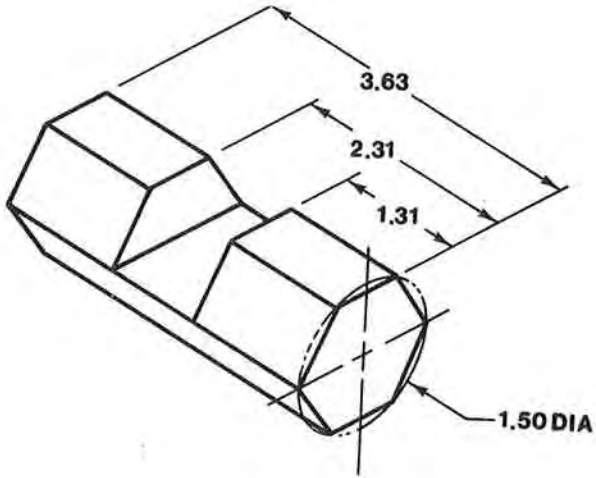
5-18



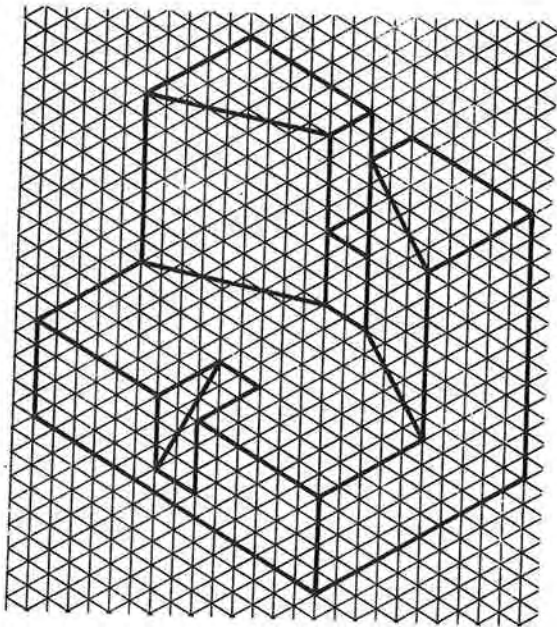
5-19



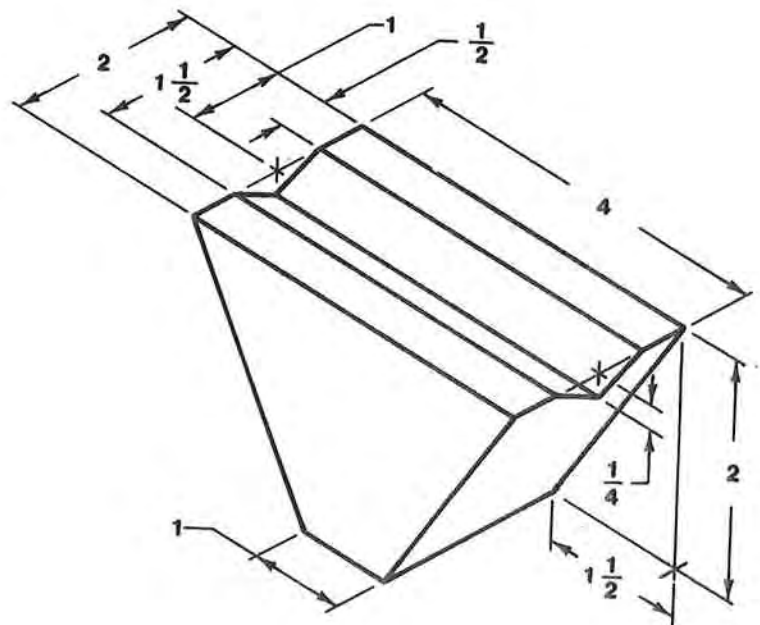
5-20



5-21



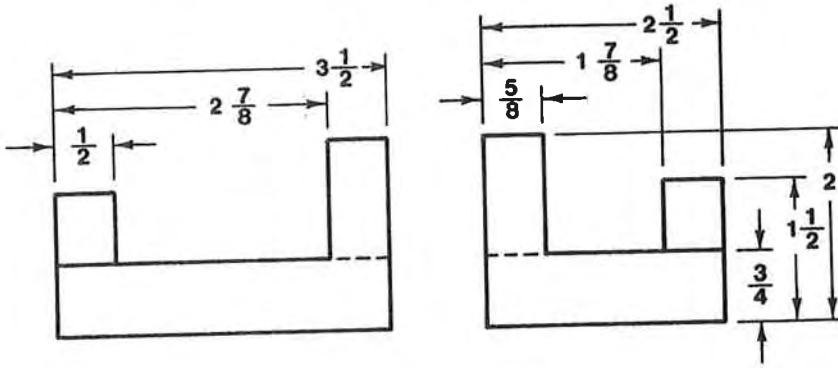
5-22



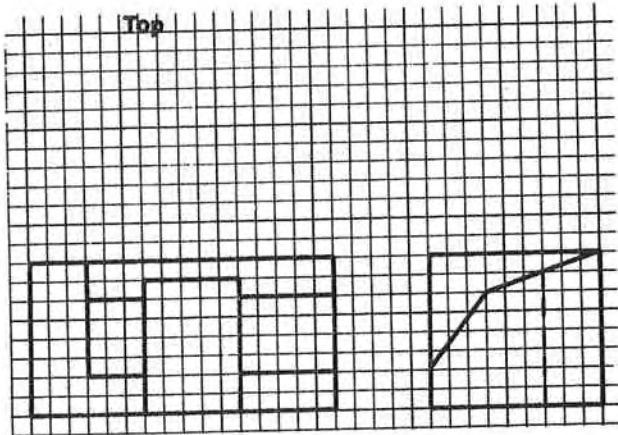
In the following, redraw the two given views and add the third as required. If assigned, prepare a freehand three-dimensional sketch of the object. Each square on the grid pattern is 0.20 per side.

5-23

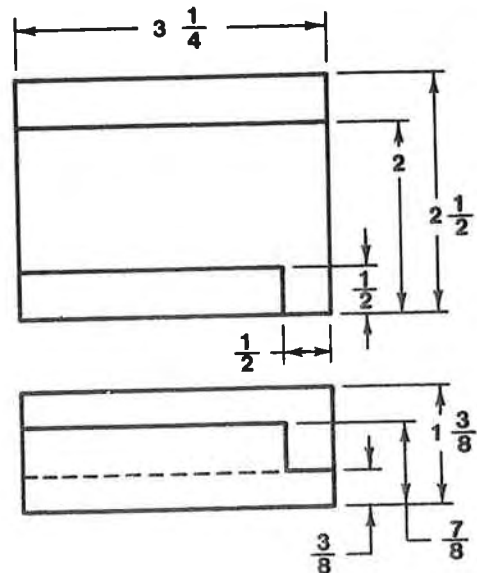
Top



5-24

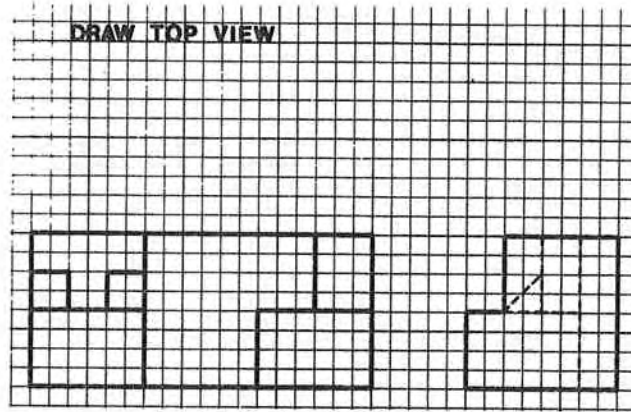


5-25

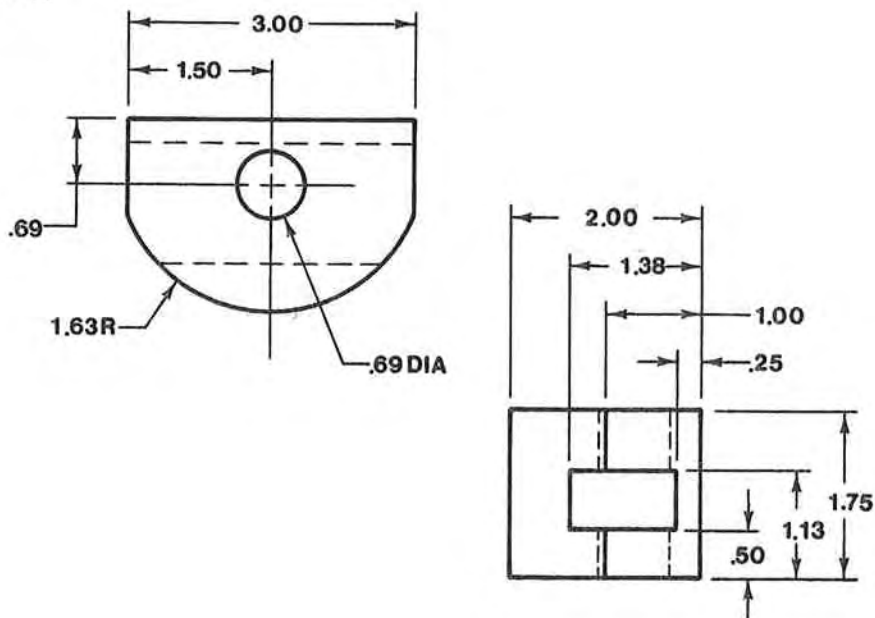


RS

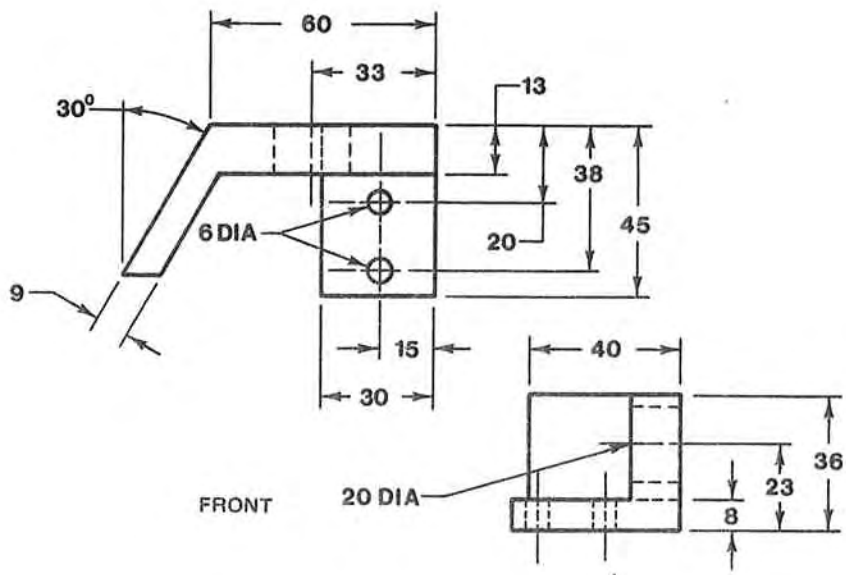
5-26 Problem created by Steve Gertz.



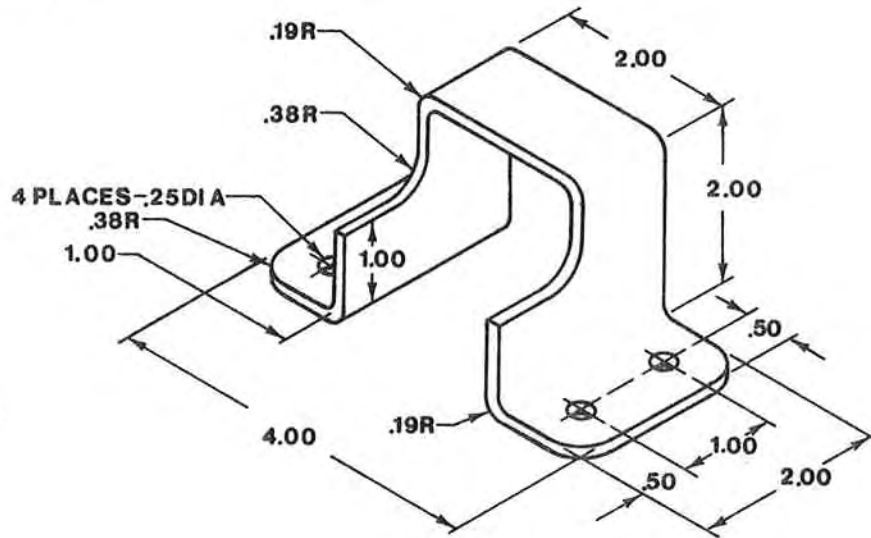
5-27



5-28 Dimensions are in millimeters.

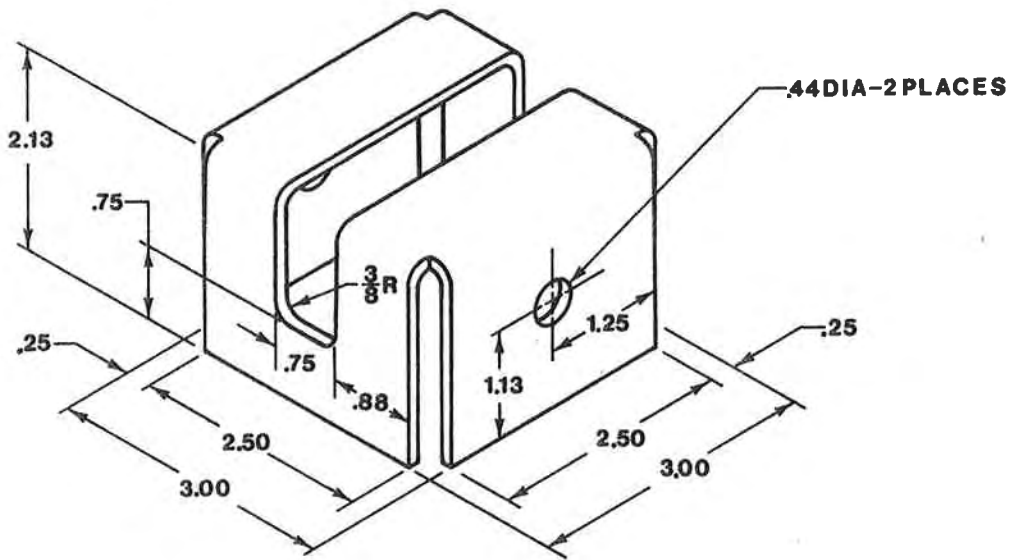


5-29



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5-30



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ALL INSIDE BEND RADII $\frac{3}{16}$

6-1 INTRODUCTION

This chapter explains and illustrates dimensioning and tolerancing. The picture portion of a drawing defines the shape of the object; the dimensions define the size; and the tolerances define the amount of variance permitted in the size. All three pieces of information are needed to form a clear, understandable, manufacturable drawing.

To help you gain an understanding of the relationships between size, shape, and tolerance, look at Figure 6-1. What is the height of the car? Is it full size or is it merely a model? We may get some approximation of the height by comparing the height of the car with the height of the girl. If we use the girl for our scale, we may say that the car is a little less than one-half a girl height. Here the picture gives us shape and the girl gives us an approximate size—but what about the tolerance? How tall is the girl? Is she wearing high-heeled shoes or is she standing on a box? For a more accurate answer, we need a more accurate scale.

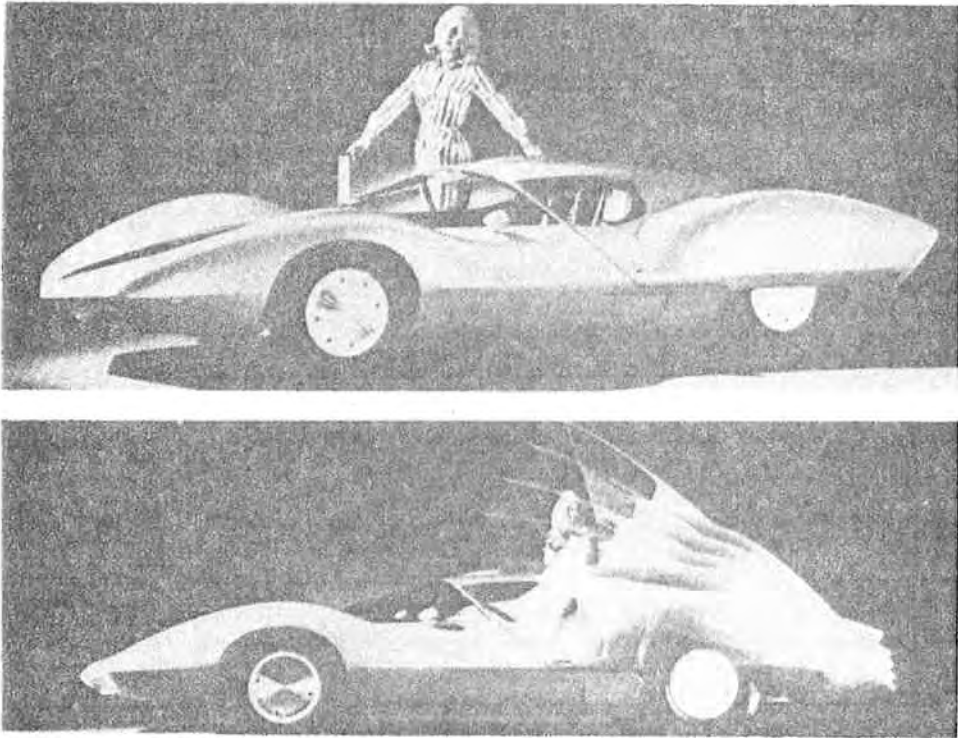


Figure 6-1 How high is the car? Photograph courtesy of General Motors Corp.

The post beside the girl has been calibrated into 6 inches-intervals. Further, it has been cut off and labeled 35½ inches. If the post is our scale and the 35½ inches-label is our dimension, we are assured of a more accurate measurement. As before, since the accuracy of our final measurement depends on the accuracy of our scale, we would pick a scale that satisfies our specific tolerance requirement. If we just want to know about how high the car is, the girl would be sufficient. If we want to know within an inch, the post dimension would probably be acceptable. If we want a more accurate answer, we would have to use a more accurate scale.

As you read through this chapter, remember that dimensions are the most important part of any drawing. Always try to dimension your drawings clearly, concisely, and in an easily understandable manner.

6-2 EXTENSION LINES, DIMENSION LINES, LEADER LINES, AND ARROWHEADS

Dimensions are placed on a drawing by using a system of extension lines, dimension lines, leader lines, and arrowheads. Figure 6-2 illustrates how these various kinds of lines are used for dimensioning. The lines are defined as follows:

EXTENSION LINES: used to indicate the extension of an edge or point to a location outside the part outline.*

DIMENSION LINES: show the direction and extent of a dimension.*

LEADER LINES: used to direct an expression, in note form, to the intended place on the drawing. The leader line should terminate in an arrowhead or dot.*

ARROWHEADS: used to indicate the ends of dimension lines and the ends of some leader lines.* Arrowheads are drawn as shown in Figure 6-3.

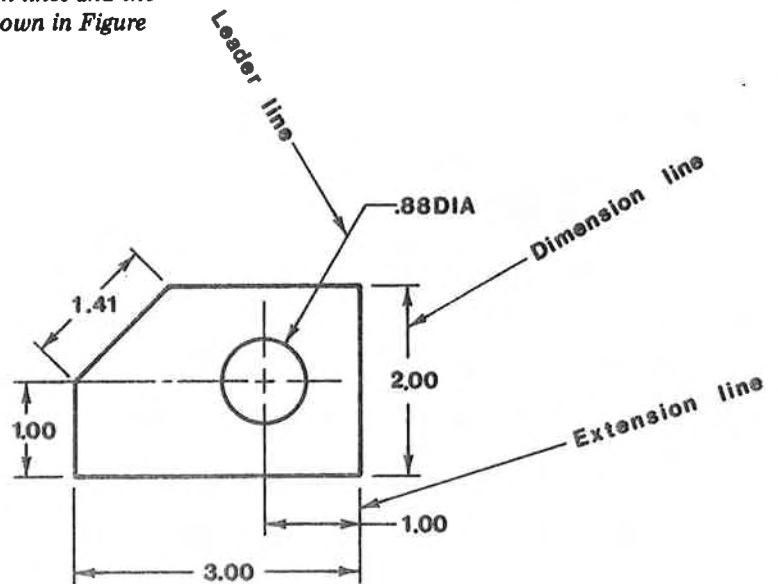


Figure 6-2 Extension, dimension and leader lines.

*Extracted from *American Drafting Standards; Line Conventions, Sectioning, and Lettering* (ASA Y14-2-1957) with the permission of the publisher, The American Society of Mechanical Engineers, 29 West 39 St., New York, N.Y.

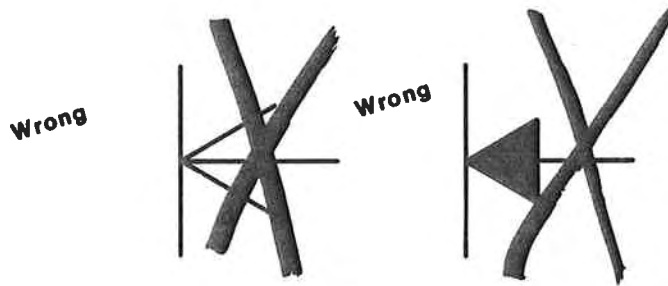
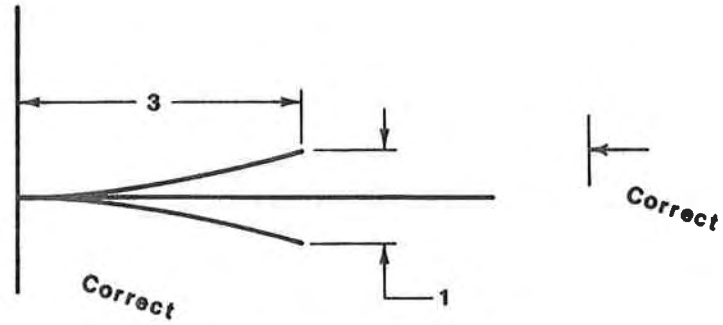
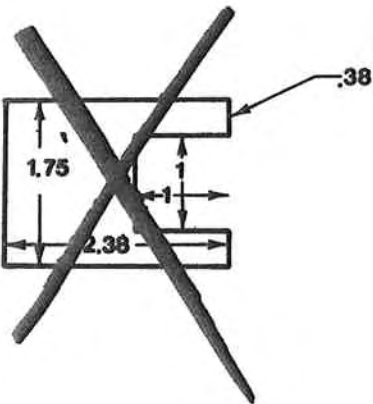


Figure 6-3 Arrowheads.

6-3 LOCATING AND PRESENTING DIMENSIONS



How do you locate and present dimensions on a drawing so that they may be easily and unmistakably understood? Unfortunately, there is no one answer to this question. Each drawing must be dimensioned according to its individual requirements, and what is acceptable in one situation may not be acceptable in another situation. Learning how to locate and how to present dimensions depends a great deal on drawing experience, but there are some general guidelines that may be followed. These guidelines are presented below and are illustrated in Figure 6-4.

6-4(a). Dimension by using extension, dimension, and leader lines placed neatly around the various views of the object. Place dimensions so that your reader will have no difficulty understanding which surface or which edge you are defining.

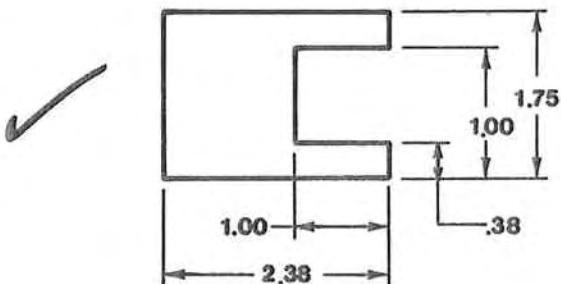


Figure 6-4(a)

6-4(b). Be sure that the size of the object is completely defined and that no surfaces or edges are left out.

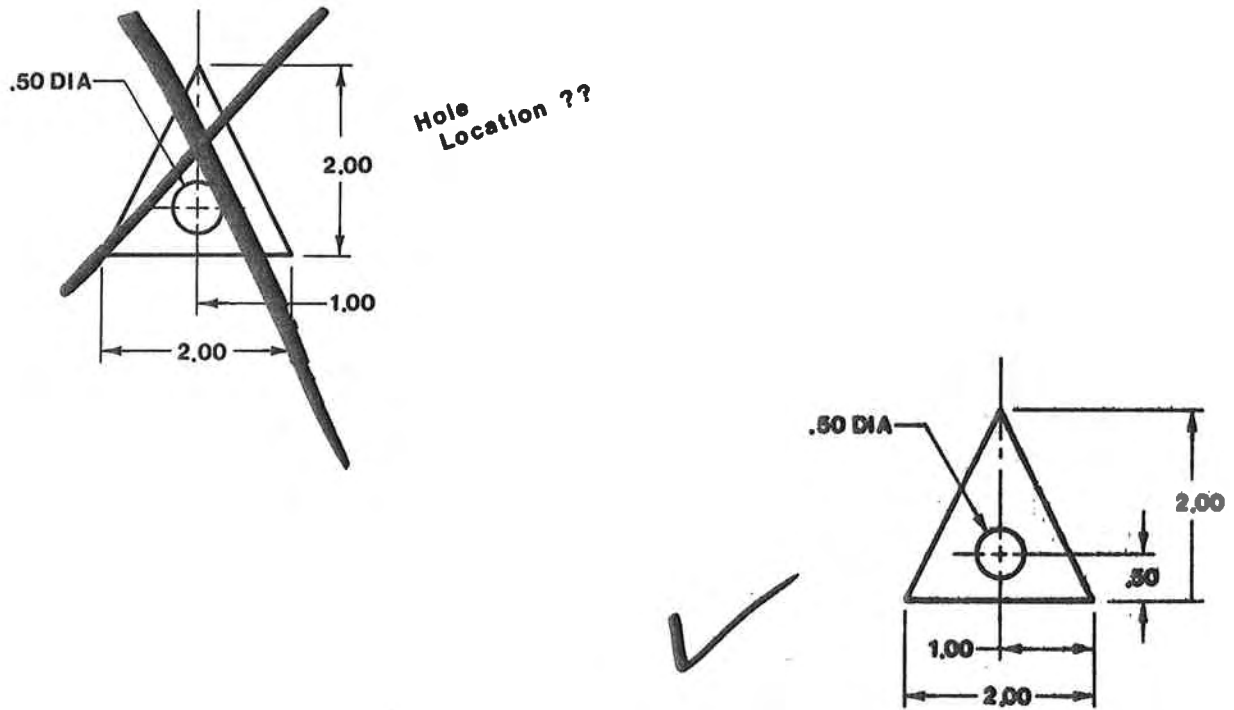


Figure 6-4(b)

6-4(c). Always keep dimensions at one constant height. 1/8 or 3/16 is the generally accepted height, although a larger height may be used in some cases (title blocks, page numbers, and so on). Letters and numbers should never be less than 1/8 in height.

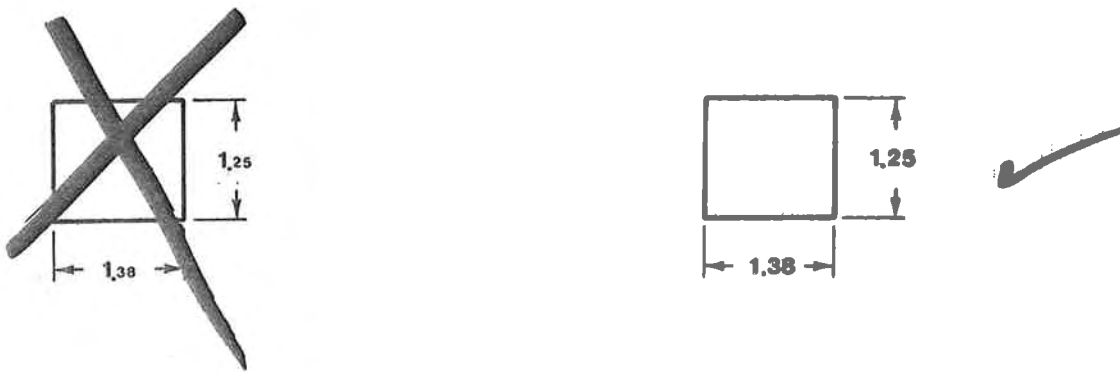


Figure 6-4(c)

- 6-4(d). Do not squeeze dimensions into small spaces and angles. Undersized dimensions are difficult to read.

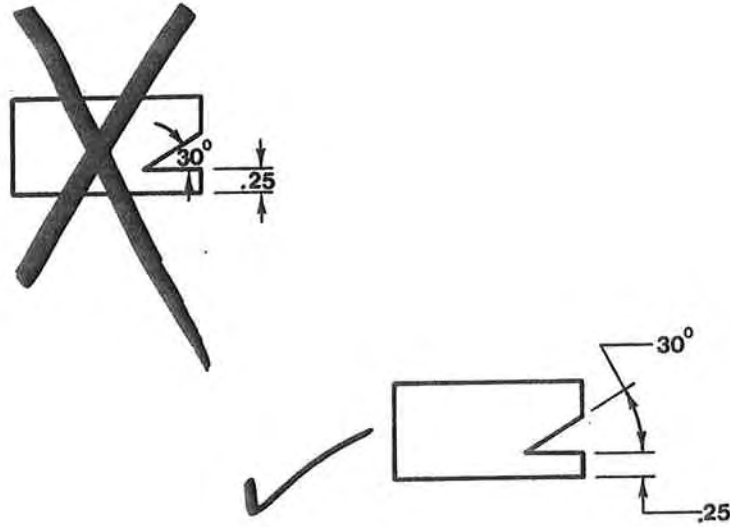


Figure 6-4(d)

- 6-4(e). Unless it is absolutely necessary, do not put any dimensions within the visible lines of the object being defined. You will never know when or how a drawing may have to be changed. It is important that you realize that drawing changes are not necessarily the result of errors. Customer requirements may change, designs may be modified, a new machine may be added to your company's manufacturing process, and so on. Any one of these reasons, and many more, could necessitate drawing changes.

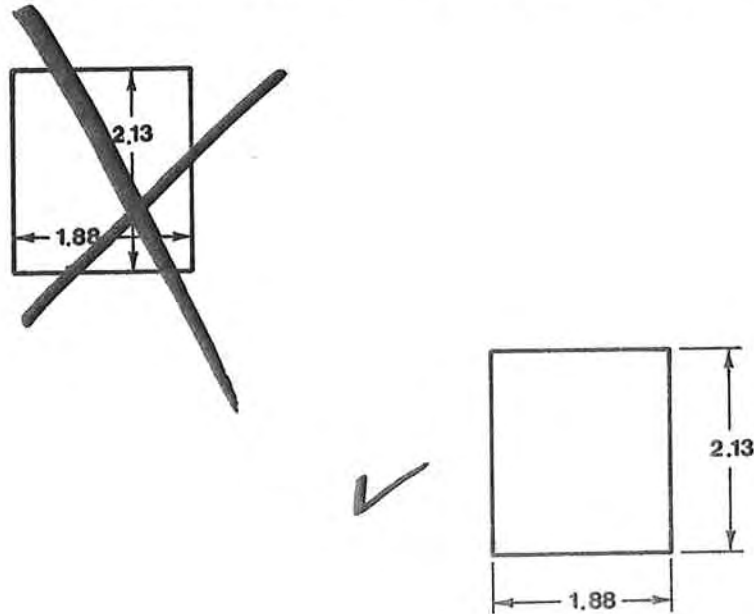


Figure 6-4(e)

6-4(f). Do not overdimension. Too many dimensions are as confusing as too few dimensions. A common mistake is to double dimension, that is, to dimension the same distance twice on the same drawing. One dimension per distance is sufficient.

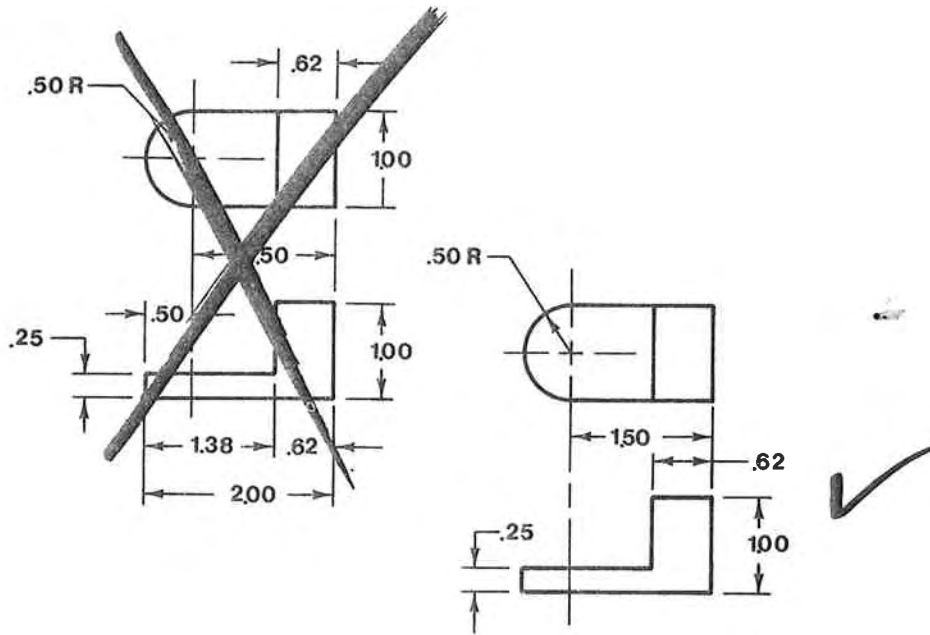


Figure 6-4(f)

6-4(g). Do not place dimensions too close to the object to be defined. A dimension line should never be closer than 3/8 to the object.

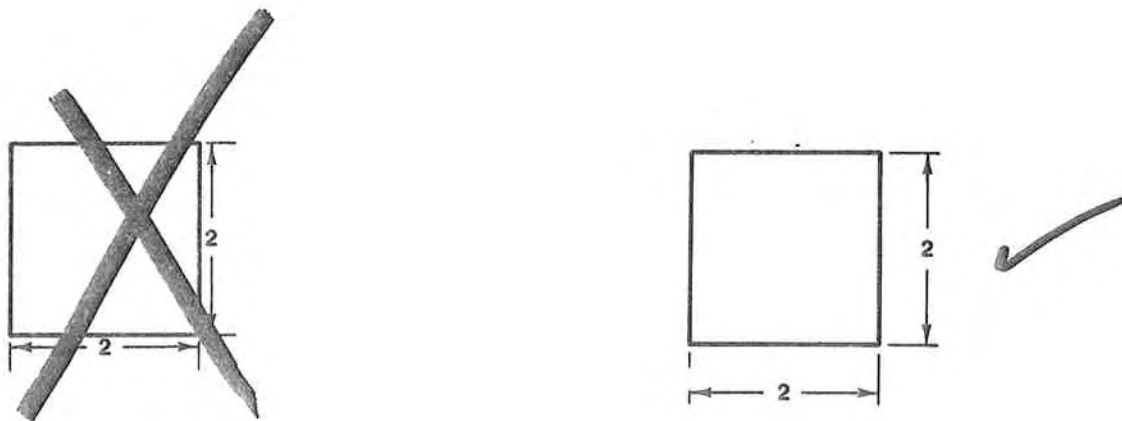


Figure 6-4(g)

6-4(h). Leader lines should all be at the same angle. This will tend to give the drawing a more organized appearance.

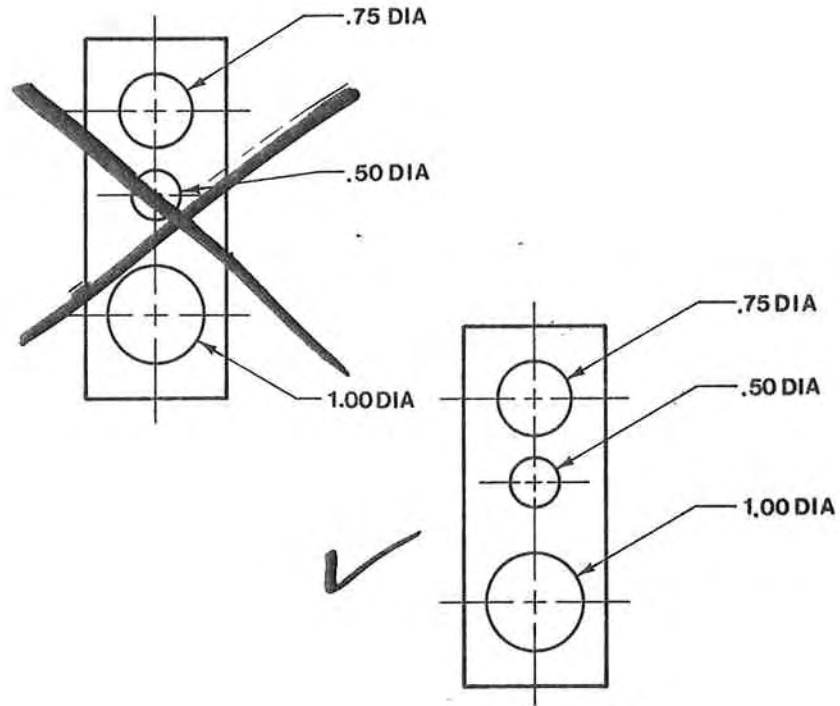


Figure 6-4(h)

6-4(i). Space dimensions evenly. This not only gives the drawing a well-organized appearance, but it also makes the dimensions much easier to read.

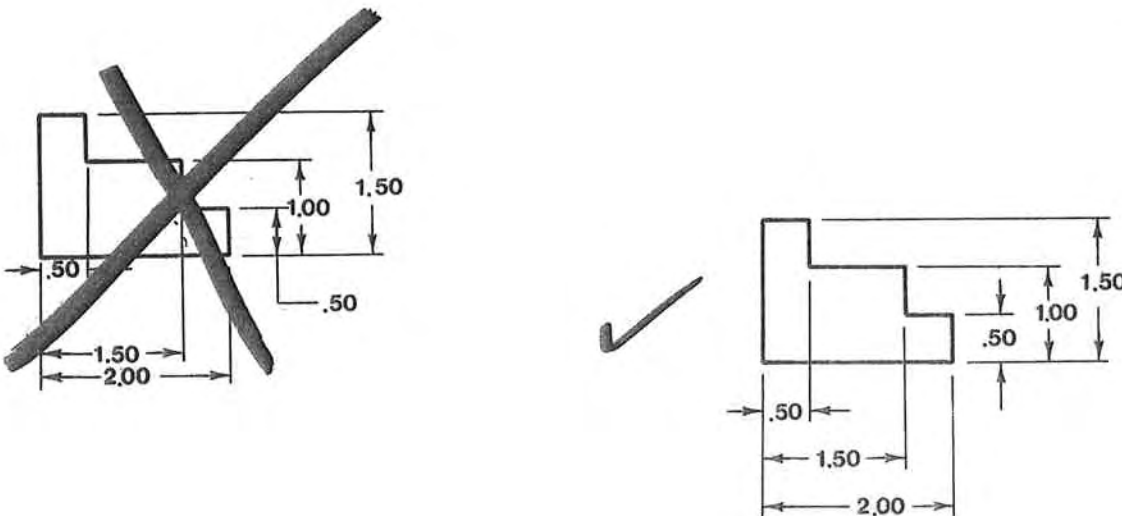


Figure 6-4(i)

6-4(j). Leader lines should not change directions until after they have extended beyond the outside edge of the object and beyond any dimension or extension lines. Leader lines should always end in a short horizontal section that will guide the reader's eye into the appropriate note.

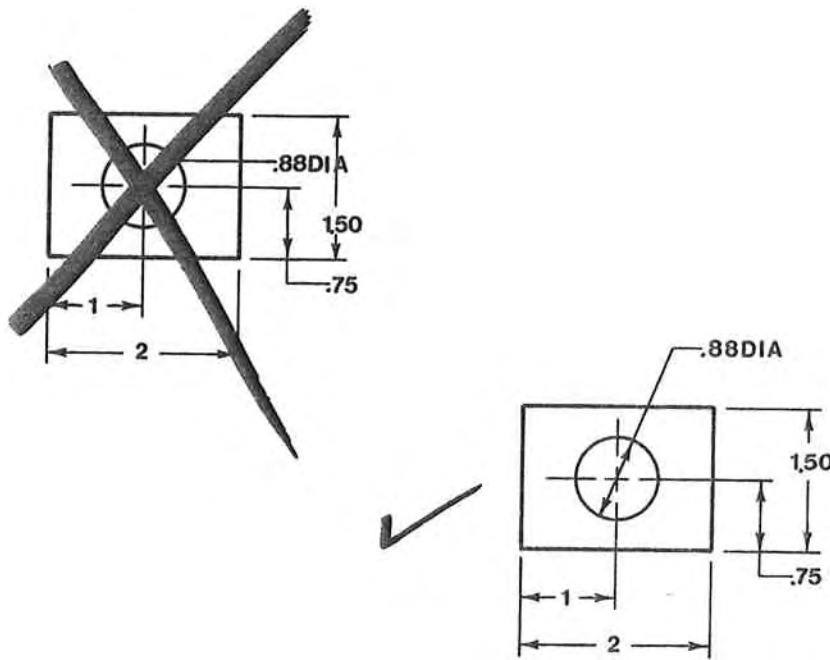


Figure 6-4(j)

6-4(k). Use either decimals or fractions. Do not mix the two. Some companies make exception to this by having critical dimensions written in decimal form and noncritical dimensions written in fractional form. No such variance is in effect for the problems in this book.

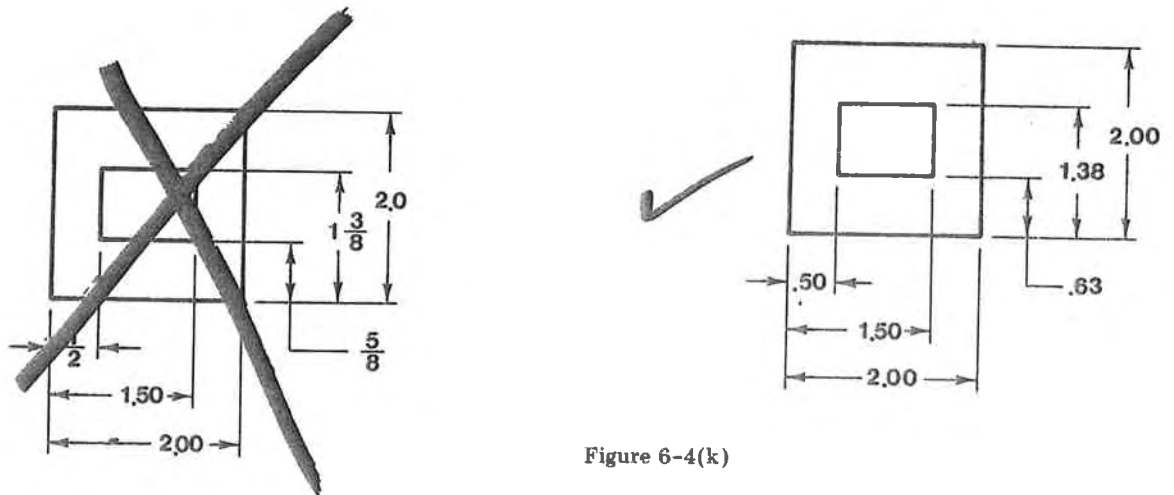


Figure 6-4(k)

6-4(l). Use either the unidirectional or aligned system. Do not mix the two.

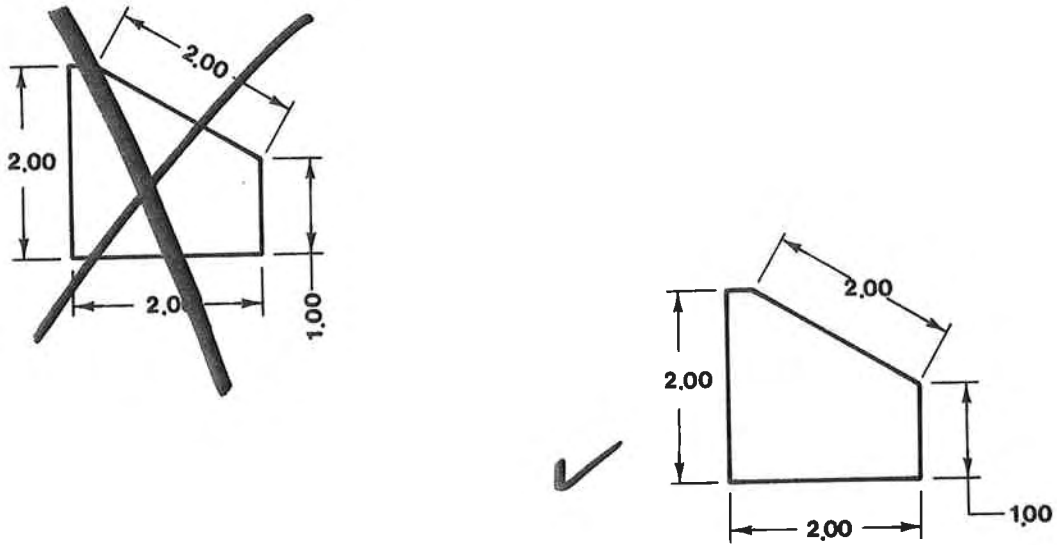


Figure 6-4(l)

6-4(m). Unless it is absolutely necessary, do not dimension to a hidden line. In most cases, the addition of a section cut (see Chapter 13) to the drawing is probably the best way to eliminate excess or confusing hidden lines.

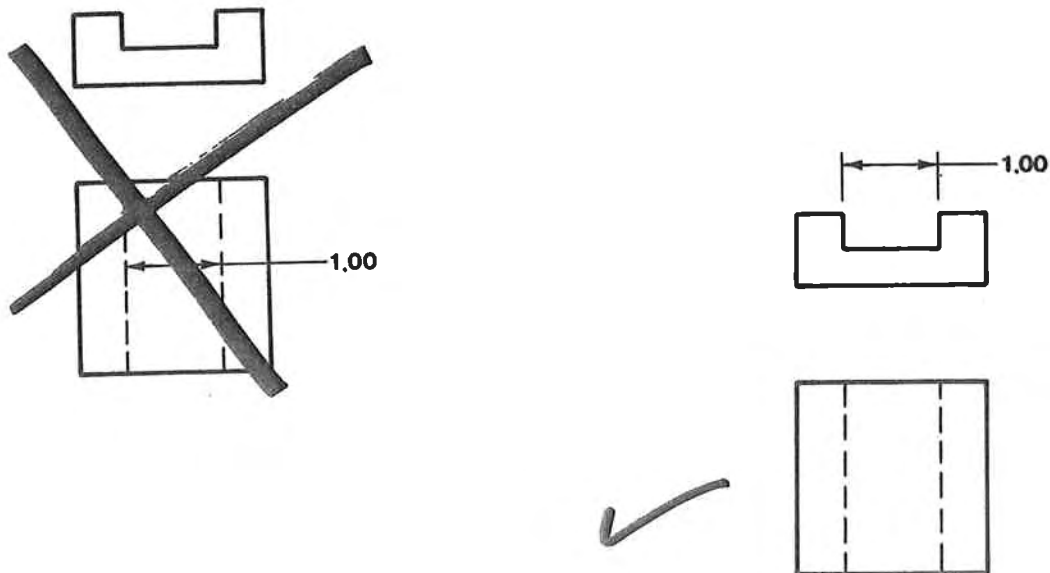


Figure 6-4(m)

6-4(n). Do not include the symbol for inches (") on dimensions. All dimensions in mechanical drafting are in inches unless otherwise stated. An exception to this rule is the number 1 which is usually written 1" so it will not make vertical dimensions lines appear as center lines.

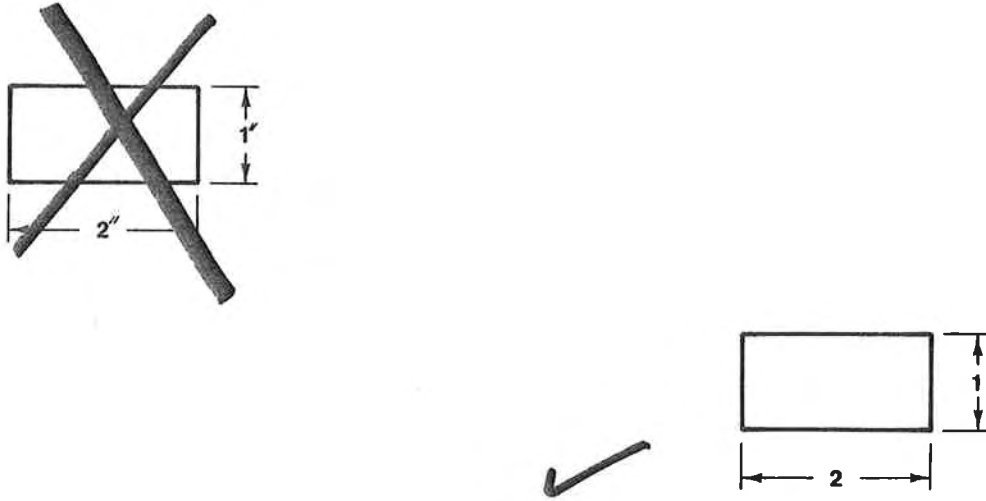


Figure 6-4(n)

6-4(o). Always specify whether or not a hole or arc dimension is a diameter or a radius. Usually, holes are dimensioned in diameters (DIA) and arcs are dimensioned by radii (R).

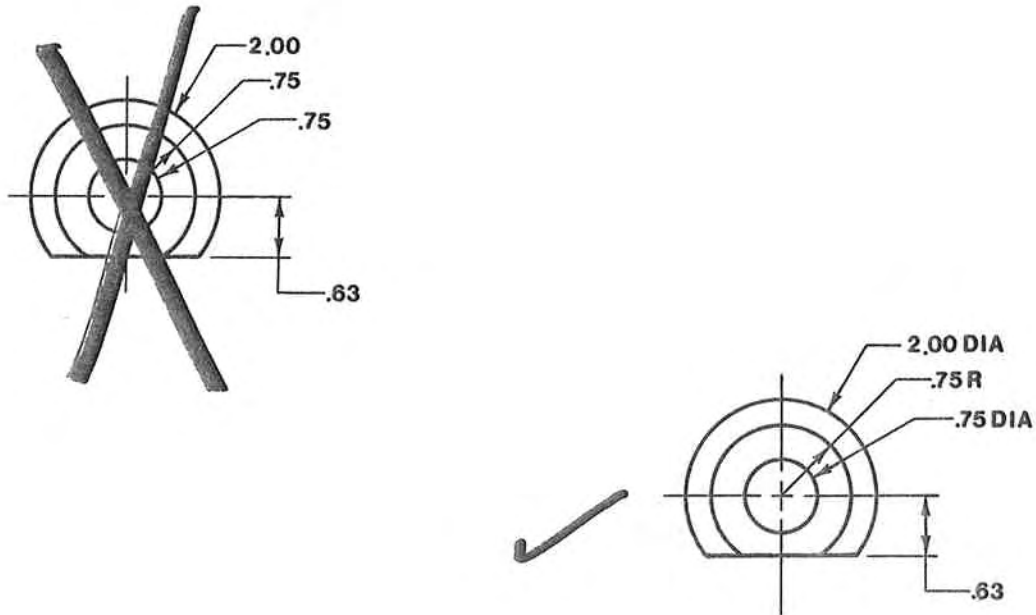


Figure 6-4(o)

- 6-4(p). Do not run extension or dimension lines through other dimension or extension lines unless there is **absolutely no other alternative**. The same is true for leader lines.

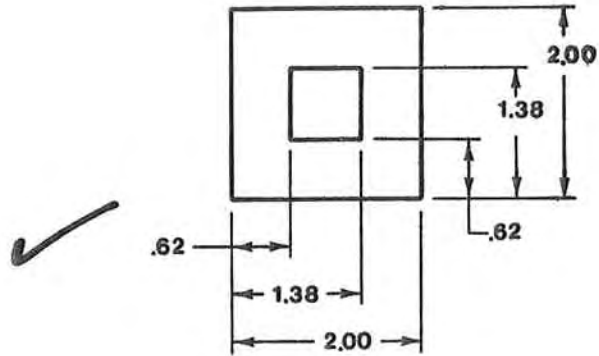
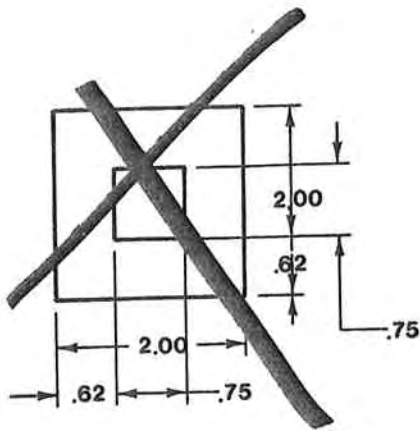


Figure 6-4(p)

- 6-4(q). Always include overall dimensions except on objects that have rounded ends. This means the total length, width, and height for rectangular objects and the largest outside diameter and height for cylinders.

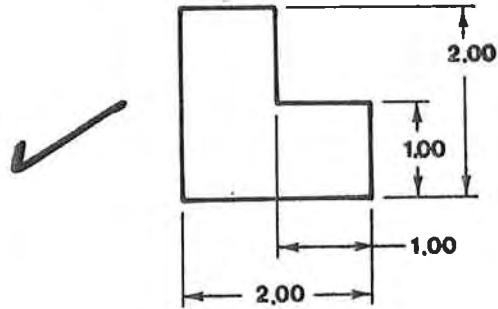
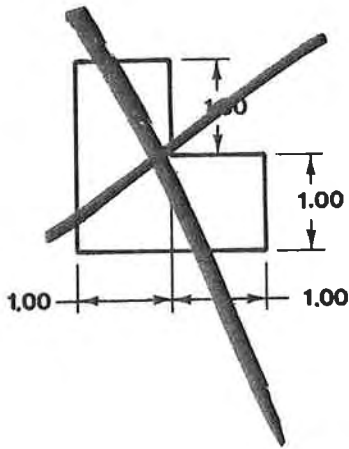


Figure 6-4(q)

- 6-4(r). Always dimension holes in the views in which they appear as circles.

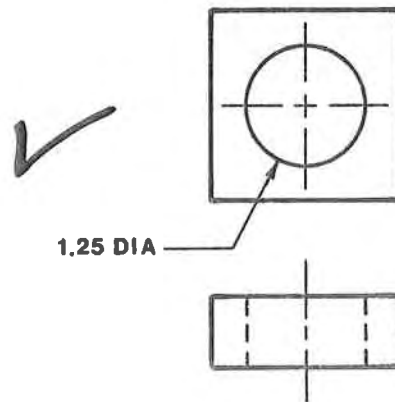
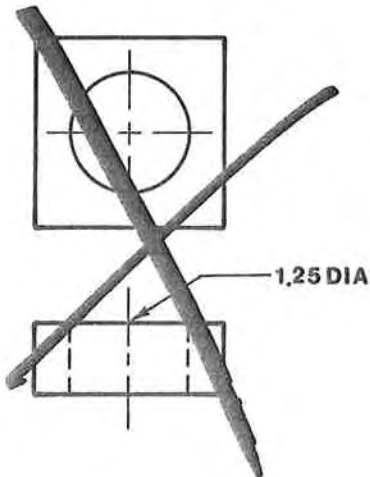


Figure 6-4(r)

6-4 UNIDIRECTIONAL AND ALIGNED SYSTEMS

Dimensions may be positioned on a drawing by using either the unidirectional or the aligned system. The unidirectional system is the preferred system. In the unidirectional system, all dimensions are placed so that they may be read from the bottom of the drawing, that is, with their guidelines horizontal. In the aligned system, dimensions are placed so that they may be read from either the bottom or the right side of the drawing, that is, with their guidelines parallel to the surface that they are defining. Figure 6-5 illustrates the difference between the two systems.

The unidirectional system is the newer of the two systems and it has become the most popular because it is easier to draw and to read. All problems in this book are dimensioned by using the unidirectional system.

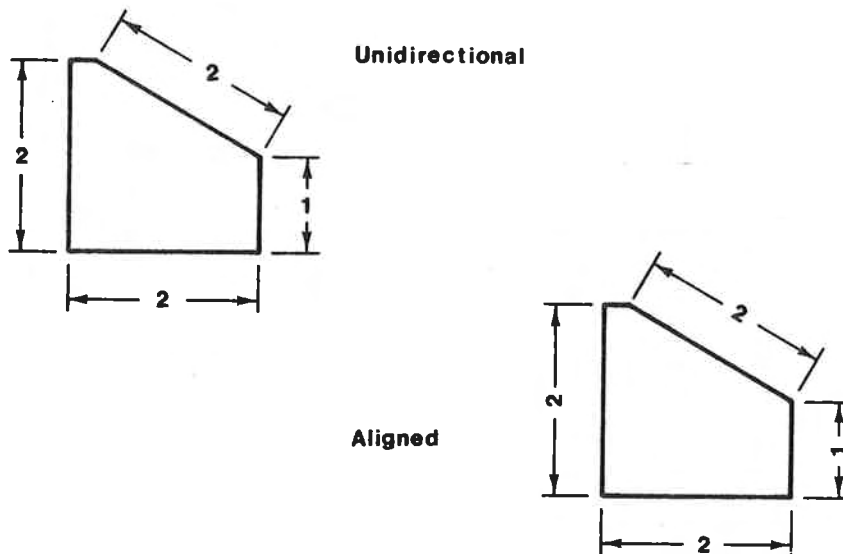


Figure 6-5 A comparison between the unidirectional and aligned dimensioning system.

6-5 DIMENSIONING HOLES

Figure 6-6 illustrates several different ways to dimension holes. Holes are usually dimensioned to their diameters because most drills, punches, and boring machines are set up in terms of diameters. Arcs are usually dimensioned according to their radii.

Always locate a hole by dimensioning to its center point. Make sure that the center point of the hole is clearly defined by crossing the short sections of center lines. The long sections of the center lines may be dimensioned as if they were extension lines.

When you use leader lines, always point the arrow end of the line at the center point of the hole. Always finish the non-arrow end

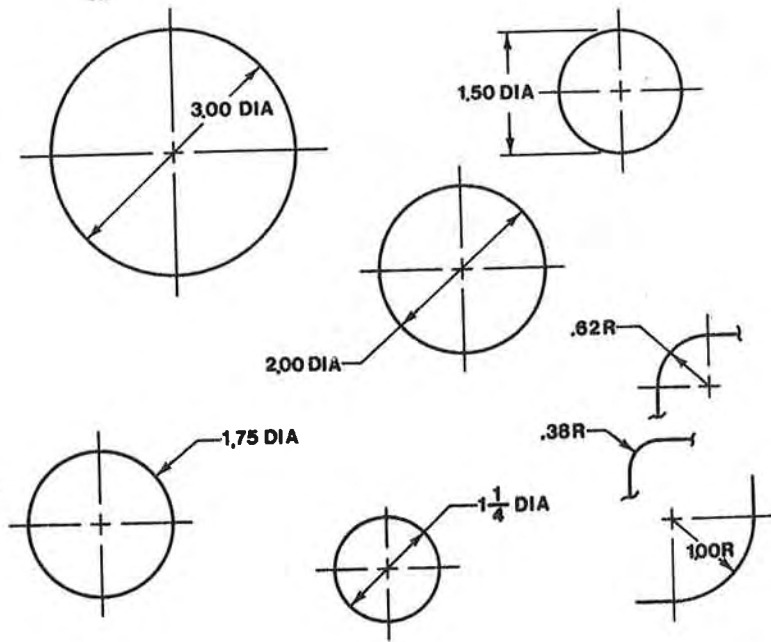


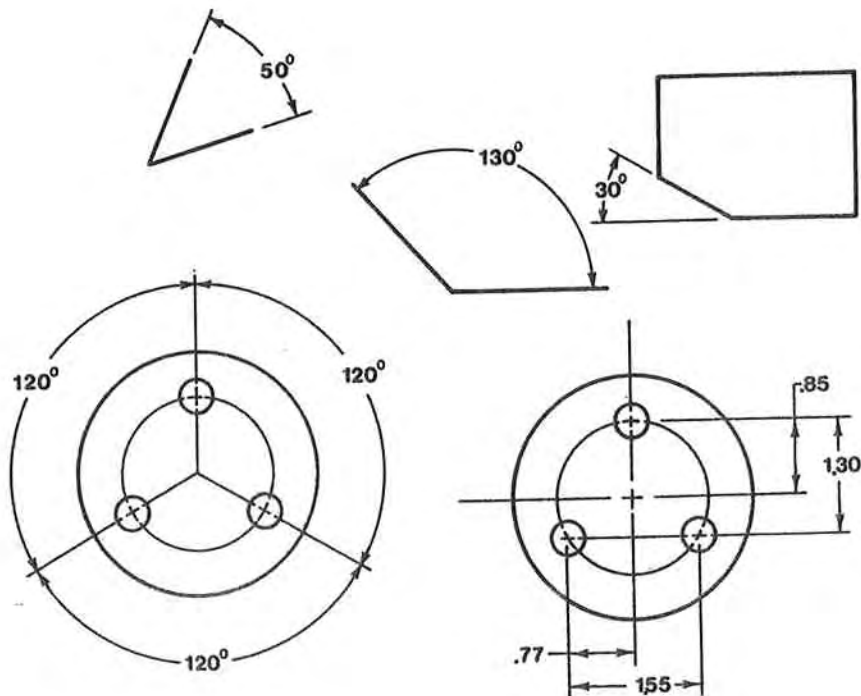
Figure 6-6 Different ways to dimension holes and arcs.

with a short horizontal section that will guide the reader's eye into the dimension note. Always place dimension notes so that they may be read from the bottom of the drawing.

6-6 DIMENSIONING ANGLES AND HOLES

Figure 6-7 illustrates several different ways to dimension angles. It also illustrates the angular (dimensioned with angles) and the coordinate (dimensioned using the center lines as base lines) systems of dimensioning holes on an object.

Figure 6-7 Examples of angle and hole dimensioning.



6-7 DIMENSIONING SMALL DISTANCES AND SMALL ANGLES

When you dimension a small distance or a small angle, always keep the lettering at the normal height of either 1/8 or 3/16. The temptation is to squeeze the dimensions into the smaller space. This is unacceptable because crowded or cramped dimensions are difficult to read, especially on blueprints which are microfilmed. Figure 6-8 shows several different ways to dimension small distances or angles and still keep the dimensions at the normal height.

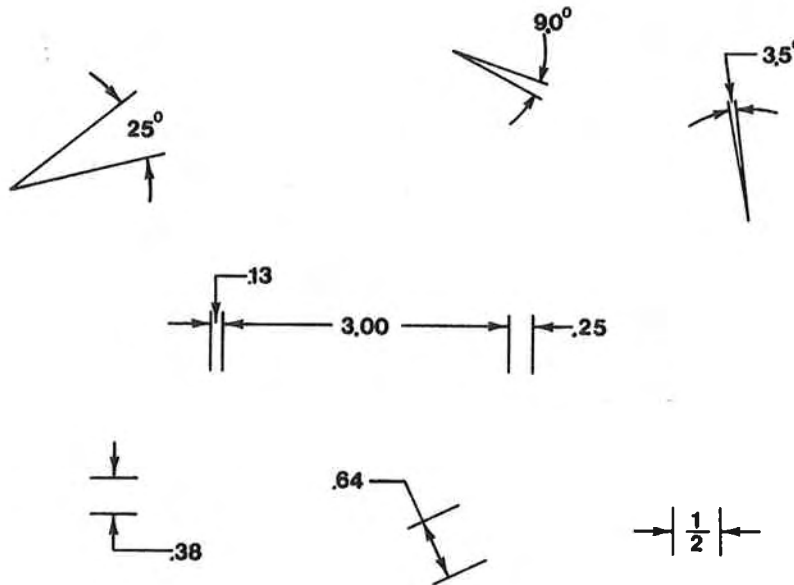


Figure 6-8 Different ways to dimension small distances and angles.

6-8 BASE LINE SYSTEM

The base line system of dimensioning is illustrated in Figure 6-9. All dimensions in the same plane are located from the same line which is called a *base line*. (It is sometimes called a *reference line* or a *datum line*.) This system is particularly useful because it eliminates tolerance

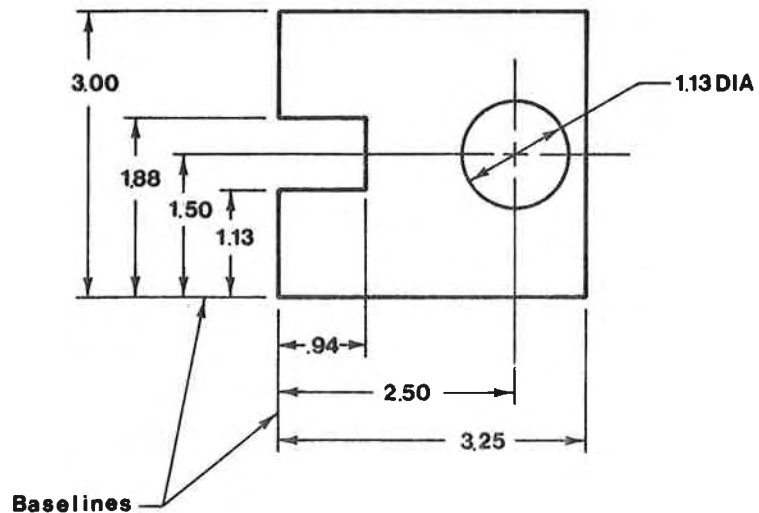


Figure 6-9 Baseline system.

buildup, it is easy for manufacturers and inspectors to follow, and it is easily adaptable to the requirements of numerical tape machines. Its chief disadvantage is that the amount of space used on the drawing paper is larger—usually at least twice the area of the surface being defined. Also, once it is set up, it is difficult to alter.

When you use the base line system, be careful to include all needed dimensions and be sure to use a large enough piece of paper.

6-9 HOLE-TO-HOLE SYSTEM

The hole-to-hole system is illustrated in Figure 6-10. It is a modification of the base line system (Section 6-8) which is used to dimension parts whose hole-to-hole distances are critical, for example, a part that must align with the shafts or dowels of another part for proper assembly.

In the hole-to-hole system, all dimensions in the same plane are measured for the lines that define the critical holes. The base line is not, in this case, a physical line, but it is the center line between the critical holes.

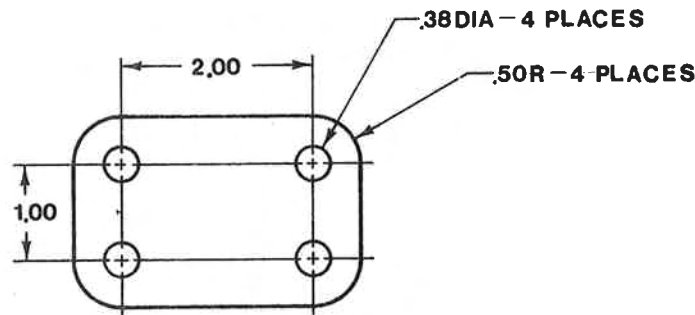


Figure 6-10 Hole-to-hole system.

6-10 COORDINATE SYSTEM

The coordinate system is a dimensioning system based on the mathematical x - y coordinate system. It is usually only used to dimension an object that contains a great many holes, for example, an electrical chassis. It is particularly well-suited to computer use and numerically controlled tape machines.

Each hole on the given surface is located relative to an x - y coordinate system and then all values are listed in a chart. The overall dimensions are not included in the chart but are located on the picture part of the drawing. Figure 6-11 is an example of an object dimensioned by using the coordinate system.

6-11 TABULAR DIMENSIONS

Often manufacturers will produce a part in several different sizes. Each part will have the same basic shape, but the part will vary in over-

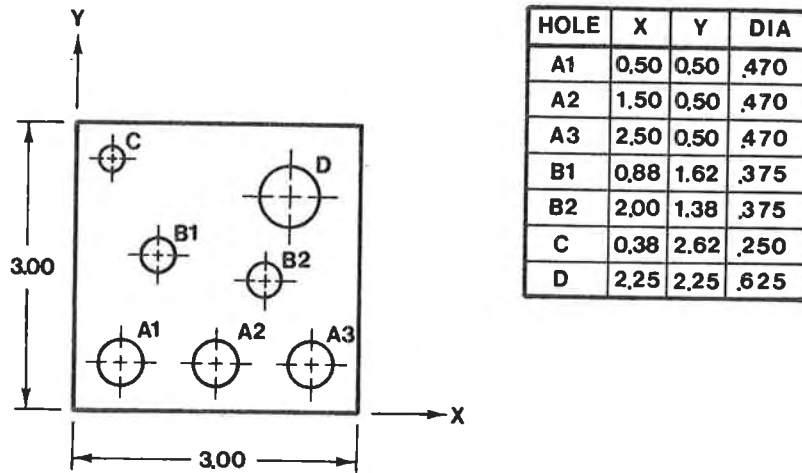


Figure 6-11 Coordinate system.

all size. To save having to dimension each part individually, a system called *tabular dimensioning* is used. Figure 6-12 illustrates an example of tabular dimensioning.

To read tabular dimensions, look up the part number in the table and substitute the given numerical values for the appropriate letters in the figure. For example, part number 1003, according to the table, has an *A* value of 2.25, a *B* value of 1.50, and so on. Part number 1005 has an *A* value of 2.50, a *B* value of 1.75, and so on. The numerical dimensions of .50 mean that these dimensions do not vary, that they remain the same for all parts.

The table may also be used in reverse. If you know what your given design requirements are, look up these values in the table to find which part number you should call out on the drawing.

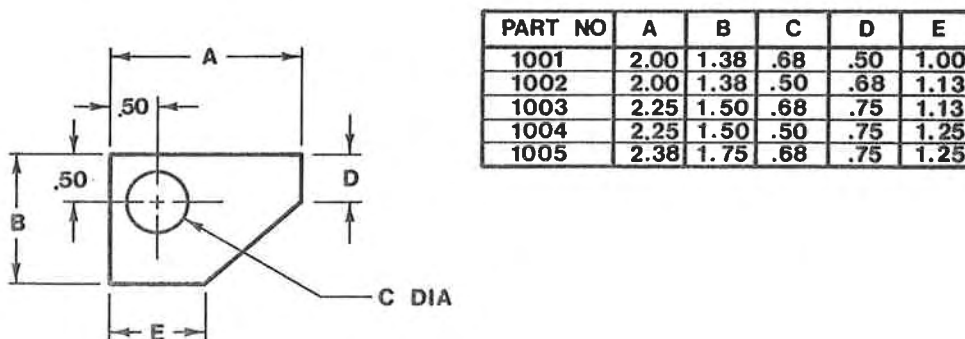


Figure 6-12 Tabular dimensions.

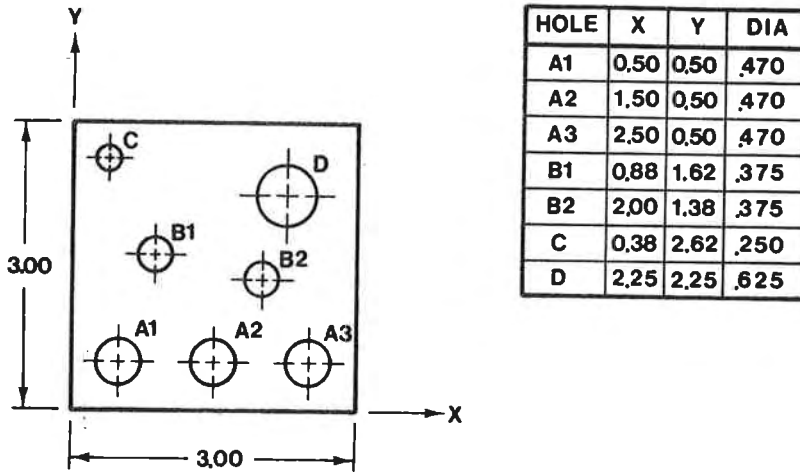


Figure 6-11 Coordinate system.

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The table may also be used in reverse. If you know what your given design requirements are, look up these values in the table to find which part number you should call out on the drawing.

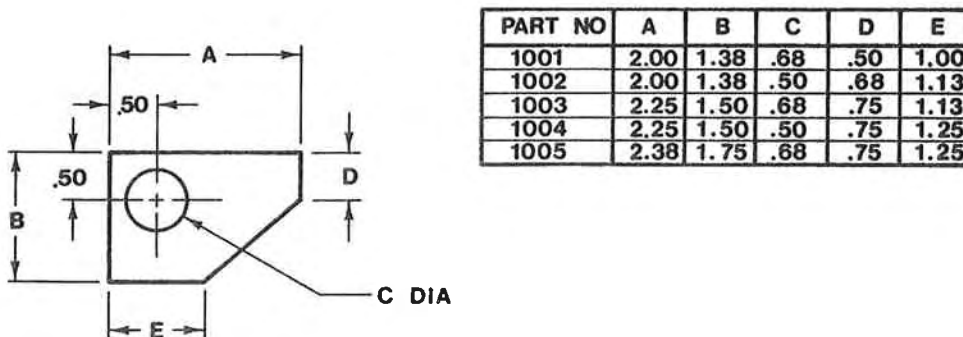


Figure 6-12 Tabular dimensions.

6-12 IRREGULARLY SHAPED CURVES

To dimension an irregularly shaped curve, dimension the points that define the line. The more points you dimension, the more accurate will be your definition. Figure 6-13 illustrates a dimensioned irregularly shaped curve.

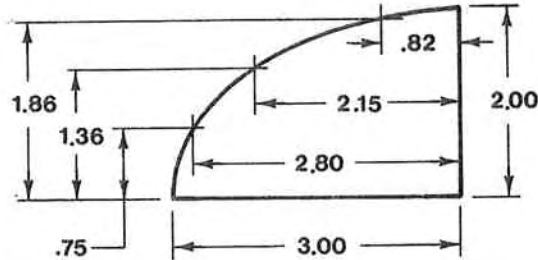


Figure 6-13 Dimensioning an irregular curve.

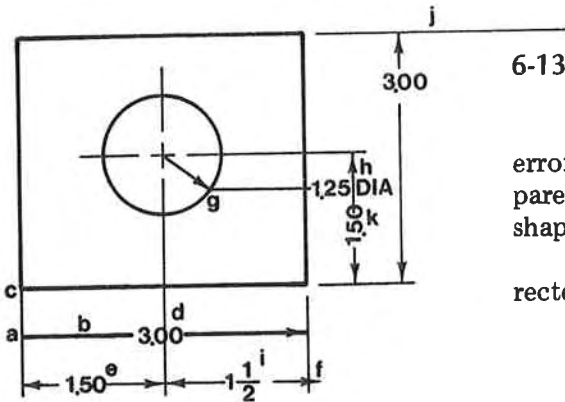


Figure 6-14 Some common dimensioning errors.

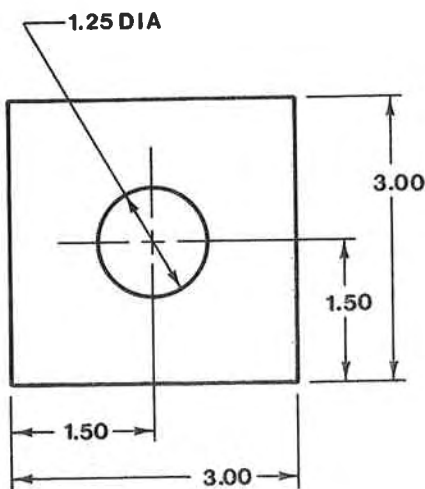


Figure 6-15 The errors illustrated in Figure 6-14 corrected.

6-13 COMMON DIMENSIONING ERRORS

Figure 6-14 demonstrates some of the most common dimensioning errors. Note how cluttered and confined the dimensions appear. Compare Figure 6-14 with Figure 6-15. Both drawings are of the same shape, but Figure 6-15 is dimensioned properly.

Study the errors in Figure 6-14 and then see how they were corrected in Figure 6-15. The errors are:

- (a). No arrowhead
- (b). Dimension line too thick
- (c). No gap between object and extension line
- (d). Dimension value placed over a center line
- (e). No gap between dimension line and dimension value
- (f). Arrowhead extends beyond extension line
- (g). Leader line changes direction within the object
- (h). Dimension value written too close to the object and over a dimension line
- (i). Fraction used while all other dimensions are in decimal form
- (j). Extension line too long
- (k). Dimension not written horizontally.

6-14 TOLERANCES

No dimension can be made perfectly. Unless you are very lucky, there will always be some variance. If, for example, you call for a dimension to be made 5 inches long, you will not get exactly 5 inches on the finished part. It may measure 5.0001 or 4.99999, etc., but it will not be exactly 5 inches.

It is not only impossible to manufacture perfect dimensions, it is also unnecessary. It is possible for a carpenter to build a house within the nearest 0.01 inches, but it isn't necessary for the structural sound-

ness of the house. Think of how much time such a constraint would add to the normal time required to build a house, and then think of how this extra time would needlessly affect the building cost of the house.

Because it is impossible to manufacture perfect dimensions, all dimensions must be toleranced. Each dimension must be considered separately in regard to how much variance is acceptable to insure a satisfactory finished product. The final judgment must be made by considering, among other things, manufacturing capabilities, customer requirements, usage requirements, material properties, and cost constraints. It takes experience and practice to make such a judgment correctly.

Many companies have "standard" tolerances. That is, their shops will always work to a given standard tolerance unless they are specifically told to do otherwise. The standard tolerance is usually printed on the drawing as part of the company's title block.

Figure 6-16 is a sample of standard tolerance. The notation $x.xx \pm 0.01$ means that any dimension that has two decimal places must be manufactured within 0.01 of the stated value. For example, a dimension of 2.04 may be manufactured as small as 2.03 or as large as 2.05 and still be an acceptable part. The other notations in the block are interpreted in a similar manner.

Tolerances—Unless Otherwise Specified are:	
Two Place Decimals	$(.xx) \pm .010$
Three Place Decimals	$(.xxx) \pm .003$
Angular	$\pm 1^\circ$

Figure 6-16 A standard tolerance notation.

Figure 6-17 illustrates several different ways that a tolerance may be specified on a drawing. Each notation is a different way of telling the builder the limits that he must work within.

There are many different kinds of tolerances; each one has its own notations and symbols. For example, surface tolerances $\sqrt{\quad}$, roundness tolerances \bigcirc , squareness tolerances \perp , and so on. To cover them all is beyond the scope of this book because each represents a very specialized field of study.

6-15 CUMULATIVE TOLERANCES

Cumulative tolerances are errors that occur when several small, seemingly insignificant errors are compounded. Usually, they are the result of improper dimensioning. For example, consider Figure 6-18(a), and assume that the object is being manufactured to a standard compa-

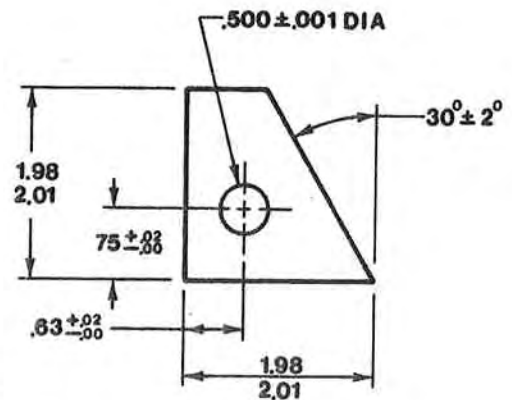


Figure 6-17 Different ways to specify tolerances on a drawing.

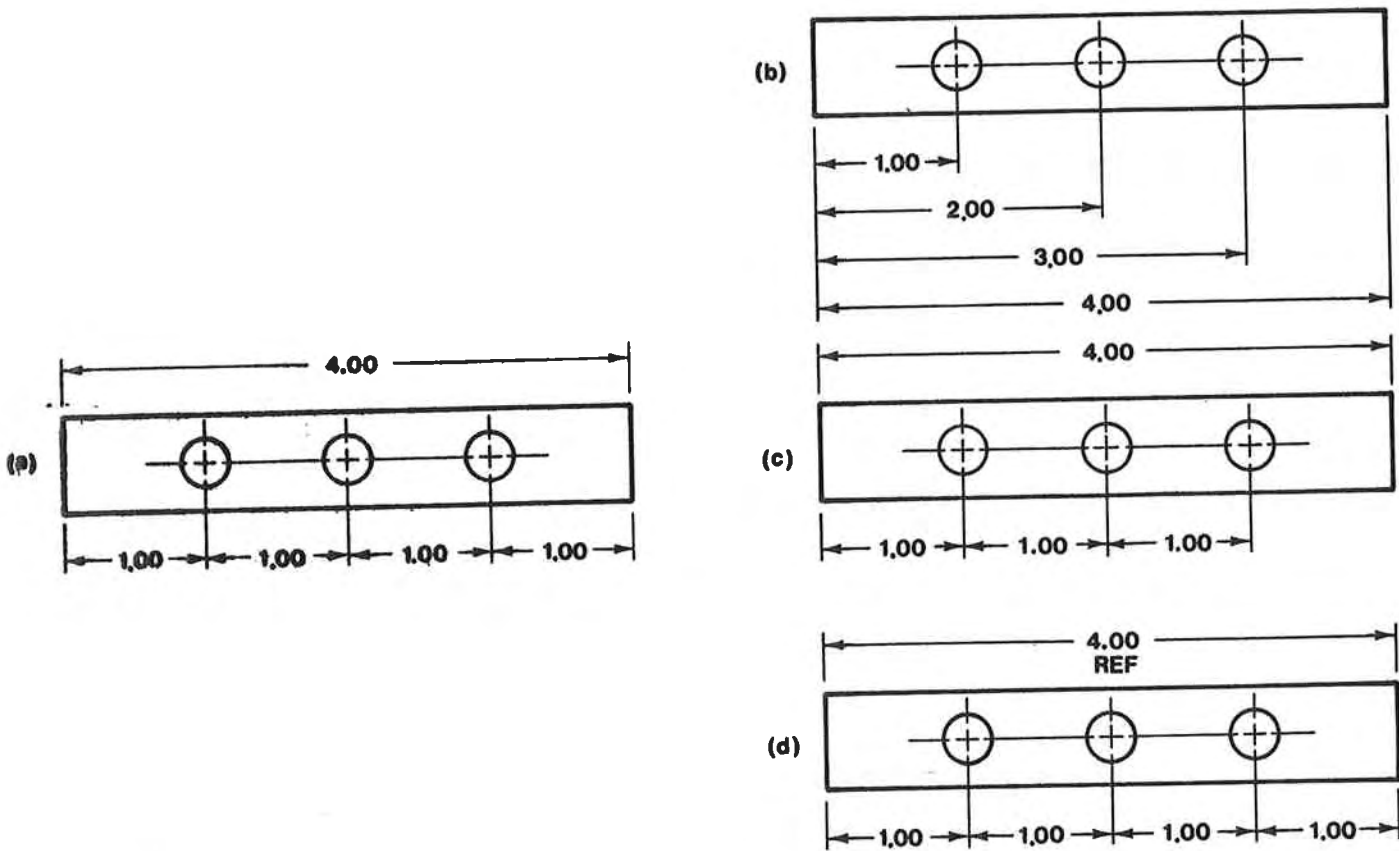


Figure 6-18 Cumulative tolerances.

ny tolerance of ± 0.02 for all two-placed dimensions. Each of the 1.00 dimensions could be made 1.02 giving an overall length of 4.08.

$$\begin{array}{r}
 1.02 \\
 1.02 \\
 1.02 \\
 1.02 \\
 \hline
 4.08
 \end{array}$$

4.08 is not an acceptable overall length, since the overall length must be, according to the given dimension, 4.00 ± 0.02 . This means that the greatest acceptable length is 4.02. The 4.08 object would not pass inspection. Unfortunately, the responsibility for this error must be placed directly on the draftsman who improperly dimensioned the object.

There are several other ways to avoid the error in Figure 6-18(a). In Figure 6-18(b), a REF note (reference note) was placed on the 4.00 dimension. The REF notation means that the dimension is not critical to the manufacturing of the object and has only been included for the reader's convenience. Be very careful when you use the REF notation that it is only used for insignificant dimensions.

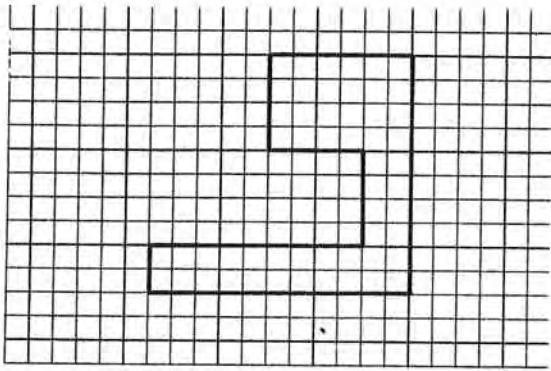
In Figure 6-18(c) one of the 1.00 dimensions was dropped. This means that the end section of the object, which is now not dimen-

sioned, may vary. All the other dimensions are still manufactured within stated tolerances. In Figure 6-18(d) the base line system of dimensioning was used. In most cases, the base line system is the best way to avoid cumulative tolerances because no one dimension is dependent on the accuracy of another dimension. Each dimension is manufactured separately.

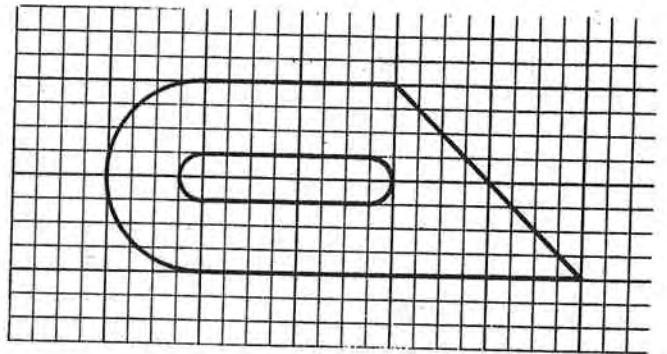
PROBLEMS

Redraw and dimension the following shapes and objects. Each square on the grid pattern is $\frac{1}{4}$ per side.

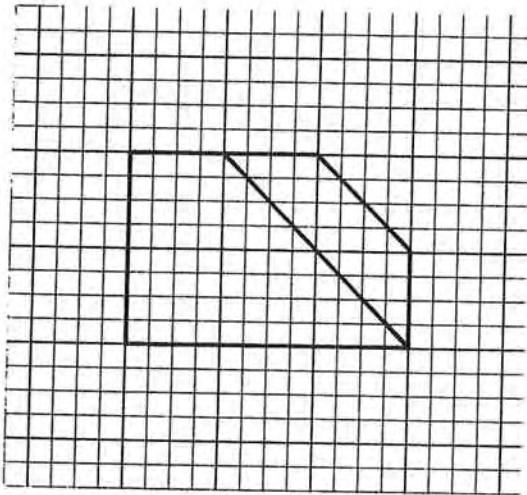
6-1



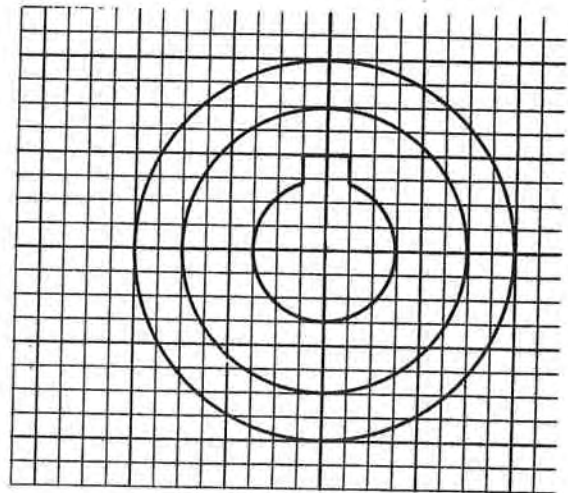
6-2



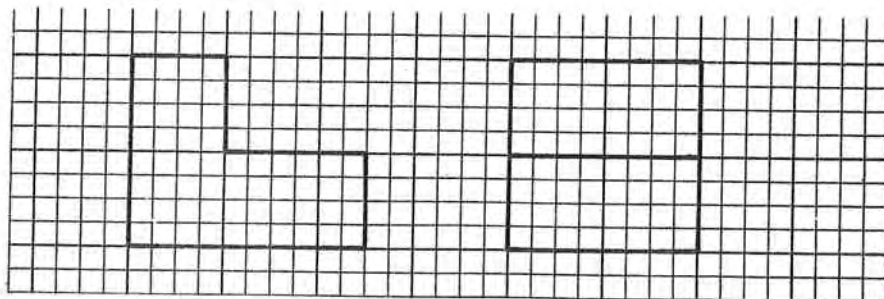
6-3



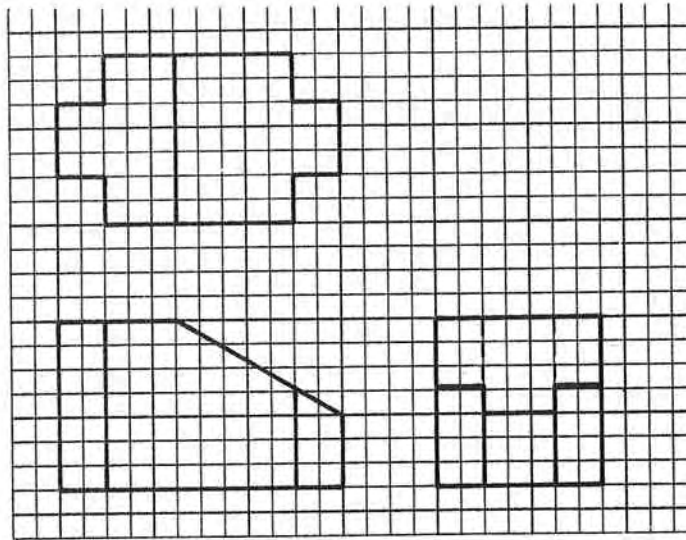
6-4



6-5

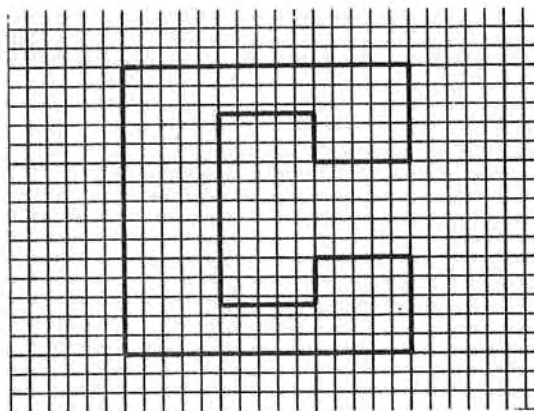


6-6

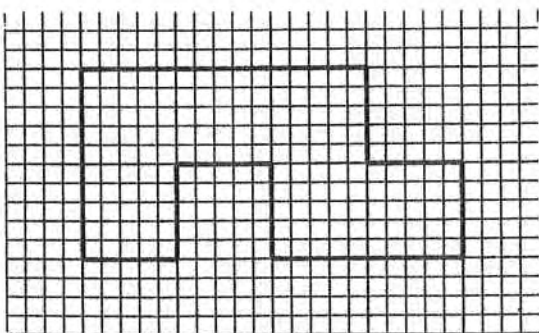


Redraw and dimension the following shapes. Each square on the grid pattern is .20 per side.

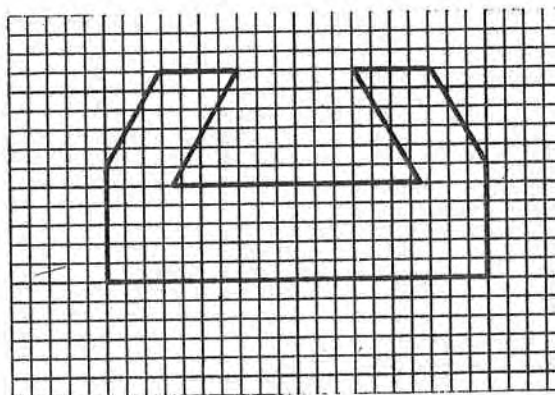
6-7



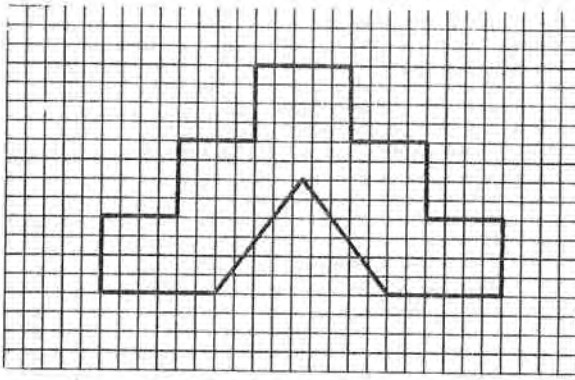
6-8



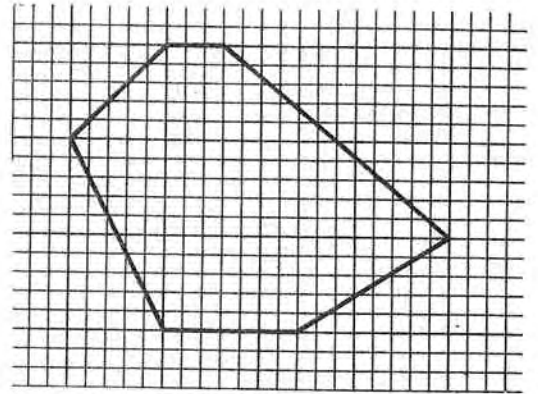
6-9



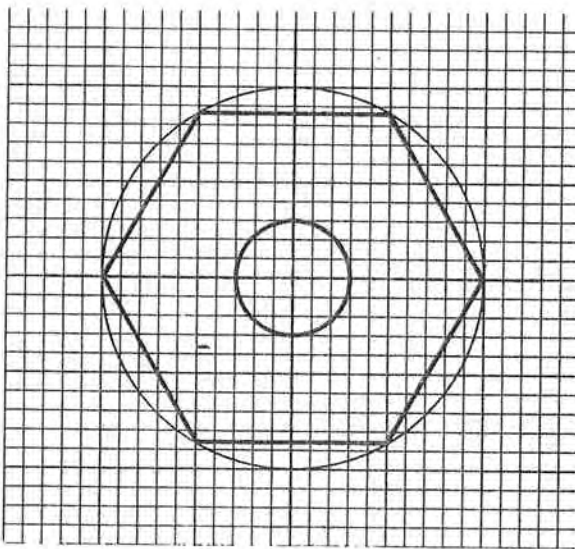
6-10



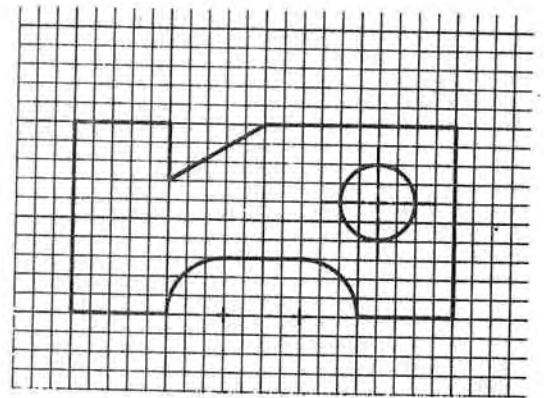
6-11



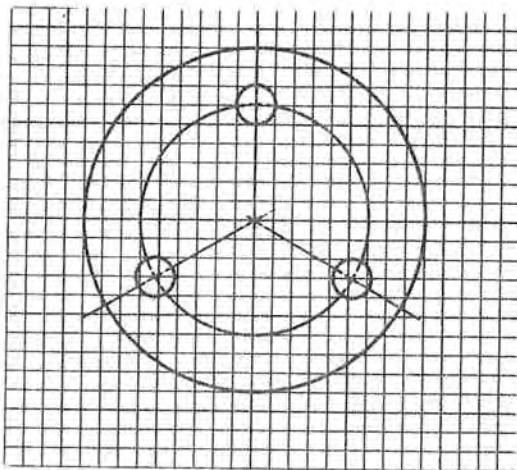
6-12



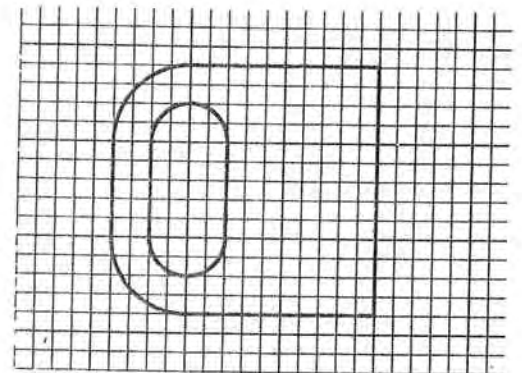
6-13



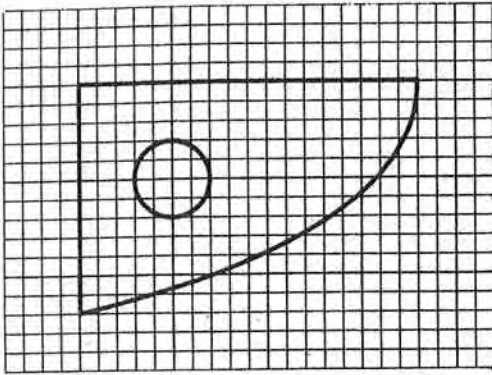
6-14



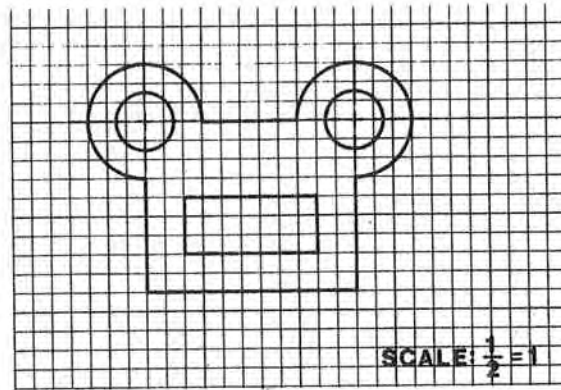
6-15



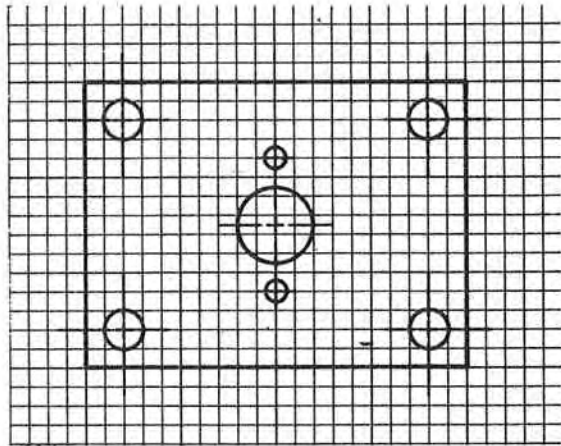
6-16



6-17

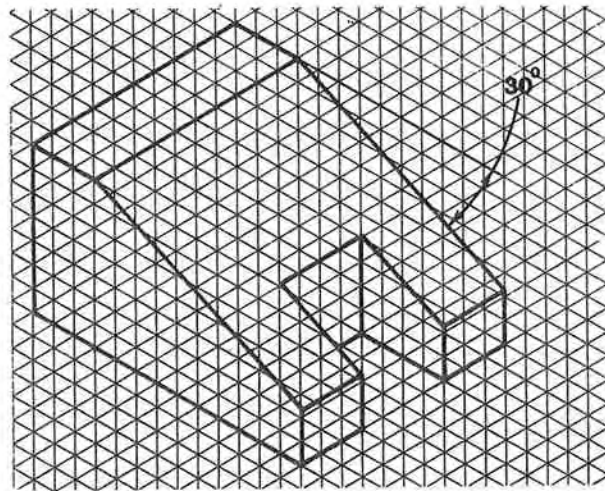


6-18 Dimension the following chassis surface twice; once using the base line system and once using the coordinate system.

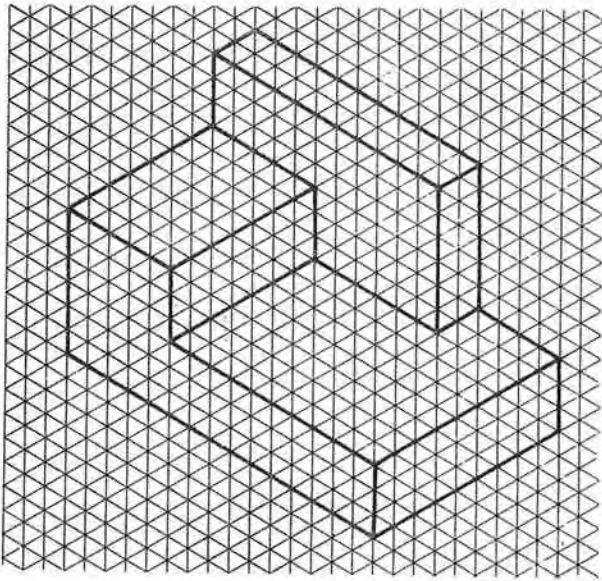


Draw three views of the following objects and dimensions. Use both the decimal and the unidirectional system. Each triangle or square on the grid pattern is .20 per side.

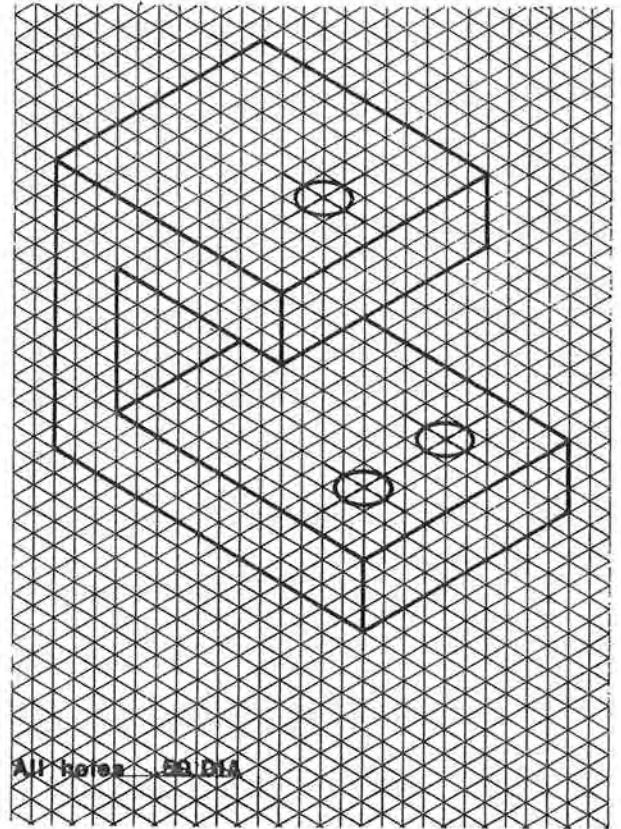
6-19



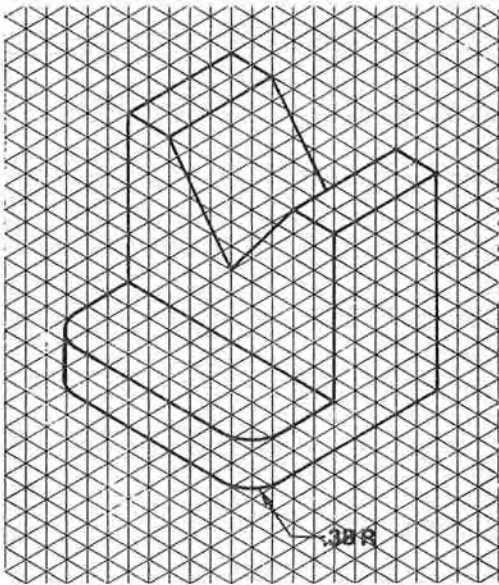
6-20



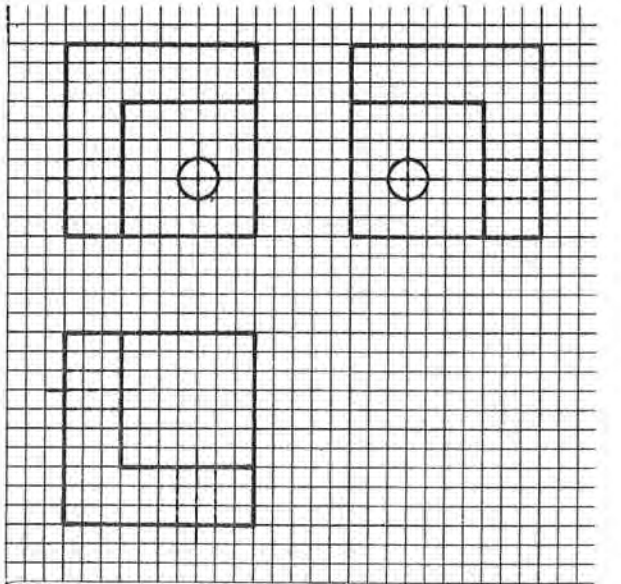
6-21



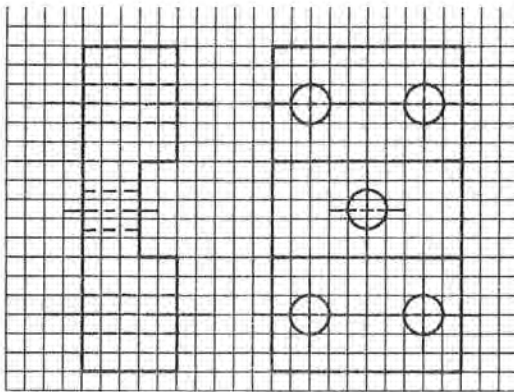
6-22



6-23

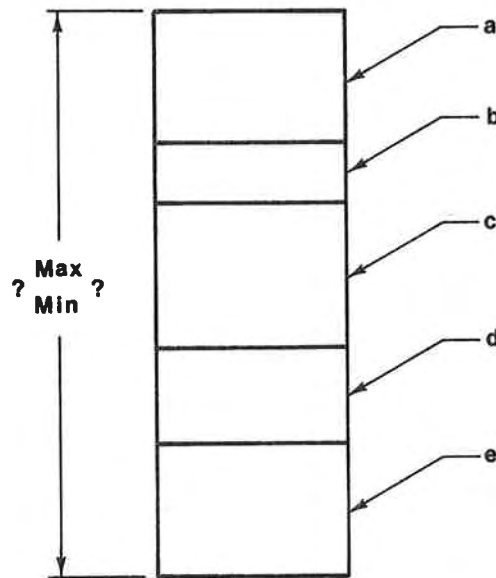


6-24

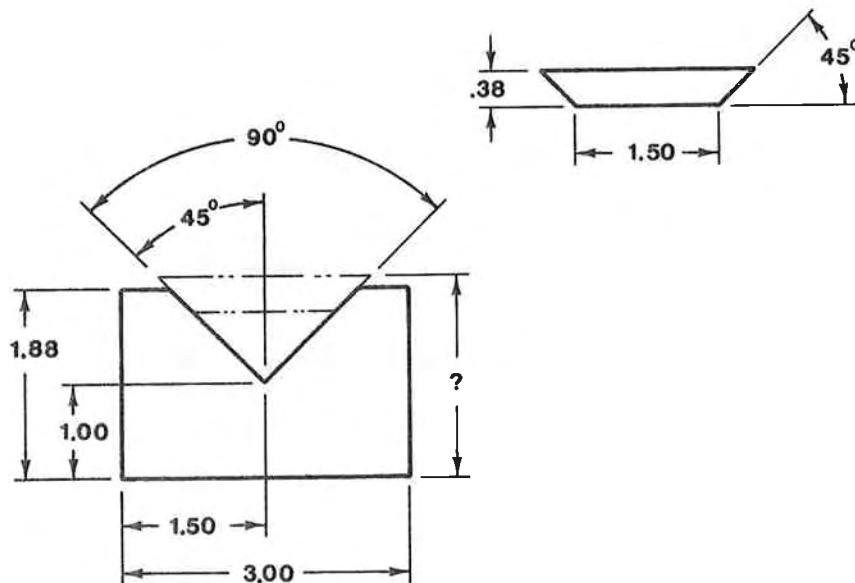


- 6-25** What is the maximum and minimum height that the following five pieces could generate if their dimensions and tolerances are as follows:

- (a) 1.38 ± 0.06
 (b) $0.63 \begin{matrix} + 0.00 \\ - 0.05 \end{matrix}$
 (c) $1.50 \begin{matrix} + 0.02 \\ - 0.00 \end{matrix}$
 (d) 1.000 ± 0.004
 (e) $1\text{-}3/8 \pm 1/32$



- 6-26** In the following problem, all linear dimensions have a tolerance of ± 0.03 and all angular dimensions have a tolerance of $\pm 1^\circ$. If the disc piece is placed within the 90° -opening of the larger base piece, what is the maximum height that the two pieces together could generate? Prepare a layout to verify your answer.



6-27 Redraw the following object and insert the following dimensions:

$$a = 2.75 \begin{matrix} + 0.01 \\ - 0.02 \end{matrix}$$

$$b = 1.88 \pm 0.01$$

$$c = 1.130 \pm 0.002$$

$$d = 2.38 \pm 0.01$$

$$e = 2.000 \begin{matrix} + 0.003 \\ - 0.002 \end{matrix}$$

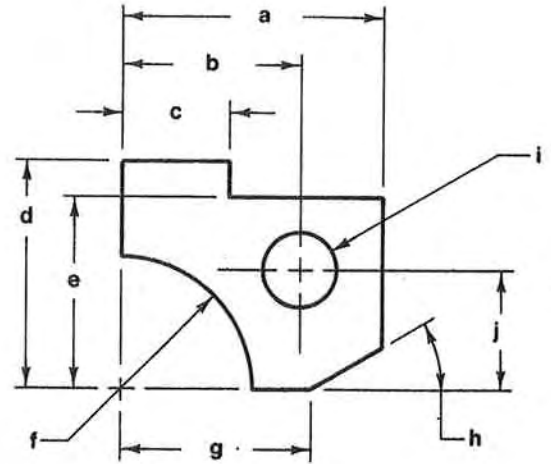
$$f = 1.38R \begin{matrix} + 0.00 \\ - 0.01 \end{matrix}$$

$$g = 2.00 \begin{matrix} + 0.05 \\ - 0.00 \end{matrix}$$

$$h = 30^\circ \pm 5^\circ$$

$$i = 0.750 \pm 0.001$$

$$j = 1.25 \pm 0.03$$



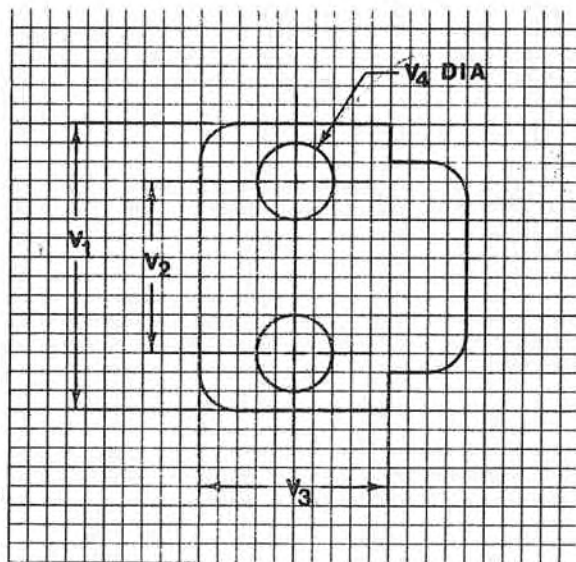
6-28 Dimension the following object by using the tabular system. For part number

1001: $V_1 = 3.00, V_2 = 1.80, V_3 = 2.00, V_4 = .80$

1002: $V_1 = 3.20, V_2 = 1.90, V_3 = 2.00, V_4 = .80$

1003: $V_1 = 4.00, V_2 = 2.20, V_3 = 2.20, V_4 = .80$

1004: $V_1 = 4.00, V_2 = 2.20, V_3 = 2.40, V_4 = 1.00$



Each square on the grid pattern is 0.20 per side.

OBLIQUE SURFACES AND EDGES 7

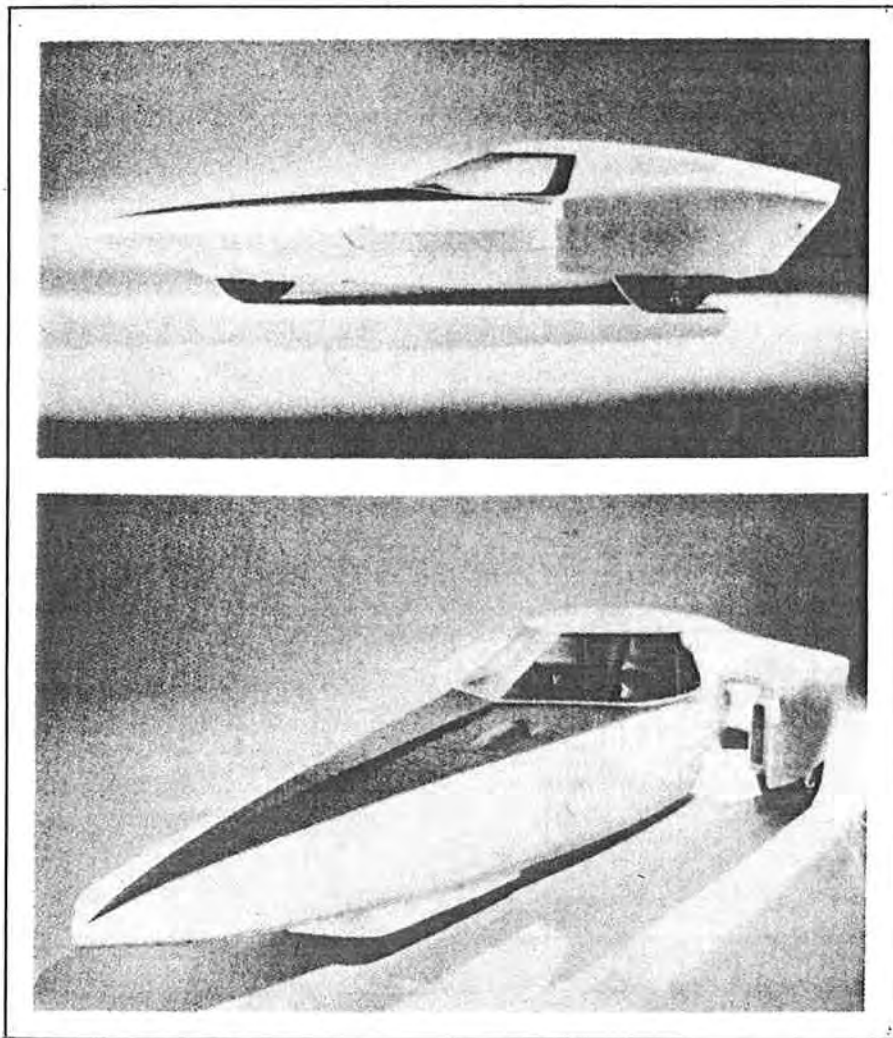


Figure 7-0 Photograph courtesy of General Motors Corp.

7-1 INTRODUCTION

Oblique surfaces and edges are made up of planes and lines that are not parallel to either principal plane line. Figure 7-1 is an example of an oblique surface. Note that none of the lines that define the surface is parallel to either principal plane line and that each line is a different length in each given orthographic view. Note also that the shape of the plane also varies in each orthographic view. This variance makes it difficult to visualize what oblique surfaces really look like (what is their true shape) and will force you to rely on projection theory to help you to formulate accurate finished drawings.

This chapter explains and illustrates the kinds of oblique surfaces most often found in drawings.

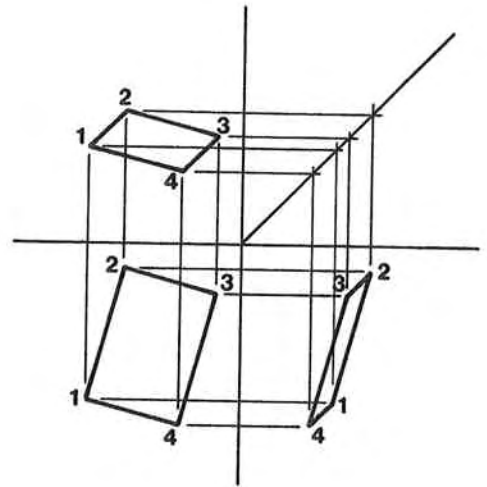


Figure 7-1 An oblique surface.

7-2 COMPOUND EDGES AND LINES

Figure 7-2 is a problem that involves a compound edge. The problem is to draw the top view, given the front and right side views. Figure 7-3 is the solution and was derived by the following procedure:

GIVEN: Front and side views.
 PROBLEM: Draw the top view.

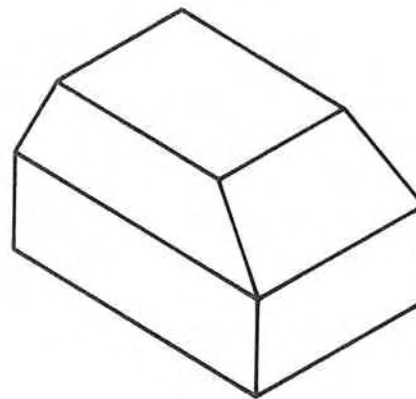


Figure 7-2

SOLUTION:

1. Make, to the best of your ability, a freehand sketch of the solution and, if possible, an isometric sketch of the entire object.

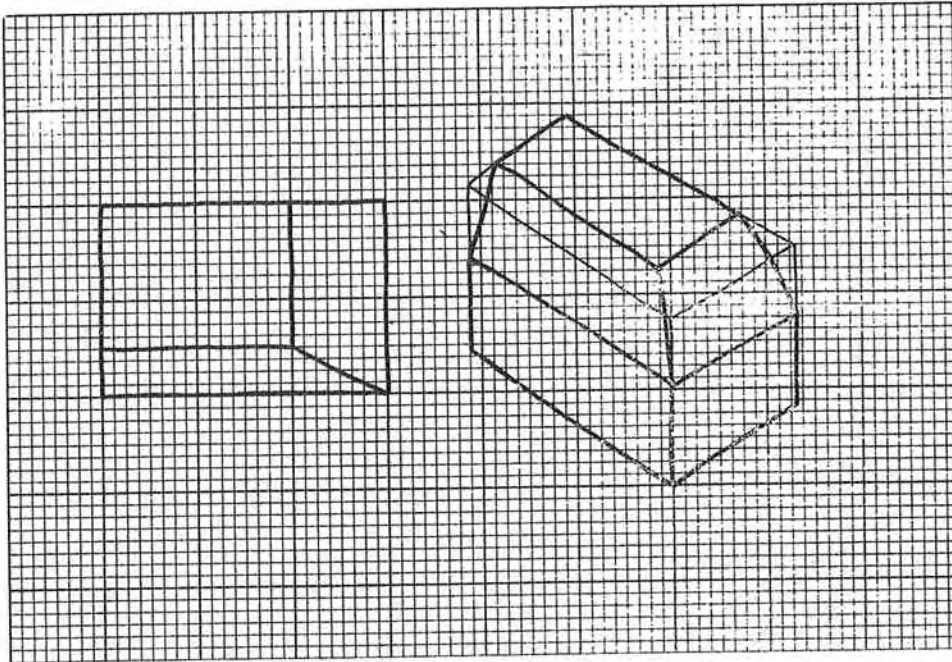


Figure 7-3(a)

2. Analyze the given information and label those points about which you are unsure. In this example surfaces 1-2-3-4 and 3-4-5-6 were labeled.

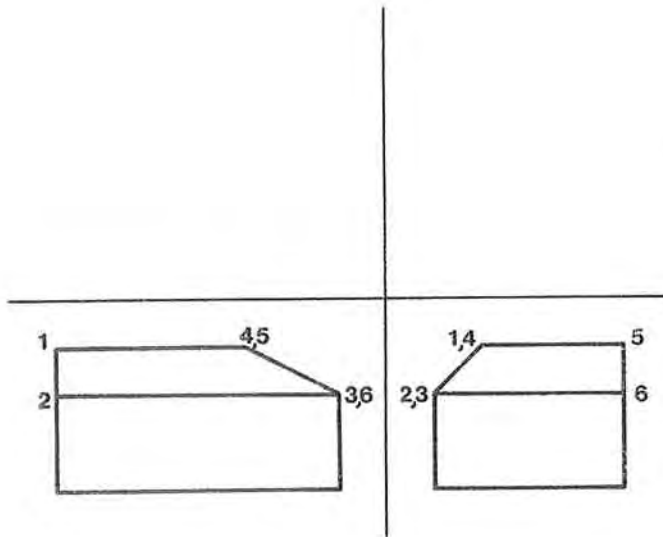


Figure 7-3(b)

- Project points 1, 2, 3, 4, 5, and 6 into the top view by using the projection theory presented in Chapter 4.

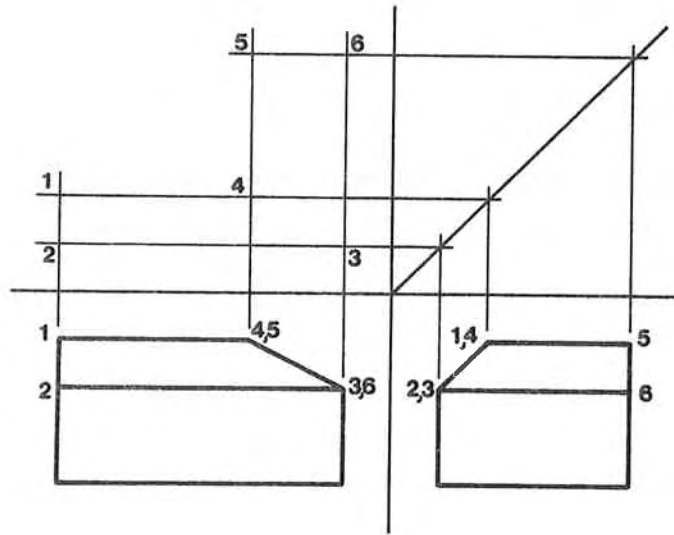


Figure 7-3(c)

- Using very light construction lines, lay out the top view of surfaces 1-2-3-4 and 3-4-5-6. Also lightly lay out the remainder of the object.

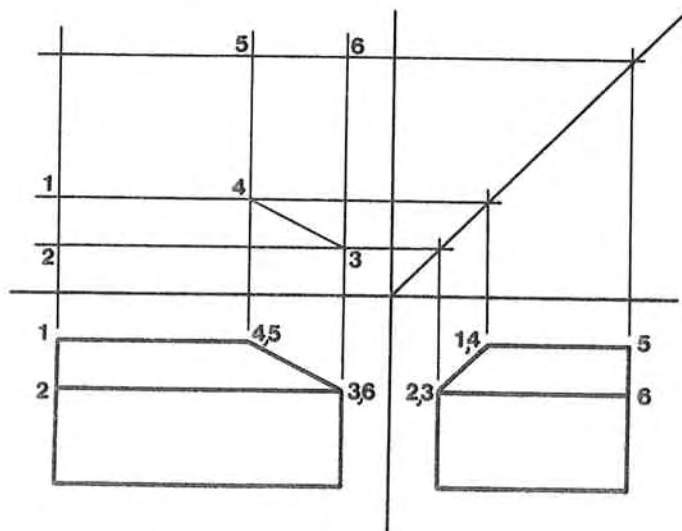


Figure 7-3(d)

5. Erase all excess lines and darken in all the lines to their final color and configuration.

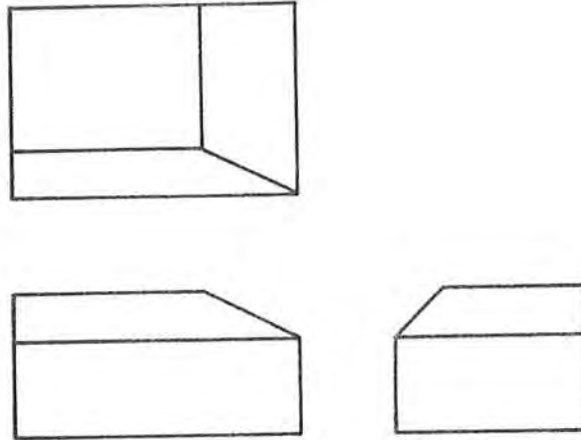


Figure 7-3(e)

GIVEN: An object.
 PROBLEM: Draw a front, top, and side views.

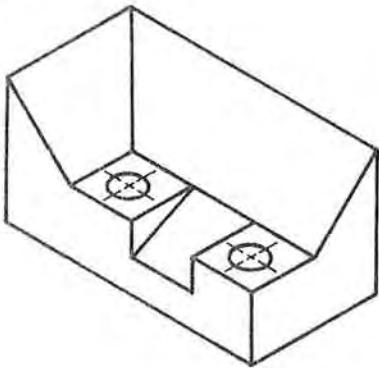


Figure 7-4

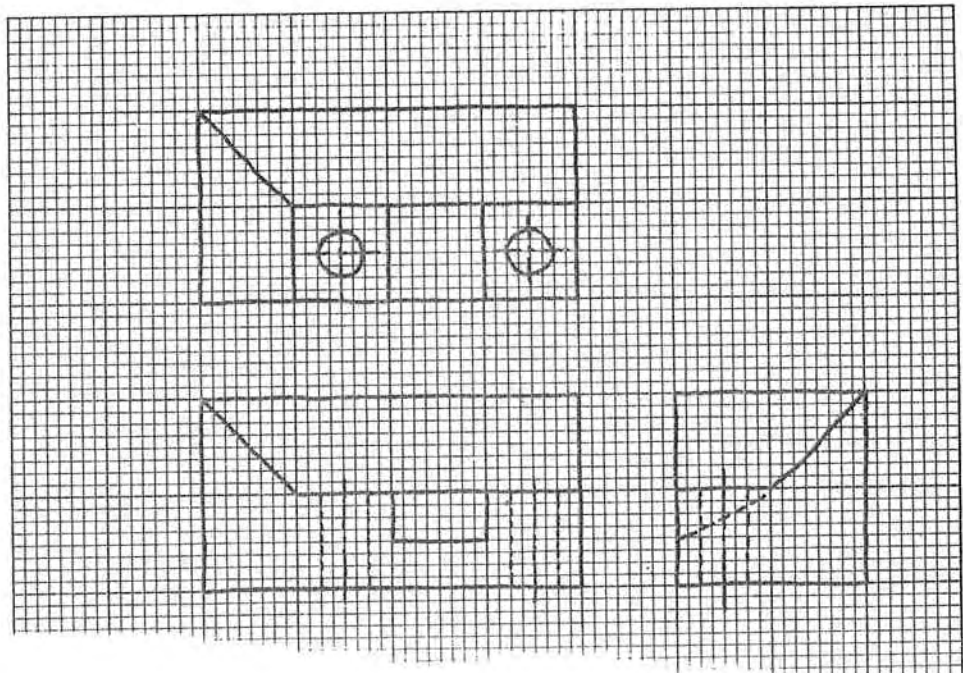
In this example line 3-4 is a compound edge. It was formed by the intersection of two inclined surfaces; yet line 3-4 is not parallel to either principal plane line.

Figure 7-4 is another problem that involves a compound edge. In this problem the object is pictured (an isometric drawing is presented) and you are asked to draw all three orthographic views: front, top, and right side. Figure 7-5 is the solution and was derived by the following procedure:

1. Make, to the best of your ability, a sketch of the solution. Make the sketches as complete and as accurate as you can. It is much easier to change sketches than to change drawings.

Figure 7-5(a)

SOLUTION:



- Working from your sketches, lightly lay out the solution. If necessary, label any confusing areas and use projection theory to work known pieces of information together to formulate the final solution. Also, use projection theory to check any areas about which you are unsure.

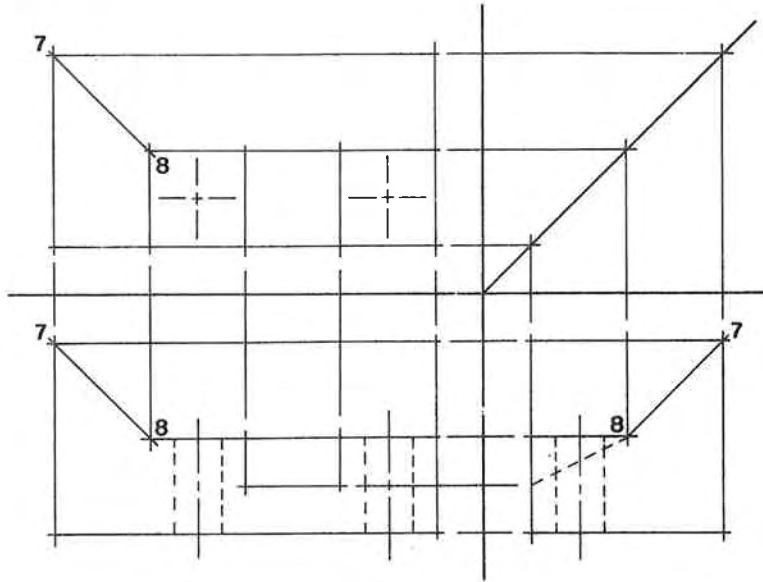


Figure 7-5(b)

- When the layout is complete, erase all excess lines and draw in all lines to their final color and configuration.

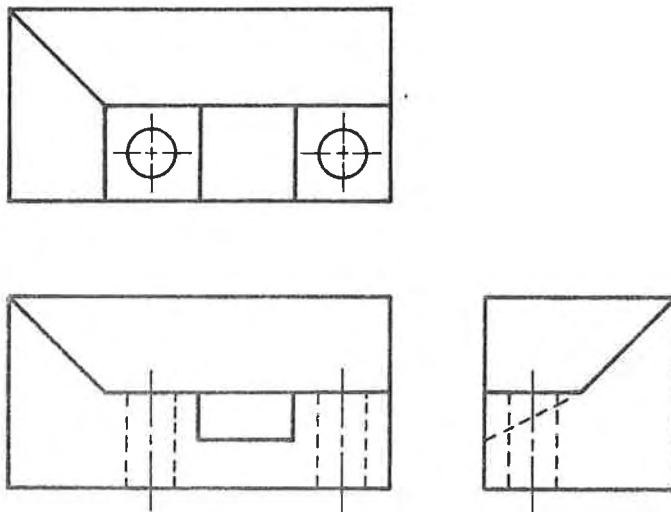


Figure 7-5(c)

7-3 OBLIQUE SURFACES

Figure 7-6 is a problem that involves an oblique surface. An oblique surface is one that is not parallel to either principal plane line (see Figure 6-1). The problem is to draw the front view given the top

GIVEN: Top and side views.
PROBLEMS: Draw front view.

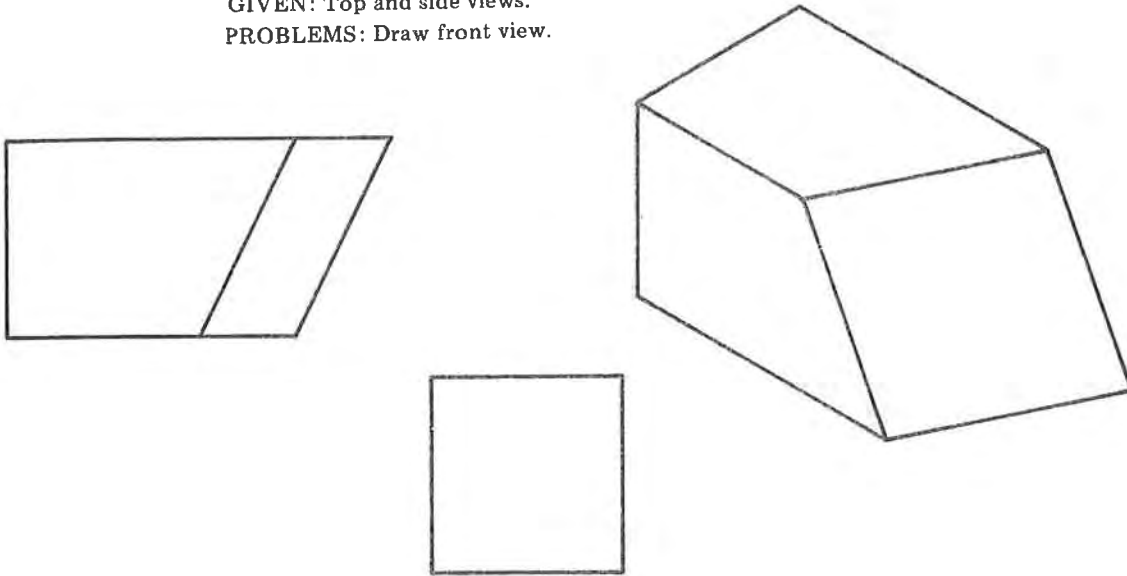


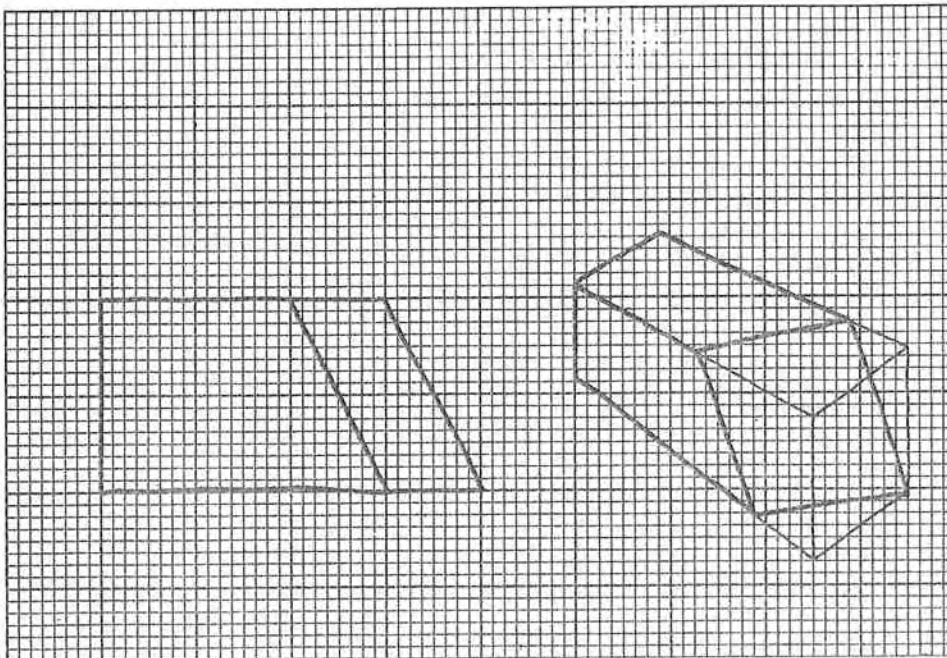
Figure 7-6

and right side views. Figure 7-7 is the solution and was derived by the following procedure:

1. Make, to the best of your ability, a freehand sketch of the solution and, if possible, an isometric sketch of the entire object.

SOLUTION:

Figure 7-7(a)



- Analyze the given information and label those points, lines, or planes about which you are unsure. In this example surface 1-2-3-4 was labeled.

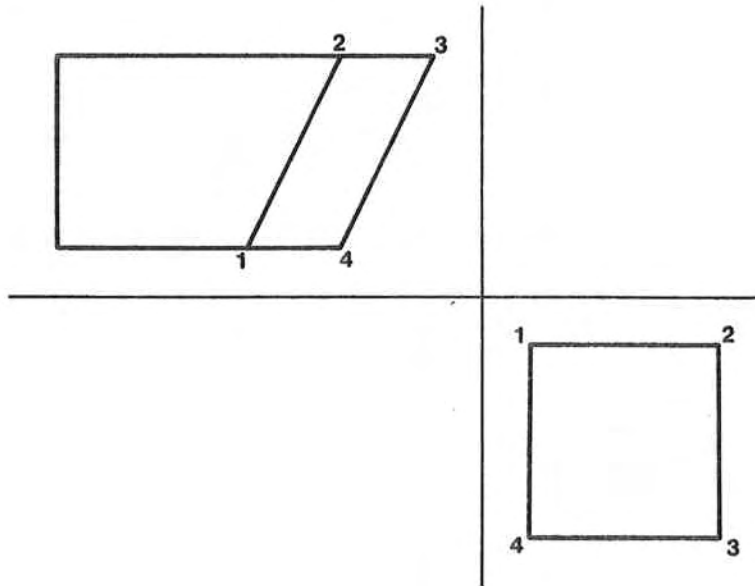


Figure 7-7(b)

- Project points 1, 2, 3, and 4 into the front view by using projection theory.

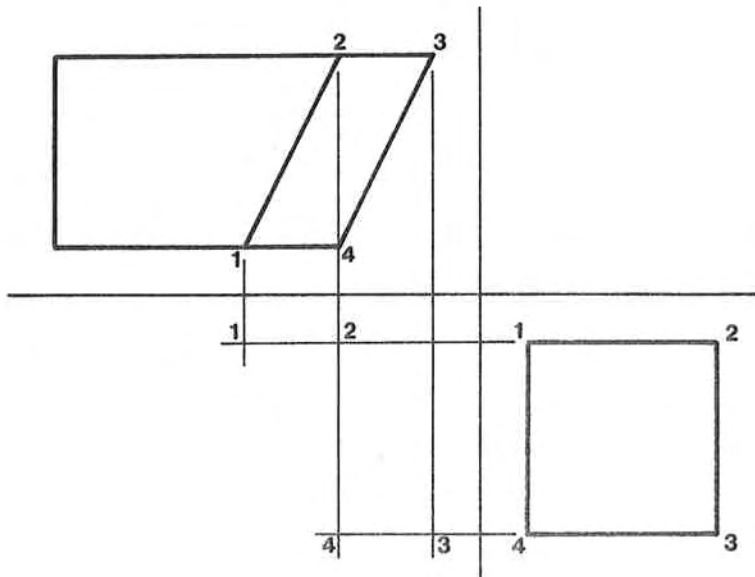


Figure 7-7(c)

4. Using very light layout lines, lay out the front view of surface 1-2-3-4. Also lay out the remainder of the object.

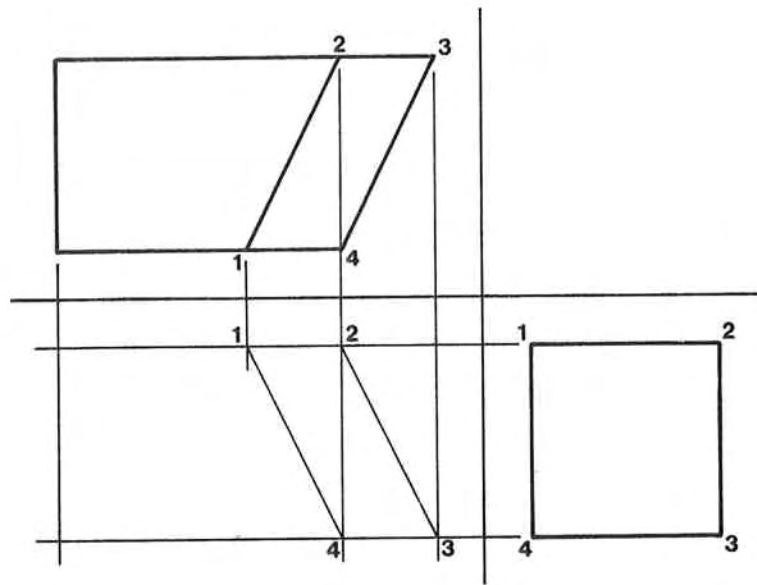


Figure 7-7(d)

5. Erase all excess lines and draw in all lines to their final color and configuration.

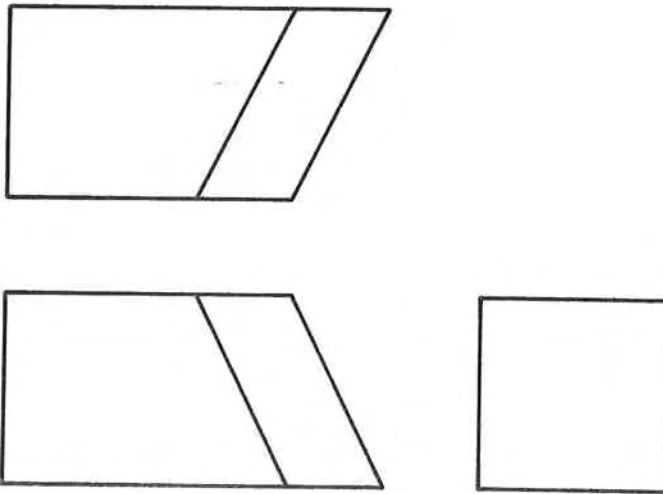


Figure 7-7(e)

Surface 1-2-3-4 in Figure 7-7 is an oblique surface. It is not parallel to either of the principal plane lines. Because it is not parallel to either principal plane line, none of the three final views represents a true picture of the shape of surface 1-2-3-4. How to find the true shape of an oblique surface is explained in Section 11-6.

Figure 7-8 is another example of a problem involving an oblique surface.

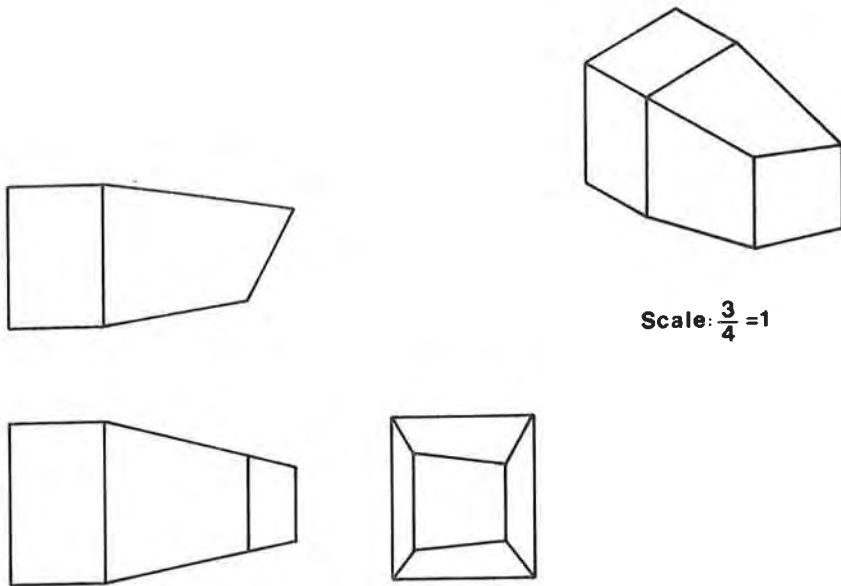


Figure 7-8 Three views of an object which contains oblique surfaces.

GIVEN: An object.
PROBLEM: Draw front, top, and side views.

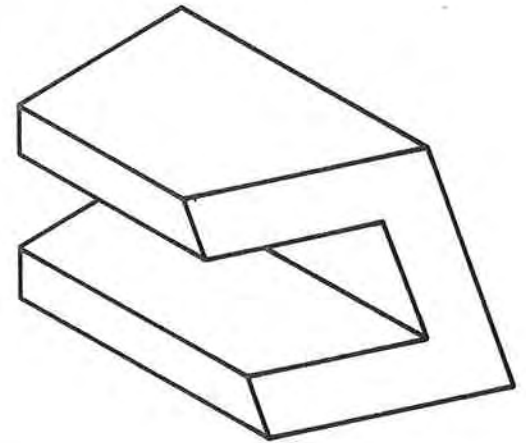


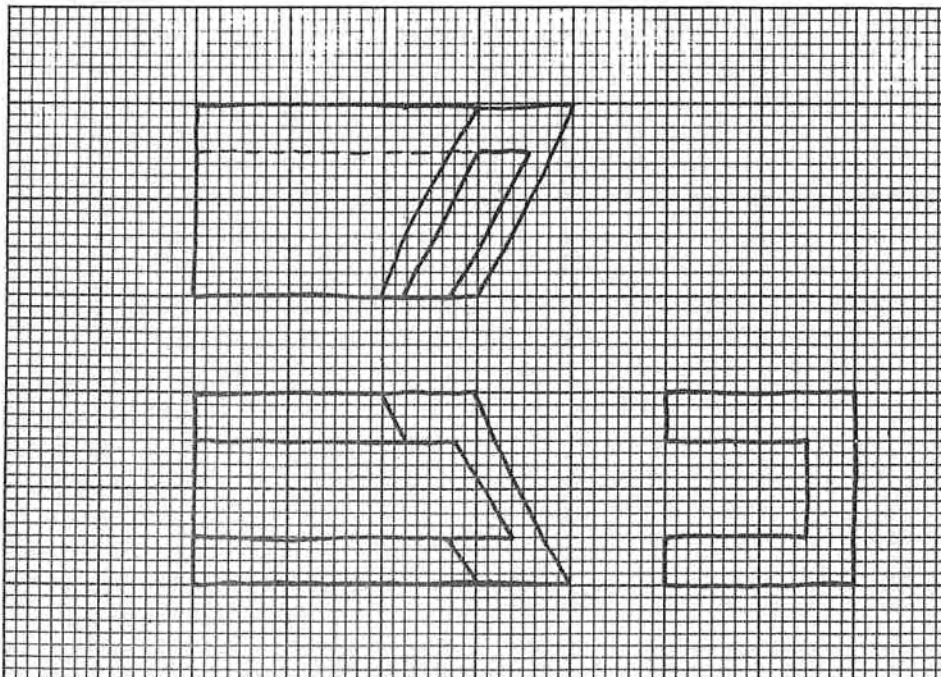
Figure 7-9

7-4 PARALLEL EDGES

Figure 7-9 is an example of a problem that involves parallel edges. Parallel edges are edges that are parallel to each other and may or may not be parallel to the principal plane lines. The problem is to draw the front, top, and right side view when an isometric drawing is given. Figure 7-10 is the solution and was derived by using the same procedure outlined for Figure 7-6.

SOLUTION:

Figure 7-10(a)



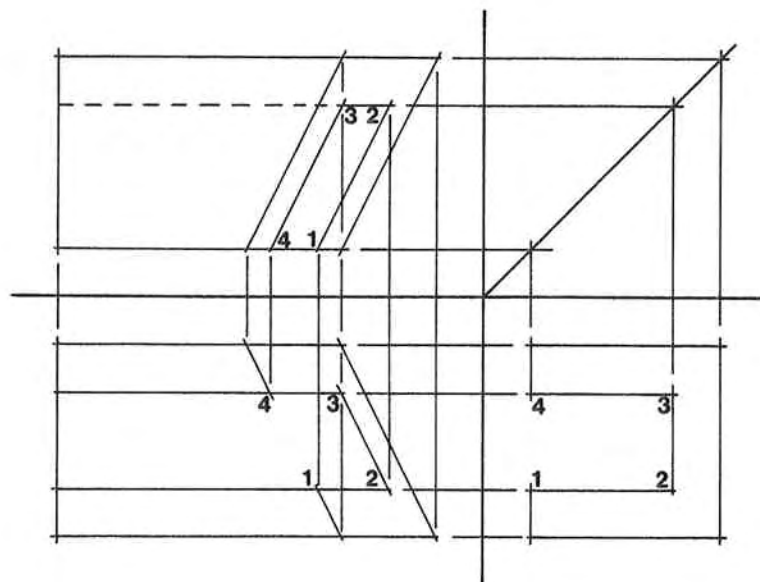


Figure 7-10(b)

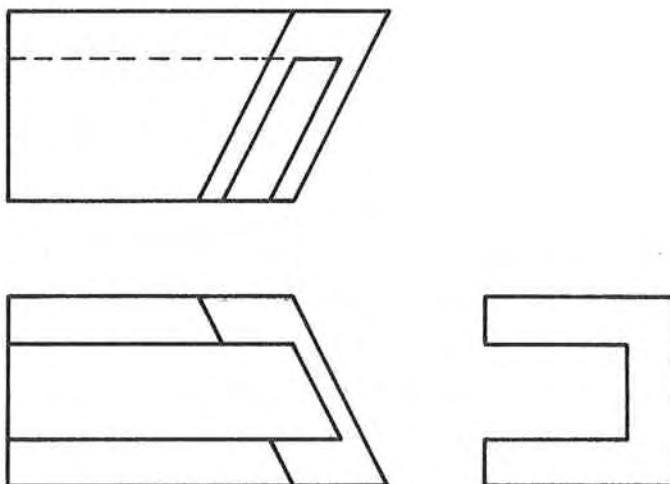


Figure 7-10(c)

In this problem surface 1-2-3-4-5-6-7-8 is an oblique flat surface that cuts across the object. The object was (before it was cut by surface 1-2-3-4-5-6-7-8) shaped like a backward C and it is important to realize that the object is still basically shaped like a backward C. (Note the left side view.) The fact that the object contains an oblique surface that cuts through several other surfaces need not complicate the drawing of orthographic views. Look back at Section 7-3 which illustrated and explained how to draw oblique surfaces and compare the solution to Figure 7-6 with the solution to Figure 7-9. With the exception of the horizontal slot in Figure 7-9, the problems are the same.

Figure 7-11 is another example of a problem that involves parallel edges.

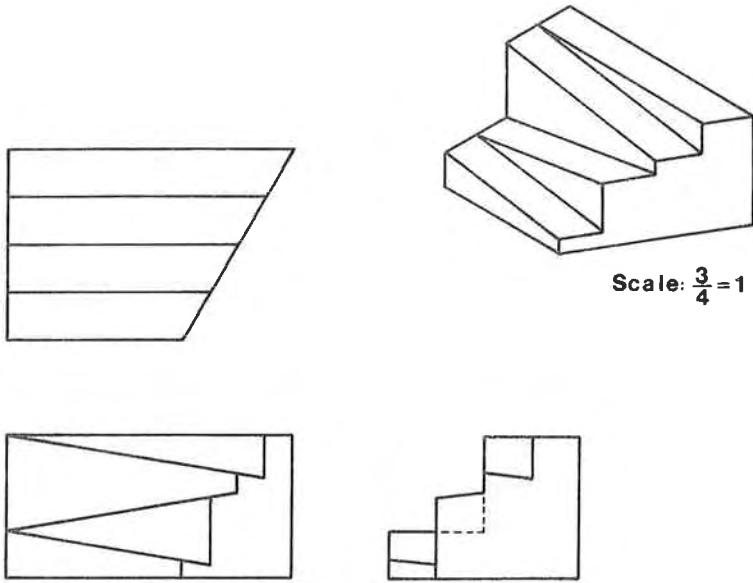


Figure 7-11 Three views of an object which contains several sets of parallel edges.

7-5 DIHEDRAL ANGLES

Figure 7-12 is a problem that involves a dihedral angle. A dihedral angle is an angle between two planes. The problem is to draw the front view of the object when the top and right side views are given. Figure 7-13 is the solution and was derived by the procedure on the following page:

GIVEN: Top and side views.
 PROBLEM: Draw front view.

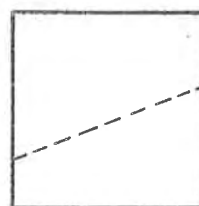
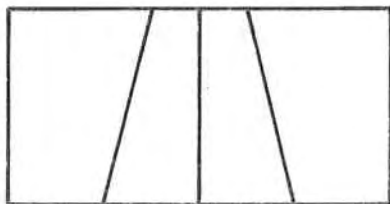
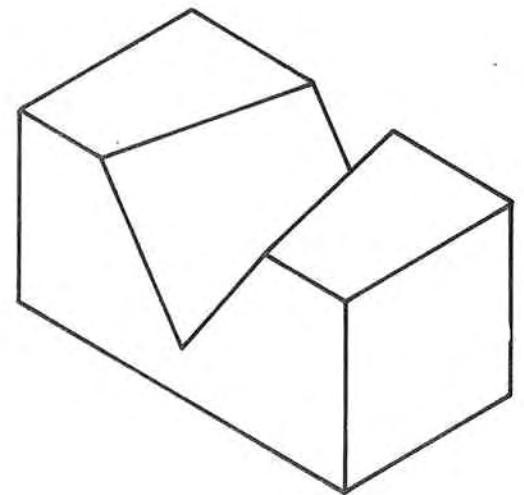


Figure 7-12

SOLUTION:

1. Make, to the best of your ability, a freehand sketch of the solution and, if possible, a sketch of the entire object.

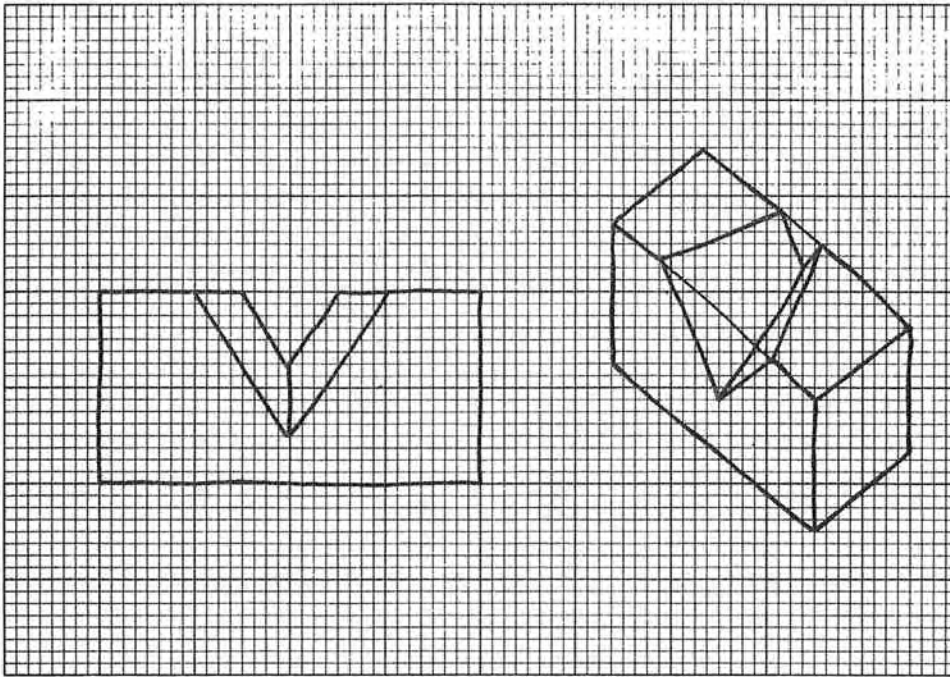


Figure 7-13(a)

2. Define the vortex line of the dihedral angle. In this example the vortex line is defined as line 1-2.

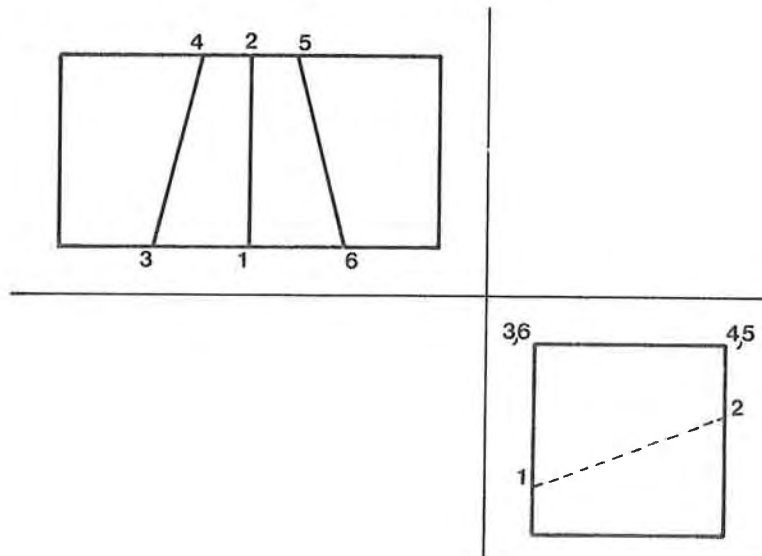


Figure 7-13(b)

- Define the surfaces that make up the dihedral angle. In this problem the surfaces are 3-4-1-2 and 1-2-5-6.

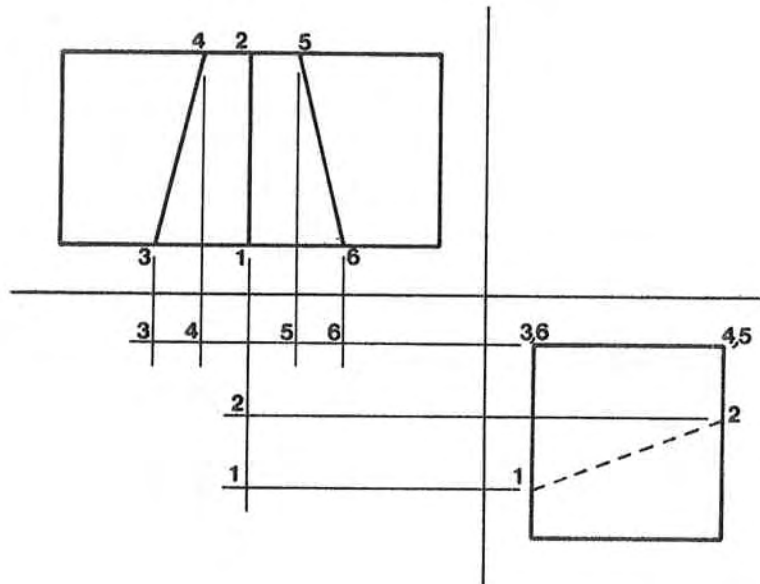


Figure 7-13(c)

- Project points 1, 2, 3, 4, 5, and 6 into the front view by using projection theory.

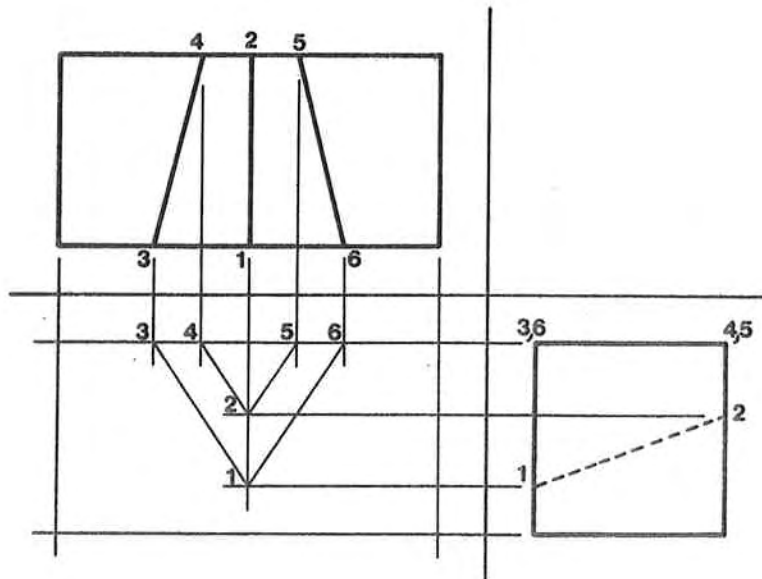


Figure 7-13(d)

5. Using very light lines, lay out the front view of surfaces 3-4-1-2 and 1-2-5-6. After checking your work, complete the initial layout of the entire object.

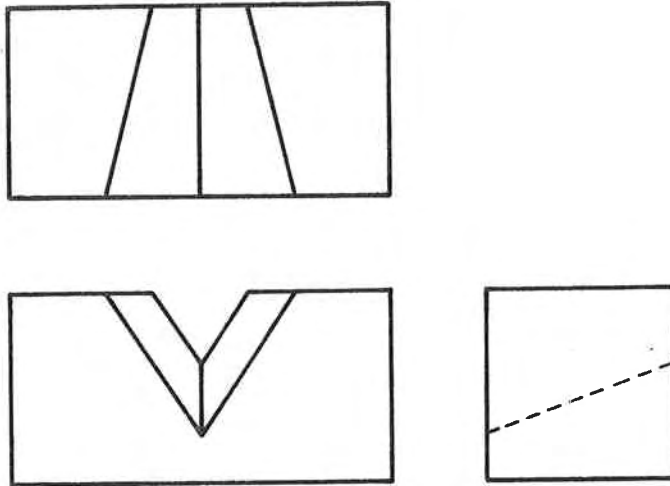


Figure 7-13(e)

6. Erase all excess lines and darken in all lines to their final color and configuration.

Figure 7-14 is another example of a problem that involves a dihedral angle.

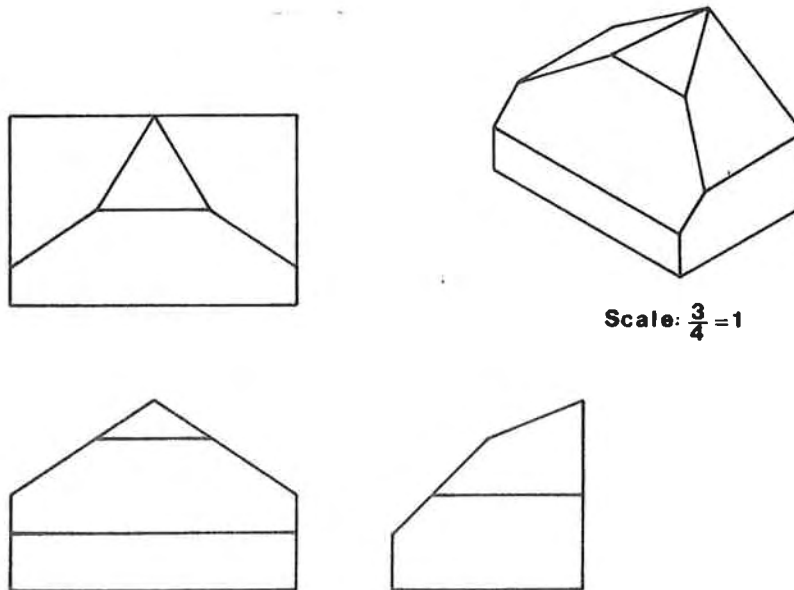


Figure 7-14 Three views of an object which contains several dihedral angles.

7-6 HOLES IN OBLIQUE SURFACES

Figure 7-15 is a problem that involves a hole in an oblique surface. The problem is to draw the top view of the object when the front and right side views are given. Figure 7-16 is the solution and was derived by the following procedure:

GIVEN: Front and side views.

PROBLEM: Draw top view.

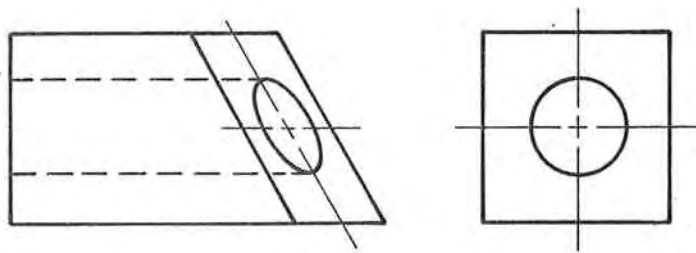
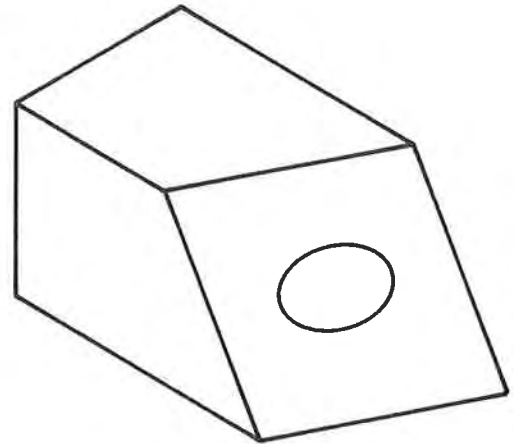
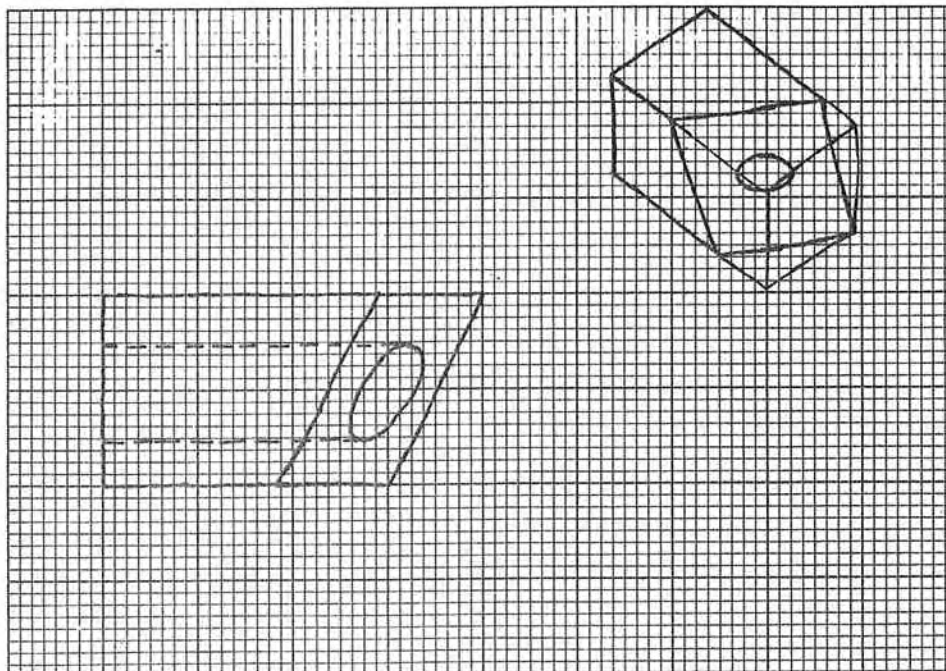


Figure 7-15

SOLUTION:

1. Make, to the best of your ability, a sketch of the solution and, if possible, the entire object.

Figure 7-16(a)



- Using very light lines, draw the top view (not including the hole) by using the procedure outlined for oblique surfaces in Section 7-3.

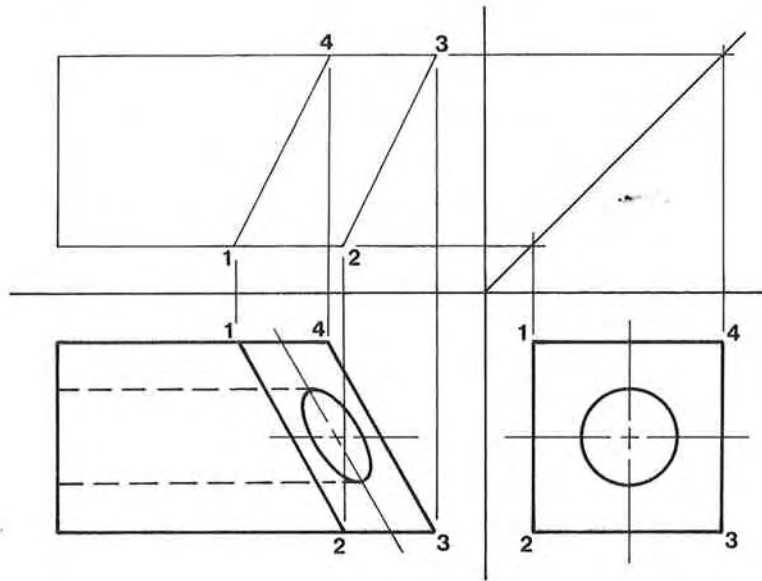


Figure 7-16(b)

- In the right side view, where the hole appears as a circle, mark off and label points 5 through 16 at 30° -intervals around the circle. Although these points do not really exist on the circle, they are to be used for reference.

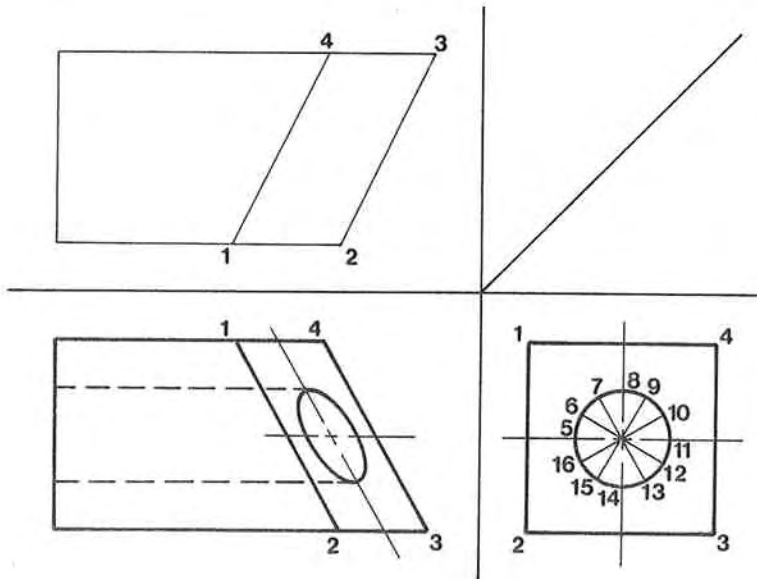


Figure 7-16(c)

- Project points 5 through 16 from the right side view into the front view as shown in Figure 7-16. Label the points. Be careful not to reverse the points when you project between views. For example, points 16 and 12 are on the same horizontal projection line, but point 16 is to the left of center and point 12 is to the right of center.

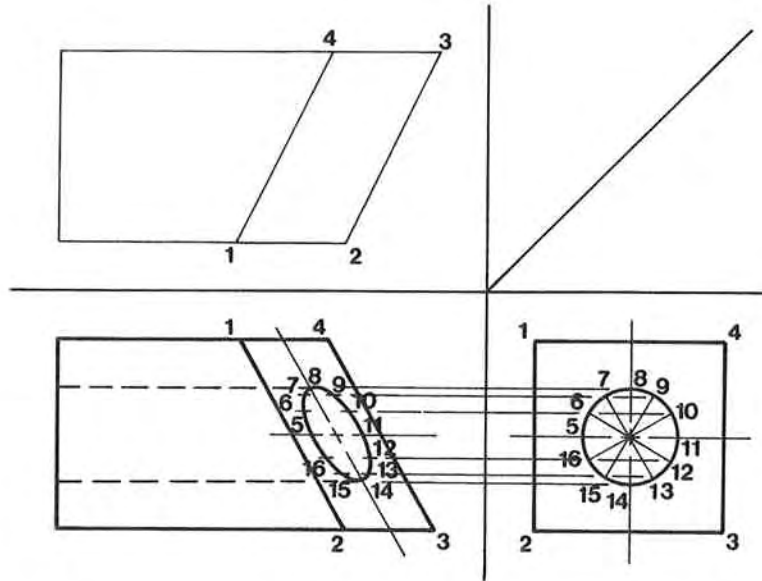


Figure 7-16(d)

- Using the information from the front and right side views, project points 5 through 16 into the top view. Check each point carefully.

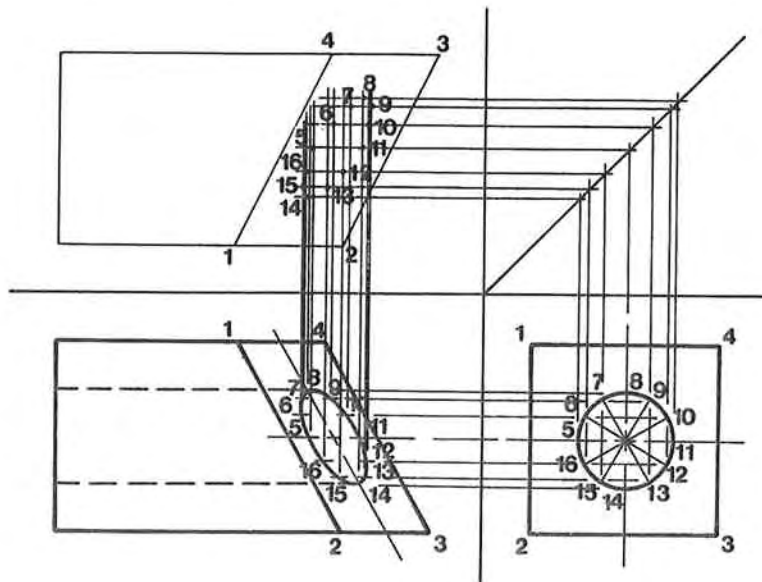


Figure 7-16(e)

6. Erase all excess lines and darken in all lines to their final color and configuration.

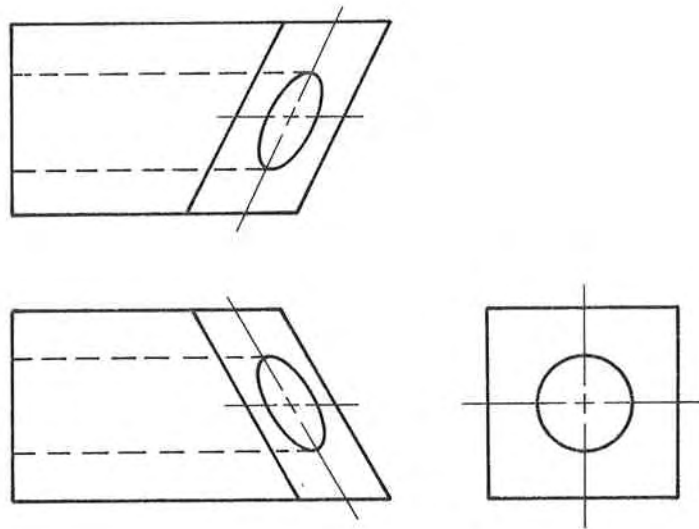


Figure 7-16(f)

GIVEN: An object.

PROBLEM: Draw front, top, and side views.

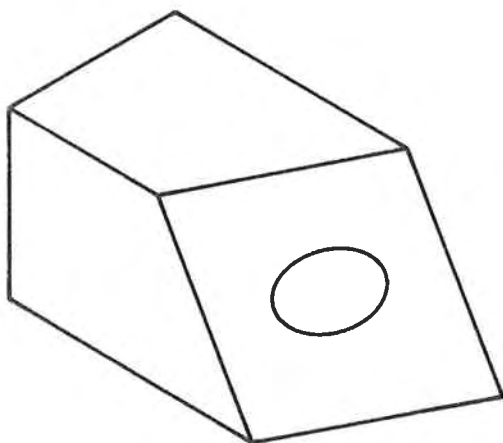


Figure 7-17

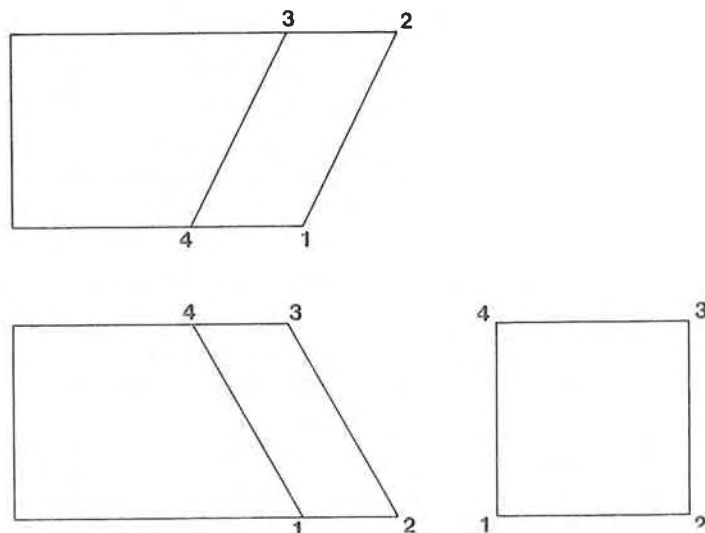
The use of 30° -intervals in step 3 was made simply because it is easy to draw 30° -angles with a T-square and a 30-60-90 triangle as a guide. Any angle could have been used, including randomly spaced angles. The more points used, the more accurate will be the projected ellipse.

But what if we must work from an isometric drawing? Figure 7-17 shows an isometric drawing of the object used for Figure 7-15, but this time we know less about the shape of the hole because we are given much less information to work with. Nevertheless, we can draw three views of the object, including the hole. Figure 7-18 is the drawing sequence used to convert the isometric drawing given in Figure 7-17 to three orthographic views. The following procedure was used:

SOLUTION:

1. Draw the front, top, and side views of the object from the given information. You will not be able to include the hole.

Figure 7-18(a)



2. Since we know that the hole will be drilled in a horizontal direction and that it will be centered in the object, we can draw it as a circle in the right side view.

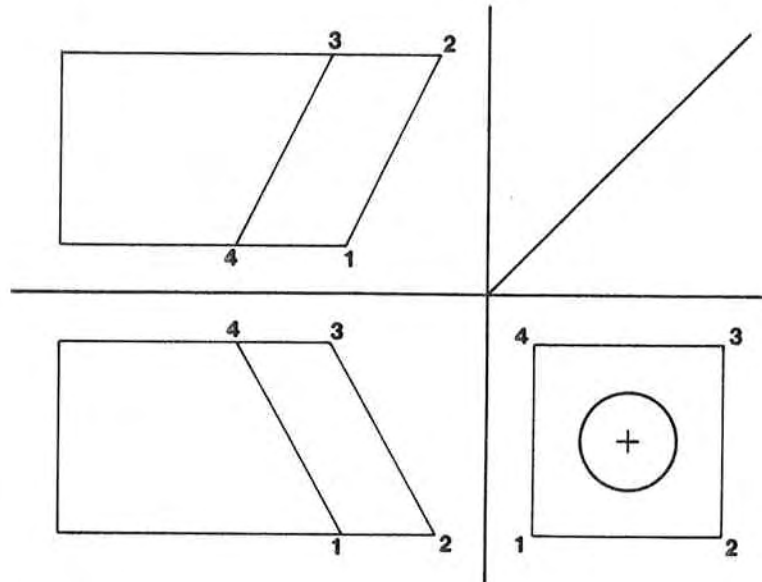


Figure.7-18(b)

3. Using a T-square and 30-60-90 triangle, mark off lines, 30° apart, in the right side view as shown. Label the lines.

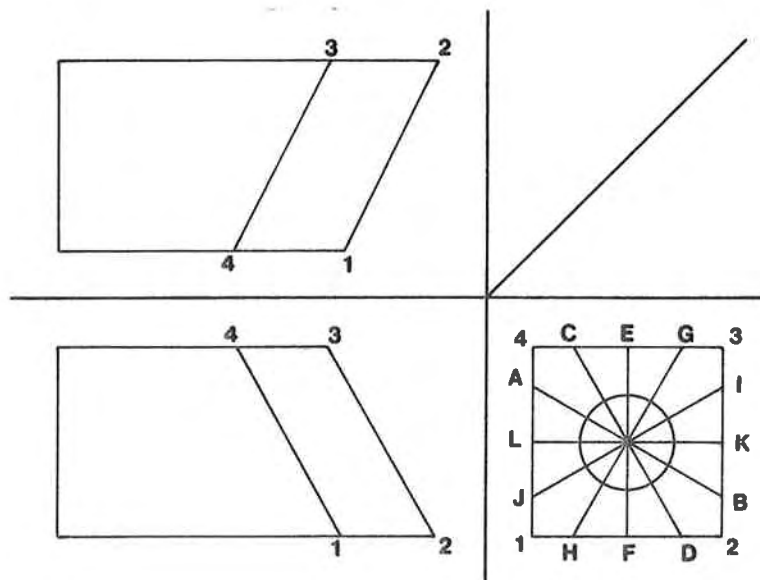


Figure 7-18(c)

- Project lines A-I, L-K, and J-B into the front view by projecting points A, L, and J from line 4-1 in the side view to line 4-1 in the front view and points I, K, and B from line 3-2 in the side to line 3-2 in the front view. Note that lines A-I, L-K, and J-B cannot be projected into the top view and that lines C-D, E-F, and C-H cannot be projected into the front view.

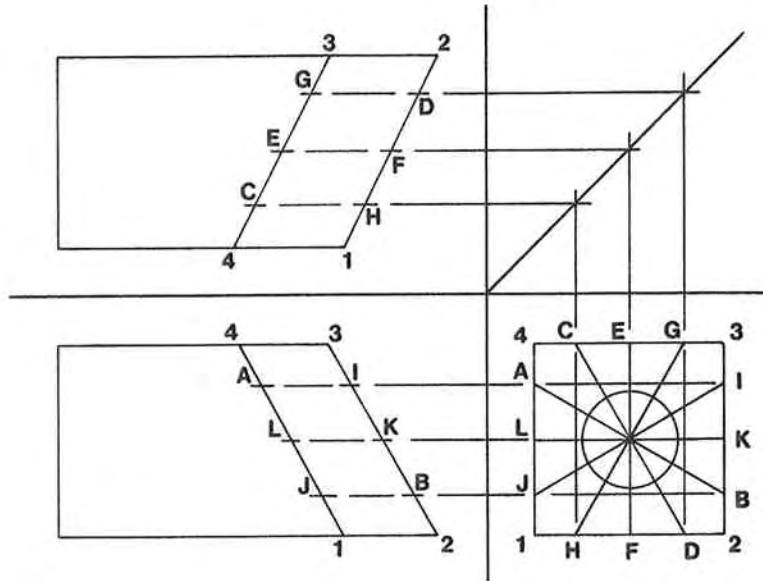


Figure 7-18(d)

- Project points A, L, J, I, K, and B from the front view to the top view as shown.

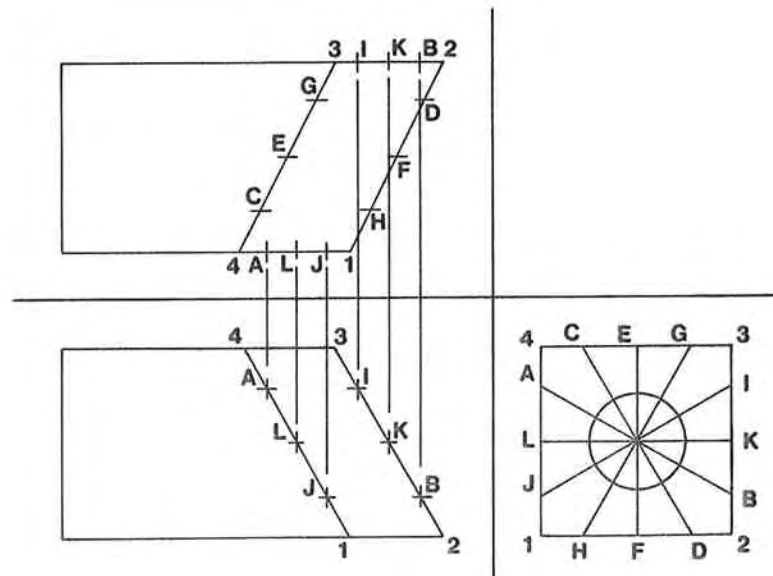


Figure 7-18(e)

- Project points C, E, G, H, F, and D from the top view into the front view as shown.

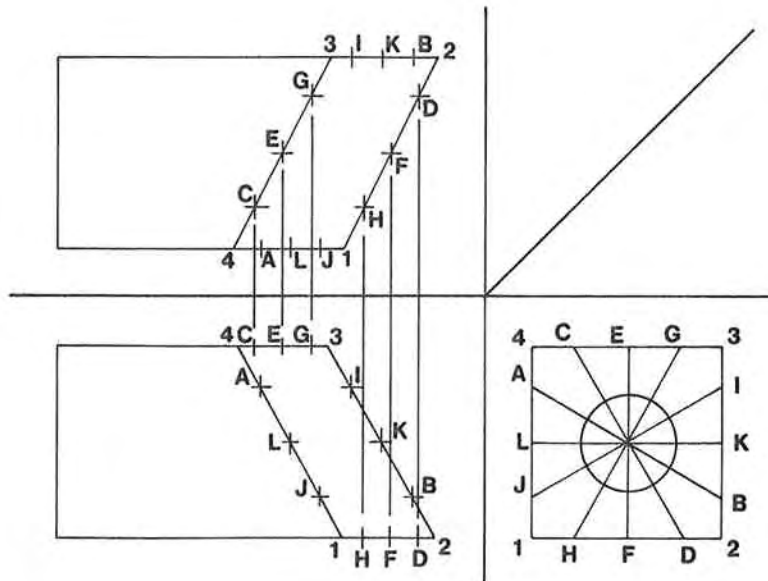


Figure 7-18(f)

- Draw in lines A-B, C-D, E-F, G-H, I-J, and L-K in the front and top views.

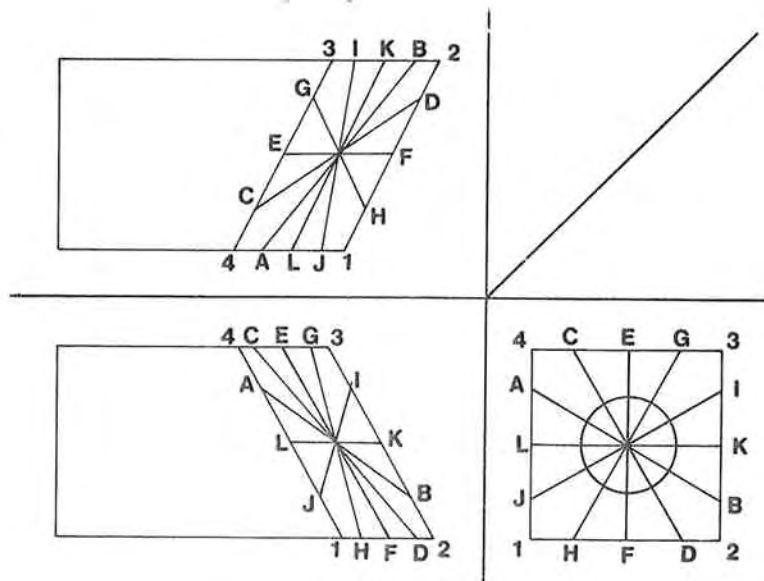


Figure 7-18(g)

8. In the side view, label the intersections that the 30°-lines make with the side view of the hole.

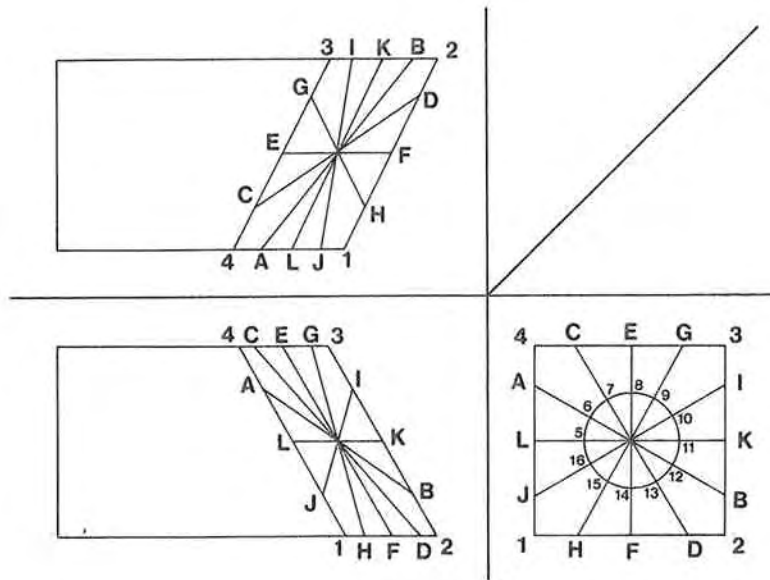


Figure 7-18(h)

9. Project points 6, 7, 8, 9, 10, 12, 13, 14, 15, and 16 into the front view and points 9, 10, 11, 12, 13, 15, 16, 5, 6, and 7 into the top view. Note that points 5 and 11 cannot be projected into the front view and that points 8 and 14 cannot be projected into the top view.

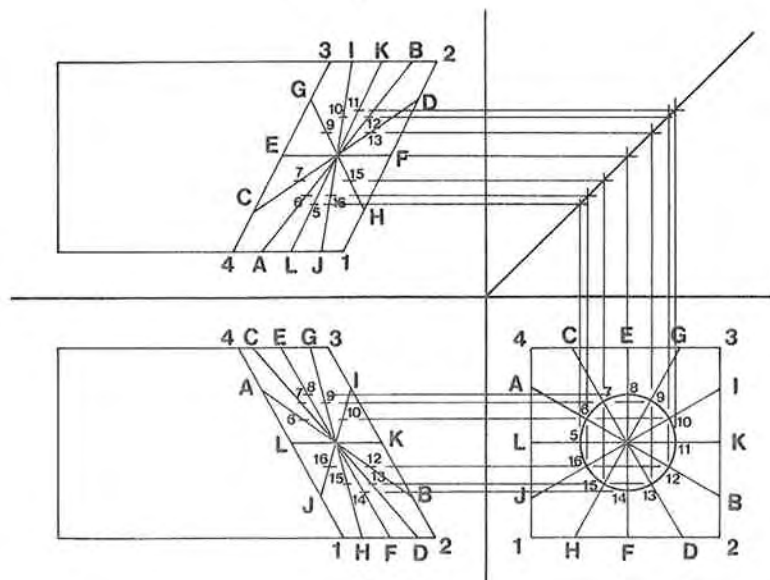


Figure 7-18(i)

- Project points 8 and 14 from the front view to the top view and project points 5 and 11 from the top view to the front view.

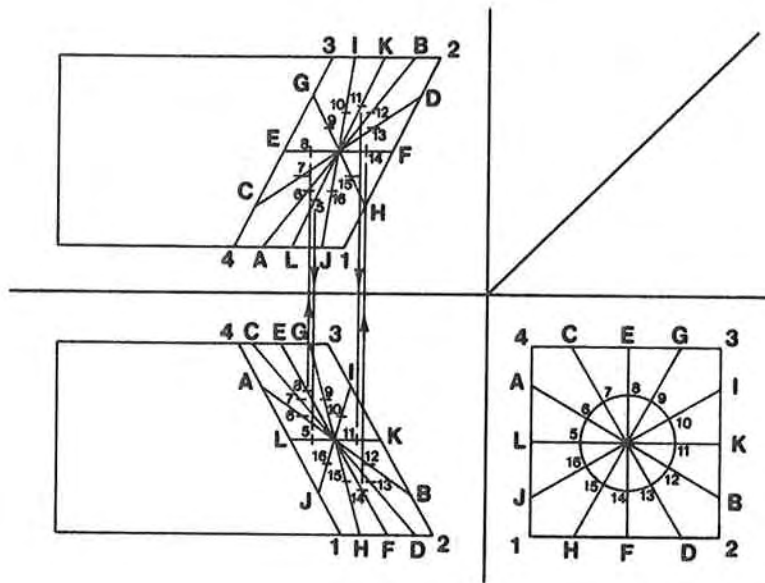


Figure 7-18(j)

- The hole is now defined in each view. Erase all excess lines and darken in the final lines (including the hole) to their proper color and configuration.

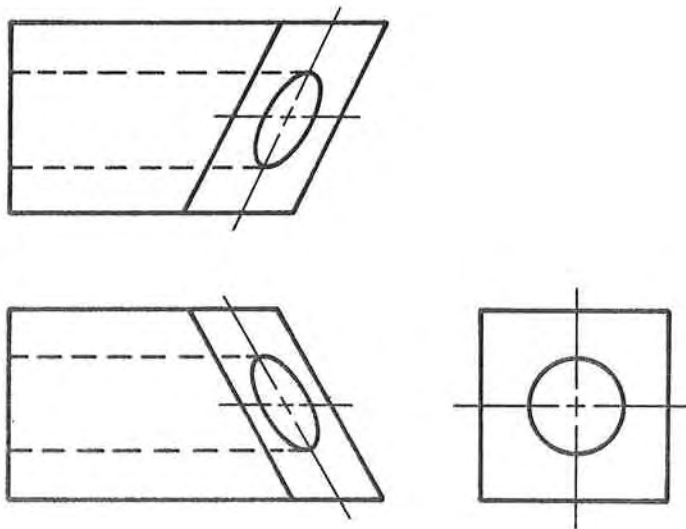


Figure 7-18(k)

7-7 INTERNAL SURFACES IN OBLIQUE SURFACES

Figure 7-19 is a problem that involves an internal surface in an oblique surface. This kind of problem is very similar to problems that involve holes in oblique surfaces. The problem here is to draw the front view of the object when the top and right side views are given. Figure 7-20 is the solution and was derived by the listed procedure:

GIVEN: Top and side views.
PROBLEM: Draw front view.

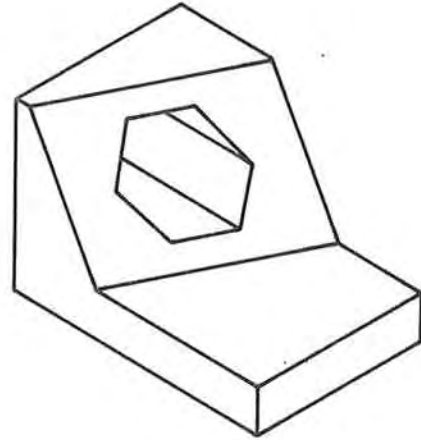
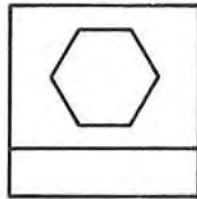
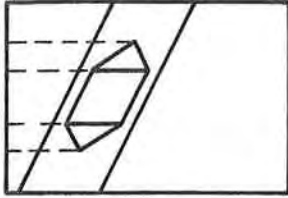
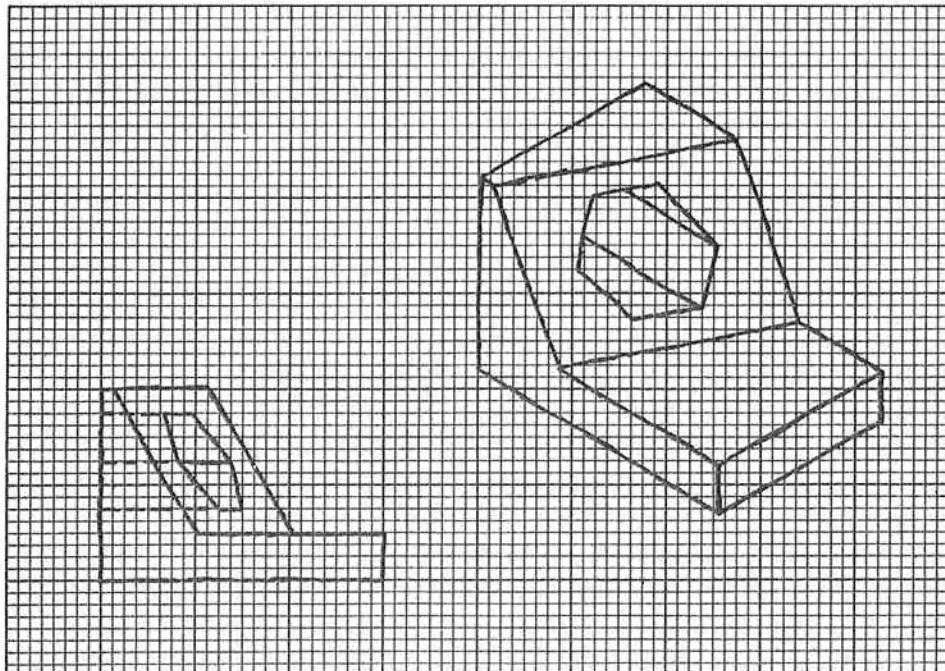


Figure 7-19

SOLUTION:

1. Draw a front view of the object. Include the oblique surface and omit the internal surfaces. Use the outline presented in Section 7-3.

Figure 7-20(a)



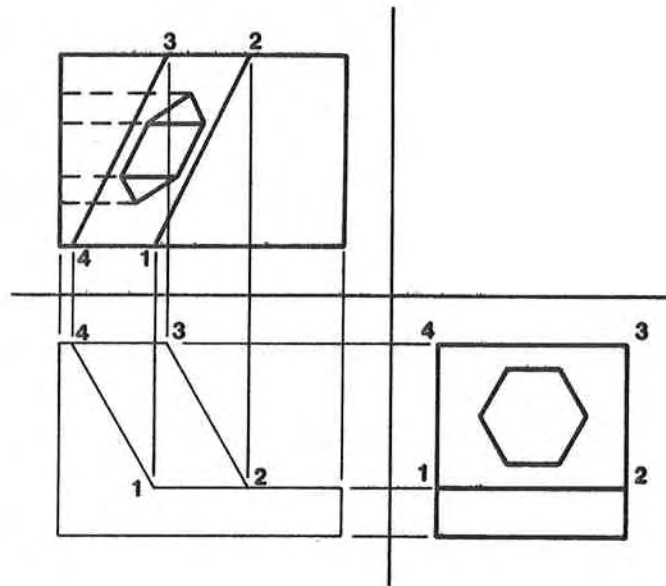


Figure 7-20(b)

2. Number the points of the internal surfaces in the given views. In this example the six corners of the hexagon cutout were labeled points 5, 6, 7, 8, 9, and 10.

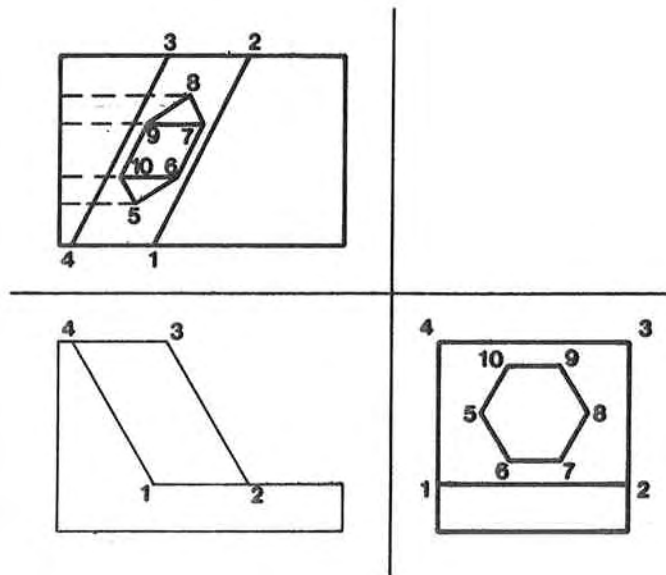


Figure 7-20(c)

- Using projection theory, project points 5 through 10 into the front view.

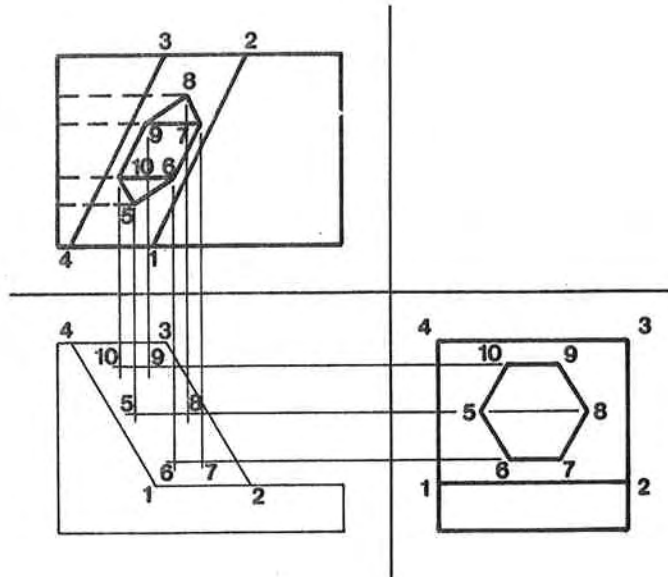


Figure 7-20(d)

- Erase all excess lines and darken in all lines to their final color and configuration.

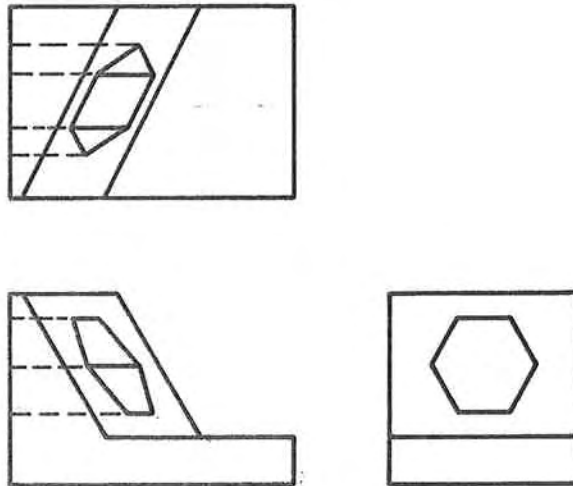


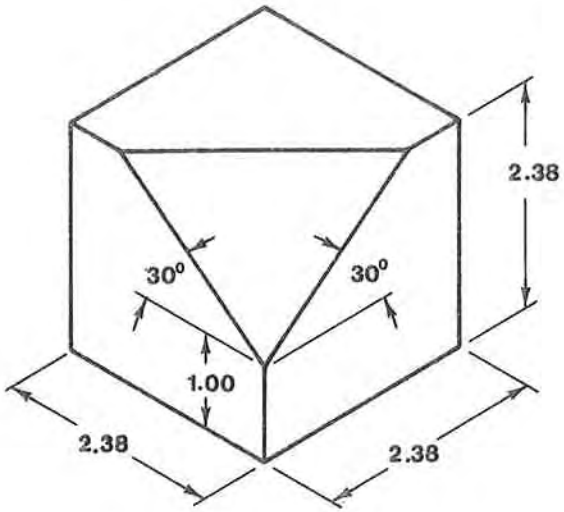
Figure 7-20(e)

When you work on a problem that involves internal surfaces, it is important that you carefully label the intersection of the internal surfaces with the outer surfaces. If necessary, add imaginary points (as was done for holes in internal surfaces) to help insure an accurate projection of the shape of the intersection.

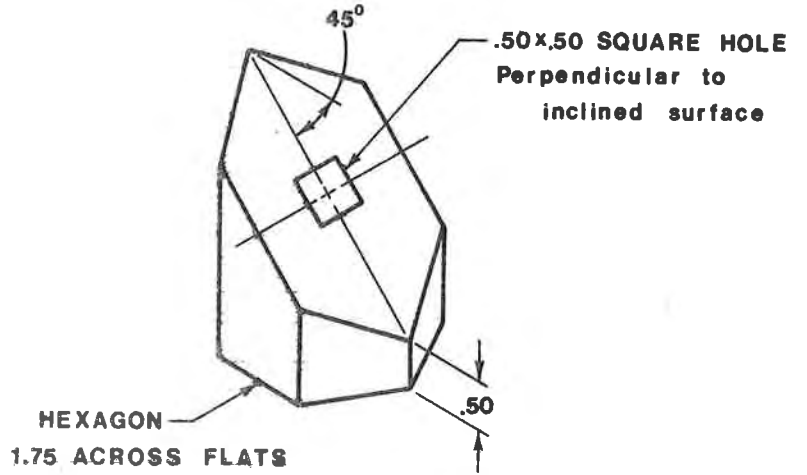
PROBLEMS

Draw three views (front, top, and side) of the following objects:

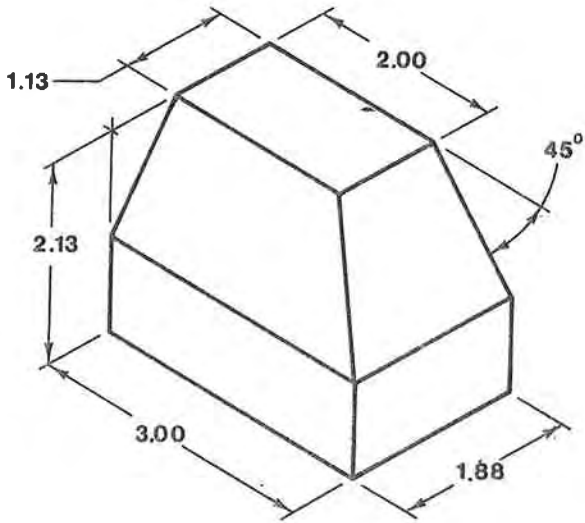
7-1



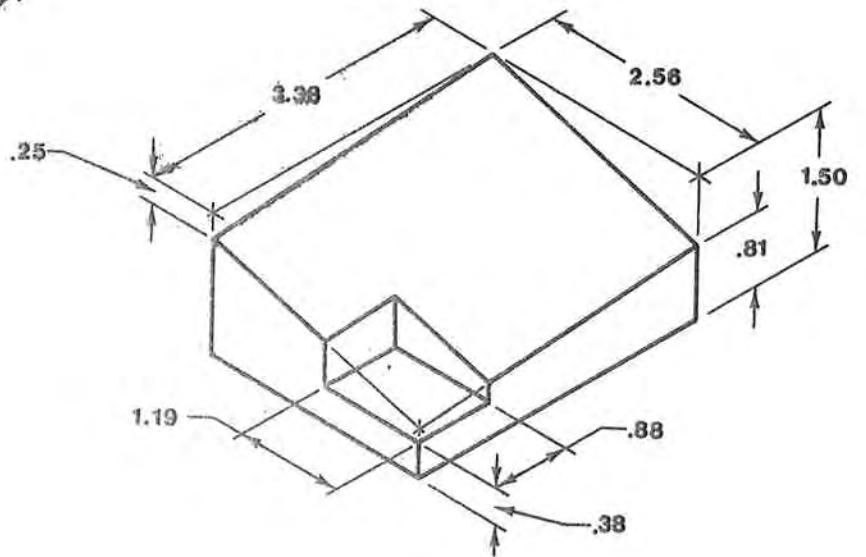
7-2



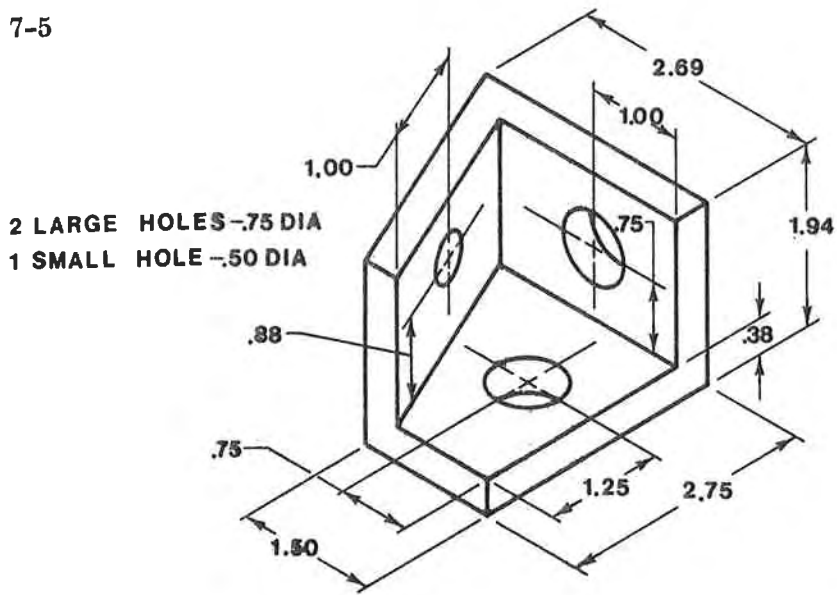
7-3



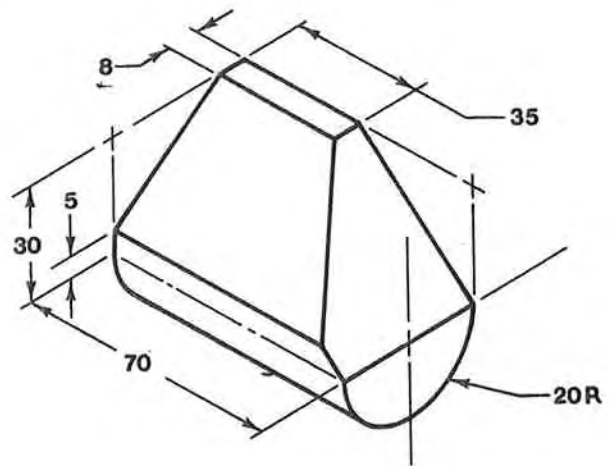
7-4



7-5



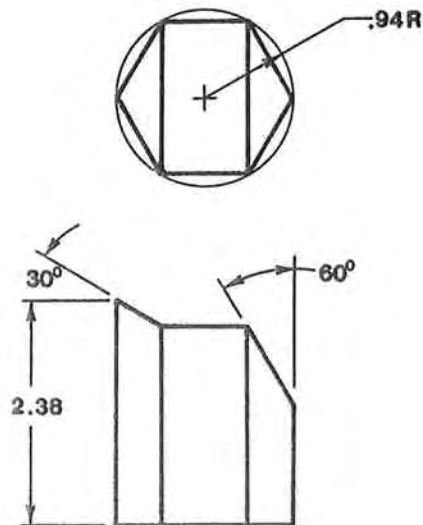
7-6



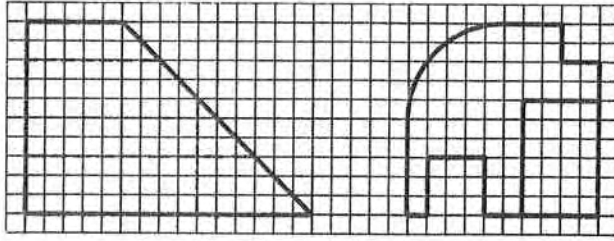
Millimeters

For each of the following problems, redraw the given two views and add the appropriate view so that each object is defined by a front, top, and side view. Each square of the grid pattern is 0.20 on each side.

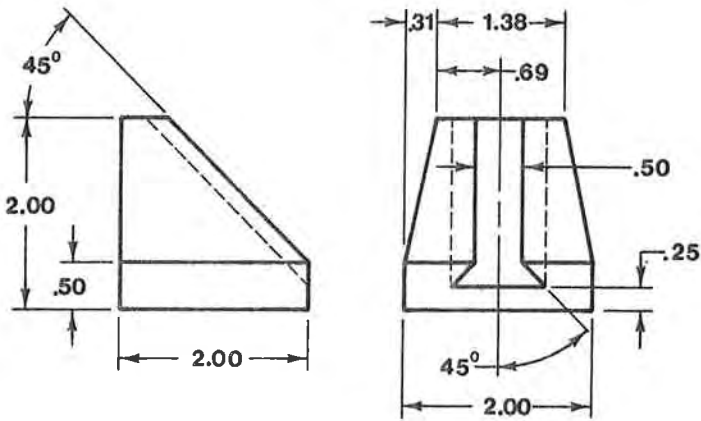
7-7



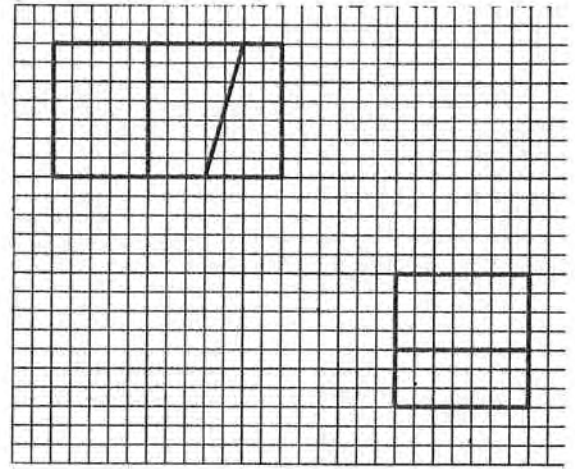
7-8



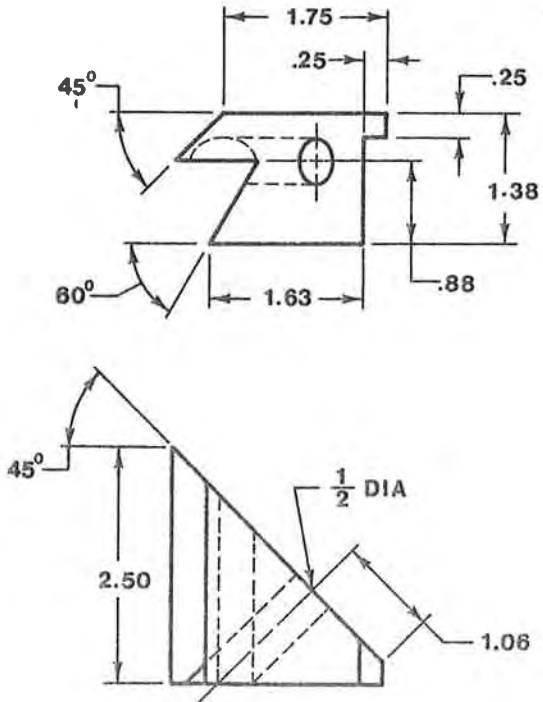
7-9



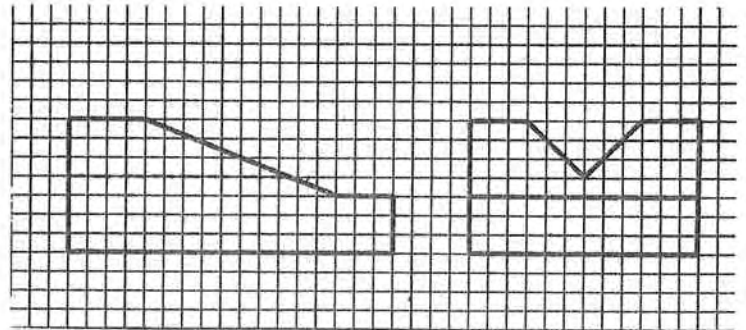
7-10



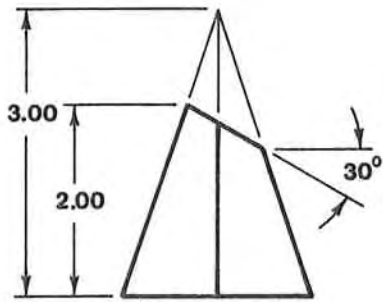
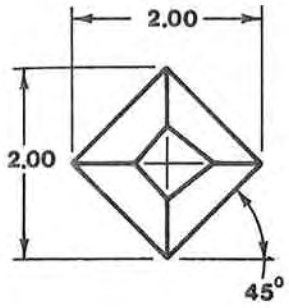
7-11



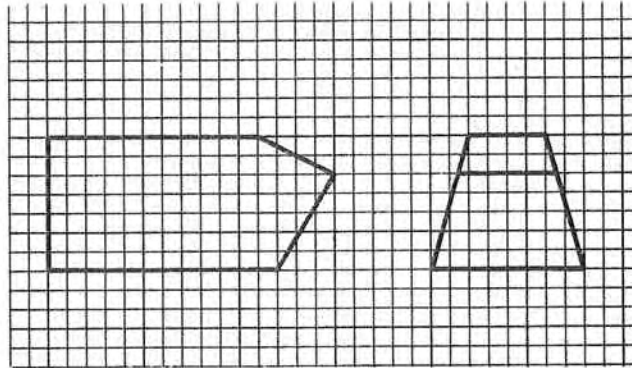
7-12



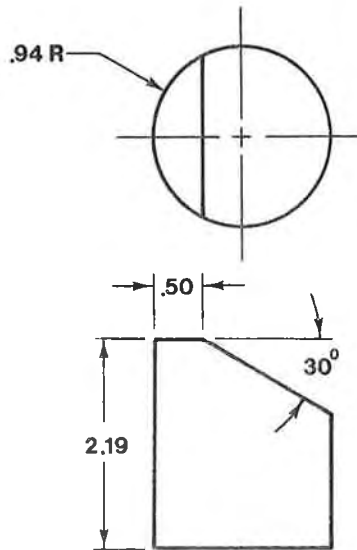
7-13



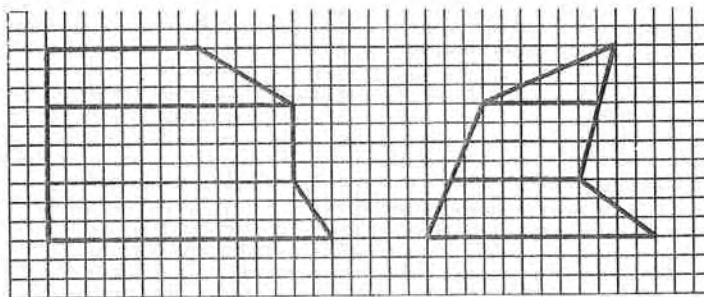
7-14 This problem is based on information supplied courtesy of Wendt-Sonis/Unimet Division of TRW, Inc.



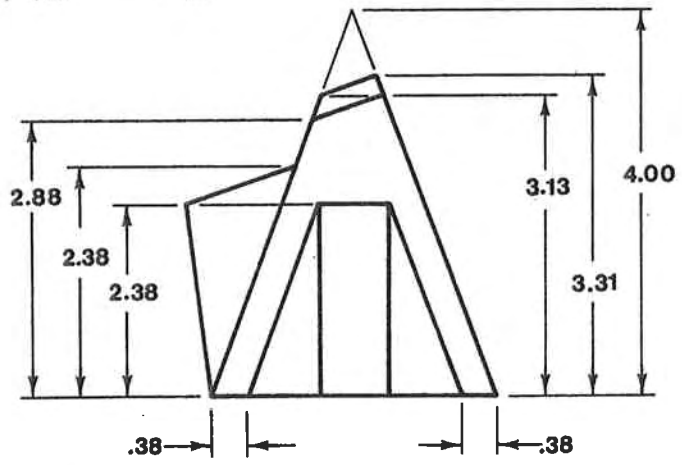
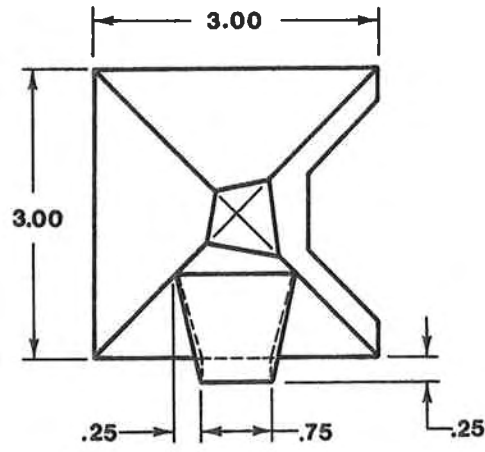
7-15



7-16



7-17 Problem courtesy of Mr. Tony Lazaris.



CYLINDERS 8

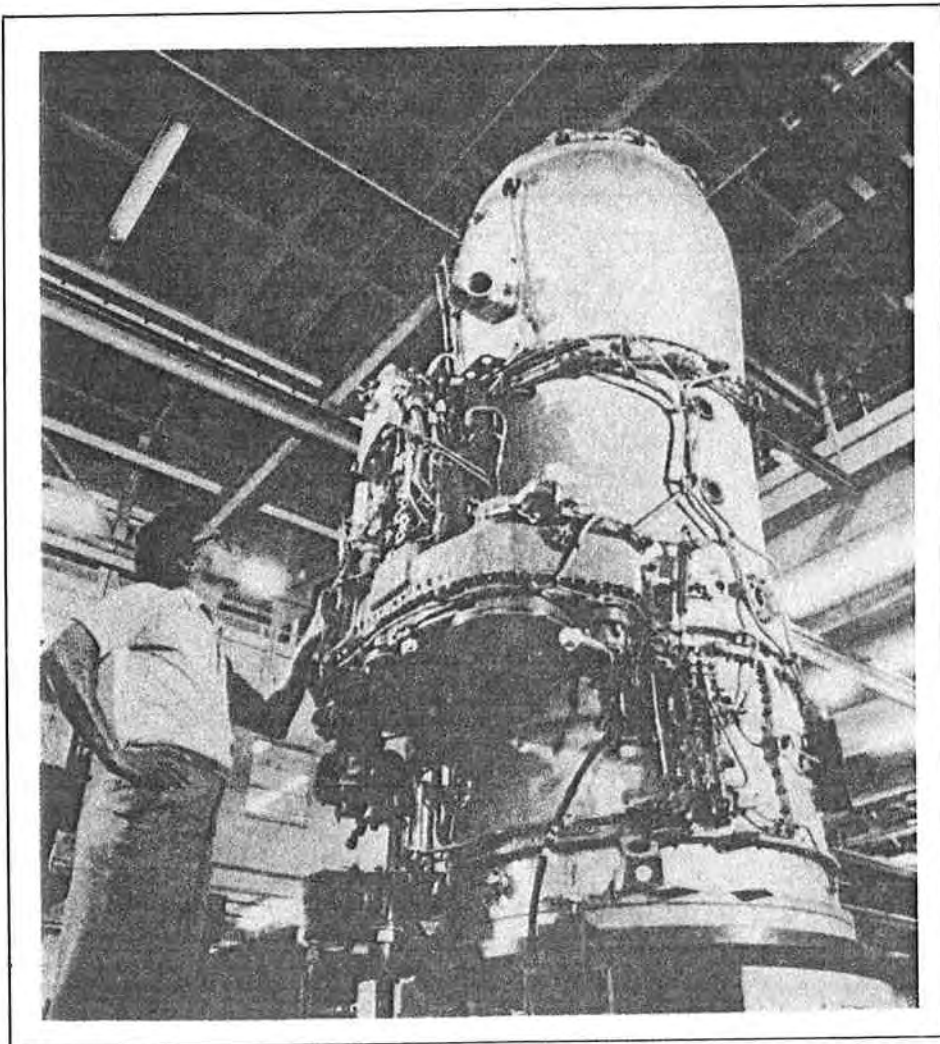


Figure 8-0 Photograph courtesy of Detroit Diesel Allison, Division of General Motors Corp.

8-1 INTRODUCTION

Cylinder problems are problems whose basic geometric shape is a cylinder. They are often difficult to visualize and draw because they have no natural flat surfaces, making it confusing to know where to start. Figure 8-1 demonstrates this point by showing front, top, and right side views of a natural, uncut cylinder. The front and top views are identical and regardless of how the cylinder is rotated about the center point, x , the front and top views remain identical. How can we label or reference cylinders to make sure that those who read the finished drawings clearly understand which view is the front and which is the top?

The key to solving the problems is in using the center lines. The right side view of Figure 8-1 defines vertical and horizontal center lines which divide the cylinder into four equal quadrants. Where the horizontal and vertical center lines cross the periphery of the cylinder is defined as *center line edge points*, and are marked points 1, 2, 3, 4, 5, 6, 7, and 8. They are all double points and represent the end views of longitudinal center lines which can be seen in the front and top views. These longitudinal center lines 1-2, 3-4, 5-6, and 7-8 can be used to define the cylinder's height and width and can be used as theoretical base lines from which to reference variances from the basic cylindrical shape (cuts, chamfers, and so on).

It should be understood that although longitudinal center lines do not physically exist on cylindrical pieces, they represent where the curved surface of the cylinder changes direction (see Section 5-5).

Center lines will be used throughout this chapter, as they are in industry, to define and give reference to cylinder problems. The first step in any cylinder problem should be to define the center lines.

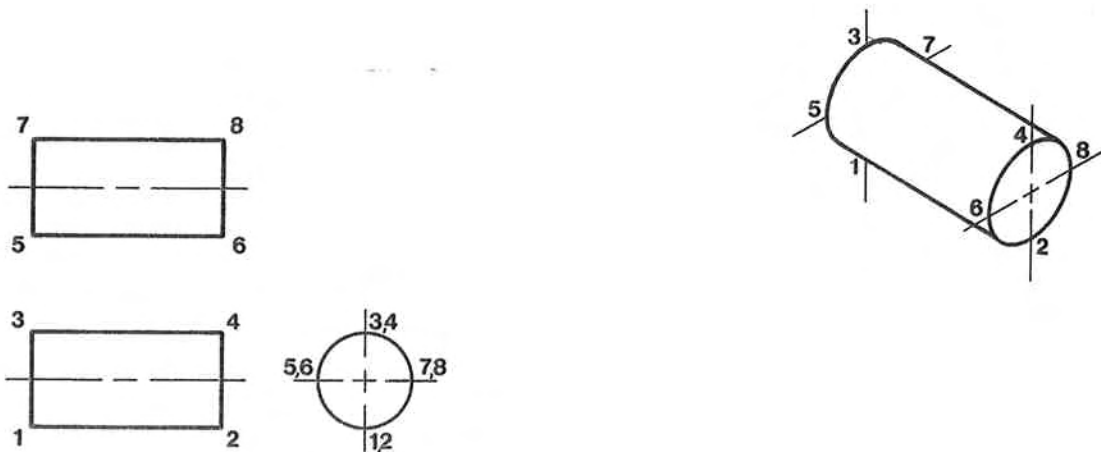


Figure 8-1 Three views of a cylinder.

8-2 CUTS ABOVE THE CENTER LINE

Figure 8-2 is an example of a cylinder cut lengthwise above the center line. The problem is to find the top view when the front and right side views are given. Figure 8-3 is the solution and was derived by the following procedure:

GIVEN: Front and side views.
PROBLEM: Draw top view.

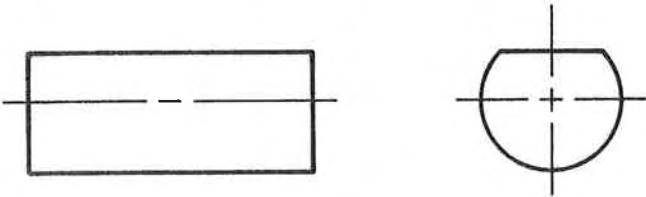
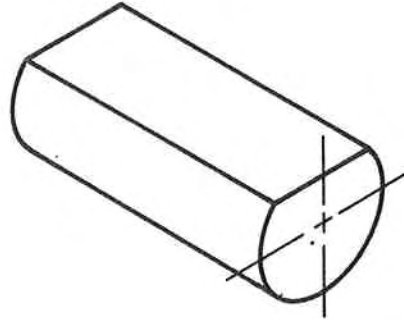


Figure 8-2 Cylinder cut above the centerline.

SOLUTION:

1. Define the horizontal center line edge points—5, 6, 7, and 8—in the front and right side views.

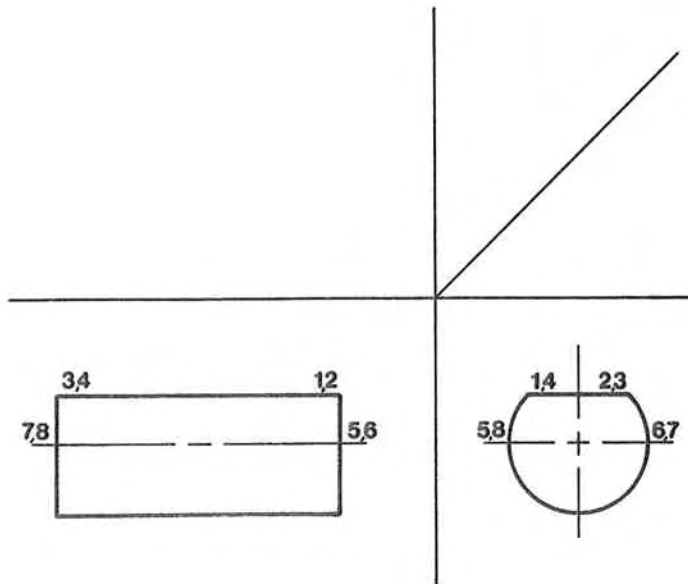


Figure 8-3(a)

2. Project points 5, 6, 7, and 8 into the top view; then, using construction lines, connect the points to form a rectangle.
3. Define the cut surface 1, 2, 3, and 4 in the front and right side views.

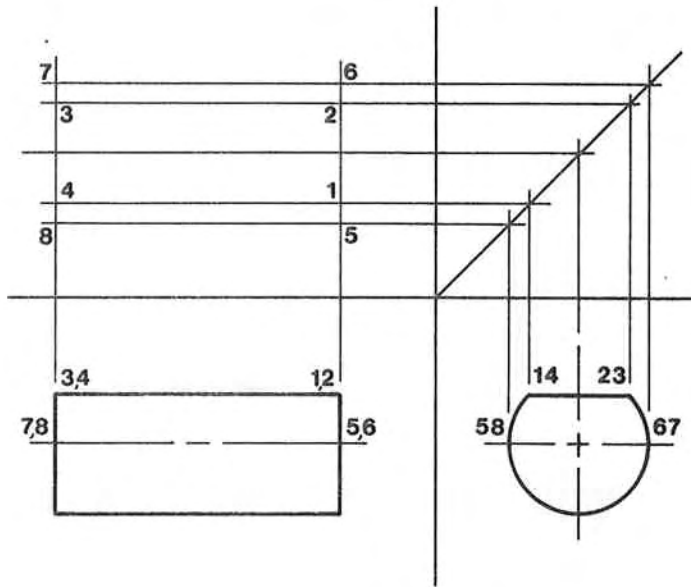


Figure 8-3(b)

4. Project points 1, 2, 3, and 4 into the top view and, using construction lines, connect the points to form a rectangle.
5. Darken in the two rectangles with object lines.

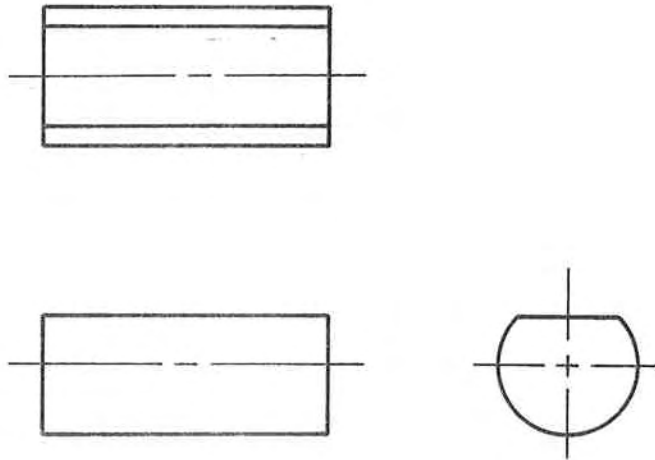


Figure 8-3(c)

Although a technical solution to the problem has been derived, there still may be some difficulty in visualizing what it means. The cut surface 1-2-3-4 which appears as a rectangle in the top view, appears as a straight line in both the front and right side views. The surfaces 8-5-1-4 and 3-2-6-7 appear in the top view to be similar to the flat surface

1-2-3-4, but they are not. Surfaces 8-5-1-4 and 3-2-6-7 are curved surfaces that start at horizontal center lines 5-8 and 7-6 and extend upward to lines 4-1 and 7-6. Study the right side view to verify the length, height, and shape of the curve. Remember that although center edge lines 8-5 and 7-6 do not really appear on the piece, they represent the widest part of the cylinder and where the curve defining the periphery changes directions from outward to inward (see Section 4-7).

8-3 CUTS BELOW THE CENTER LINE

Figure 8-4 is an example of a cylinder cut lengthwise below the center line. The problem is to find the top view when the front and side views are given.

GIVEN: Front and side views.
PROBLEM: Draw the top view.

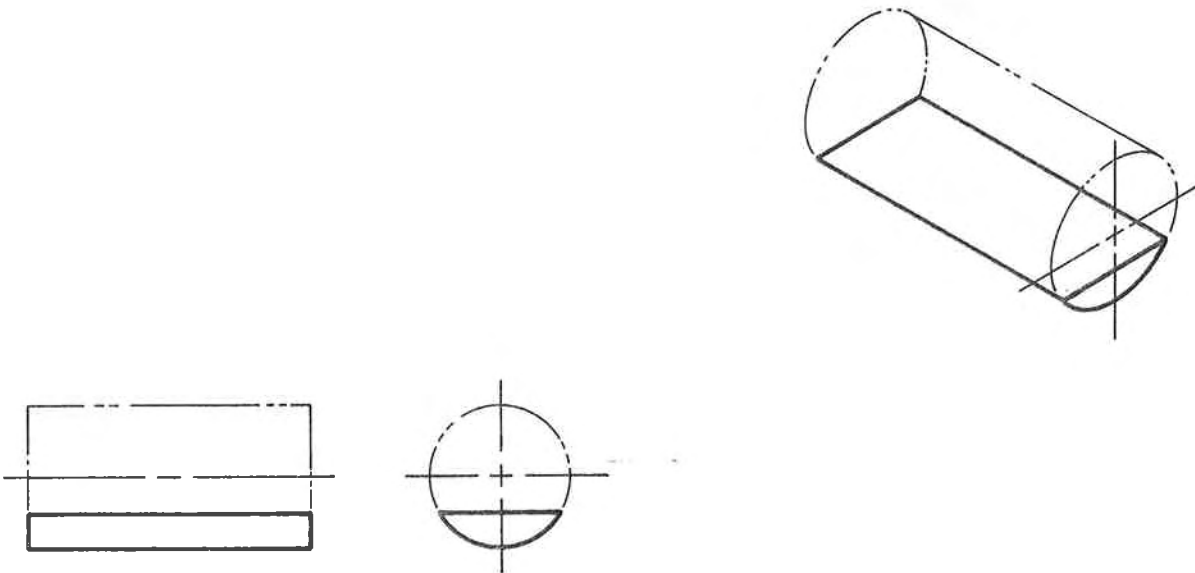


Figure 8-4 Cylinders cut below the centerline.

views are given. Figure 8-5 is the solution and was derived by the following procedure:

SOLUTION:

1. Define the four corners of the cut surface 1-2-3-4 in the front and top views.

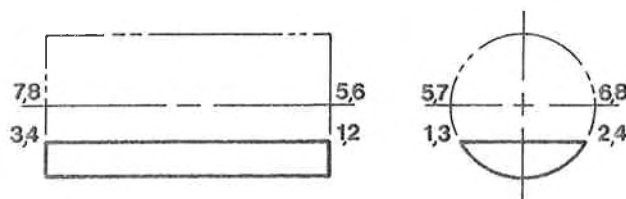


Figure 8-5(a)

2. Project points 1, 2, 3, and 4 into the top view.

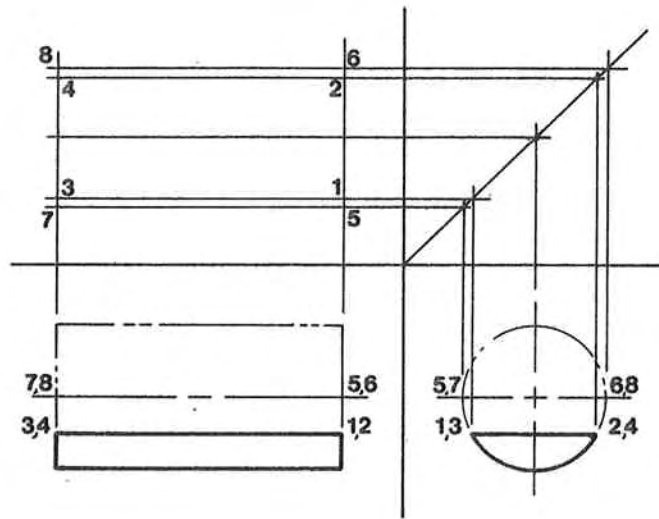


Figure 8-5(b)

3. Connect points 1, 2, 3, and 4 with object lines to complete the top view.

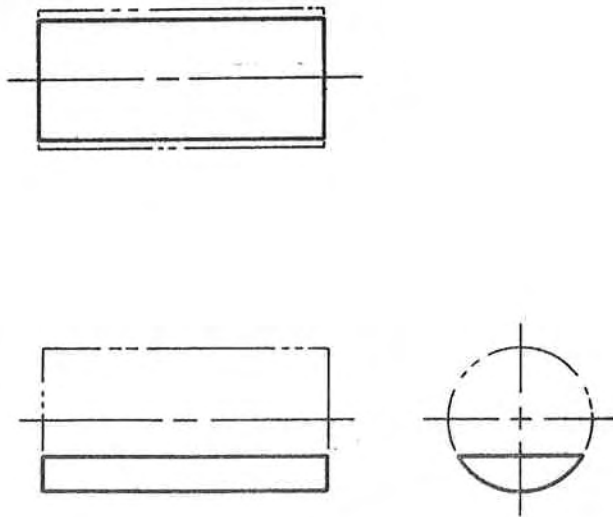


Figure 8-5(c)

The plane 1-2-3-4 is a flat surface that has a round surface directly under it.

8-4 INCLINED CUTS

Figure 8-6 is an example of an inclined cut. The problem is to find the top view when the front and right side views are given. Figure 8-7 is the solution and was derived by the listed procedure:

GIVEN: Front and side view.
PROBLEM: Draw top view.

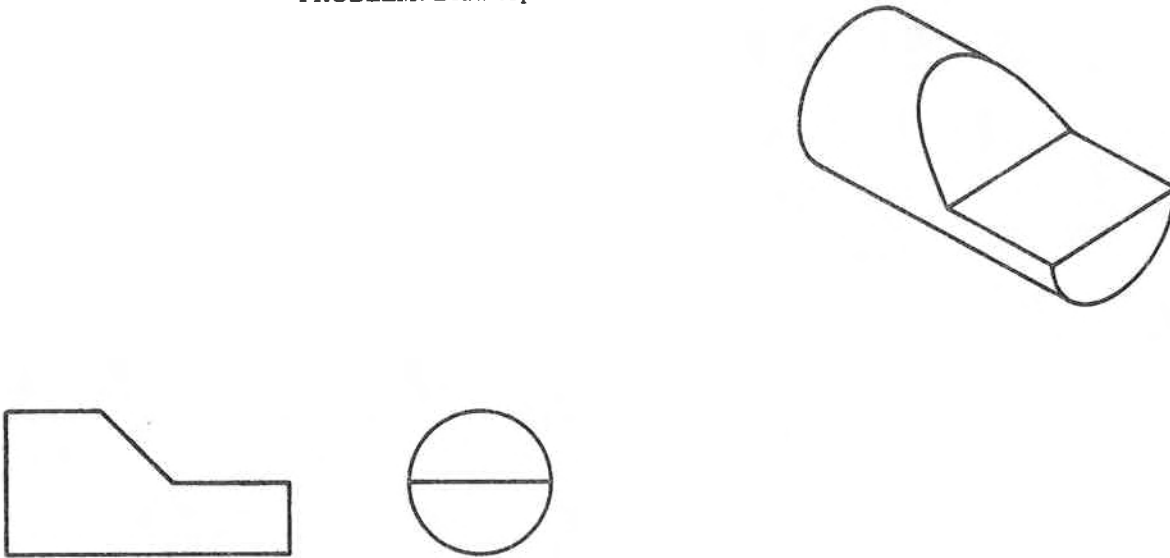


Figure 8-6 Cylinder with an inclined cut.

SOLUTION:

1. Define the horizontal center line edge points 1, 9, 10, and 11 in the front and right side views.
2. Project the horizontal center line edge points 1, 9, 10, and 11 into the top view thereby defining the outside edge of the cylinder.
3. Create points 2, 3, 4, 5, 6, 7, and 8 in the right side view by marking off angles of 0° , 30° , 60° , 90° , 60° , 30° , and 0° from the horizontal center line (30° -increments were chosen because they are easy to draw with a 30-60-90 triangle). These points are for drawing purposes only and do not represent any corners or edges which appear on the piece and, therefore, they should be drawn very lightly. Once the solution has been derived, these points should be erased.
4. Project points 2, 3, 4, 5, 6, 7, and 8 into the front view. This is done by drawing lines parallel to the horizontal principal plane line from the created points 2, 3, 4, 5, 6, 7, and 8 to the inclined surface in the front view. Points (6, 4), (7, 3), and (8, 2) become double points in the front view.
5. Project points 2, 3, 4, 5, 6, 7, and 8 into the top view.
6. Using a French curve, carefully draw in the elliptical shape by connecting points 2, 3, 4, 5, 6, 7, and 8. Be careful to avoid a lumpy or ragged curve. The finished ellipse should be smooth and symmetrical.
7. Complete the top view by projecting the necessary points from the front and right side views.

8-5 CURVED CUTS

Figure 8-8 is an example of a cylinder with a curved cut. The problem is to find the top view when the front and right side views are given. Figure 8-9 is the solution and was derived by the listed procedure:

GIVEN: Front and side views.
PROBLEM: Draw the top view.

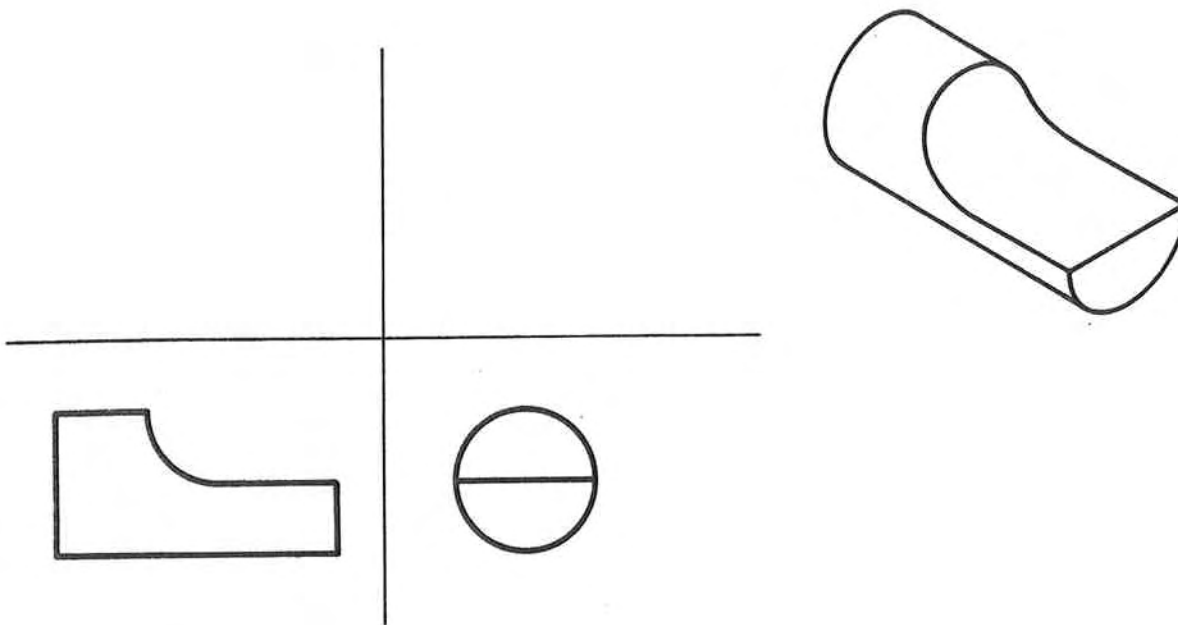


Figure 8-8 Cylinder with a curved cut.

SOLUTION:

1. Define the horizontal center line edge points 1, 2, 3, and 4 in the front and right side views.

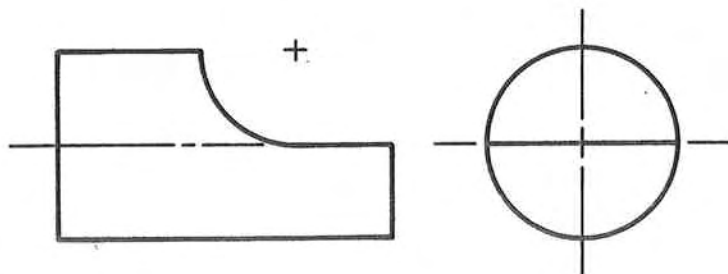


Figure 8-9(a)

2. Project the horizontal center line edge points 1, 2, 3, and 4 into the top view thereby defining the outside edge of the cylinder.

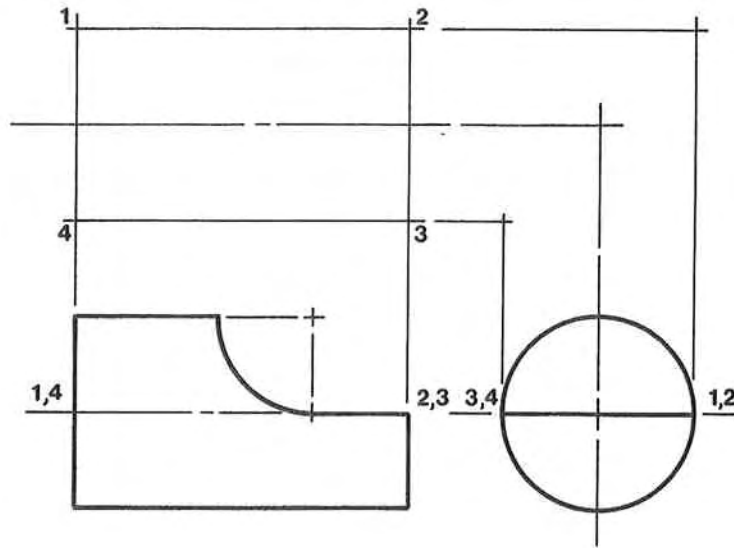


Figure 8-9(b)

3. Create points 5, 6, 7, 8, 9, 10, and 11 in the right side view by marking off angles of 0° , 30° , 60° , 90° , 60° , 30° , and 0° from the horizontal center line (30° increments were chosen because they are easy to draw with a 30-60-90 triangle). These points are for drawing purposes only and would never appear on the piece; therefore, they should be drawn very lightly. After the solution has been derived, these points should be erased.

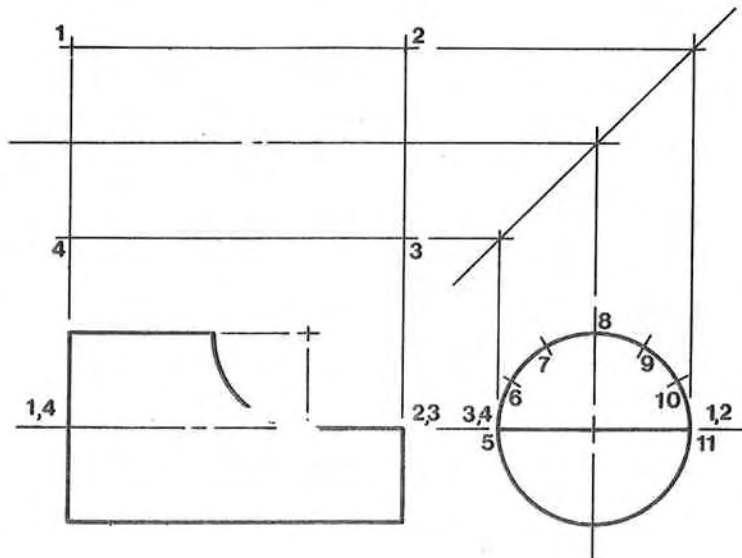


Figure 8-9(c)

4. Project points 5, 6, 7, 8, 9, 10, and 11 into the front view. This is done by drawing lines parallel to the horizontal principal plane line from the created points 5, 6, 7, 8, 9, 10, and 11 to the inclined surface in the front view. Points (5, 11), (6, 10), and (7, 9) become double points in the front view.

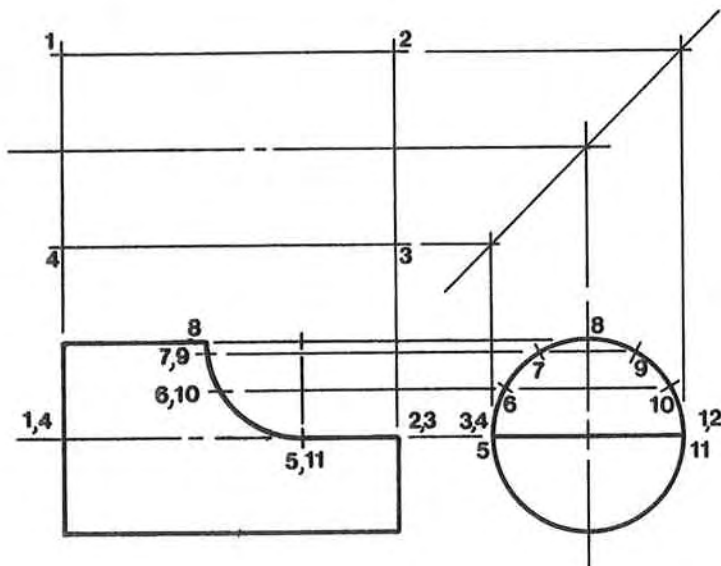


Figure 8-9(d)

5. Project points 5, 6, 7, 8, 9, 10, and 11 into the top view.

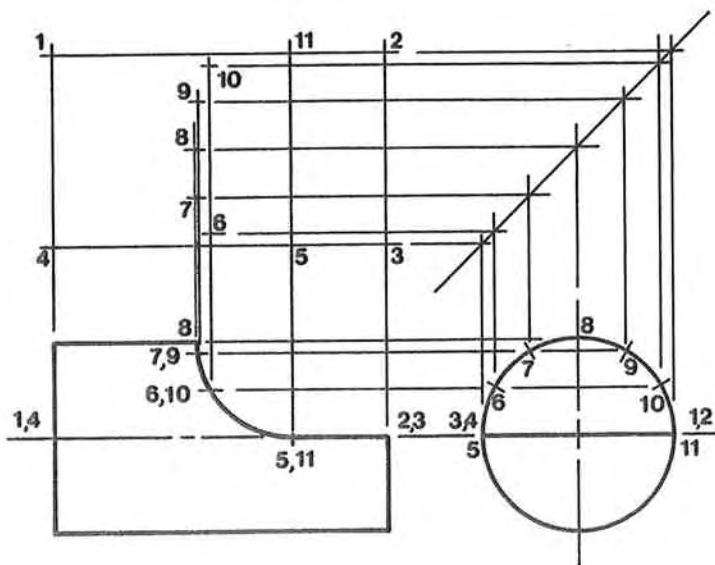


Figure 8-9(e)

6. Using a French curve, carefully draw in the elliptical shape by connecting points 5, 6, 7, 8, 9, 10, and 11. Be careful to avoid a lumpy or ragged curve. The finished ellipse should be smooth and symmetrical.

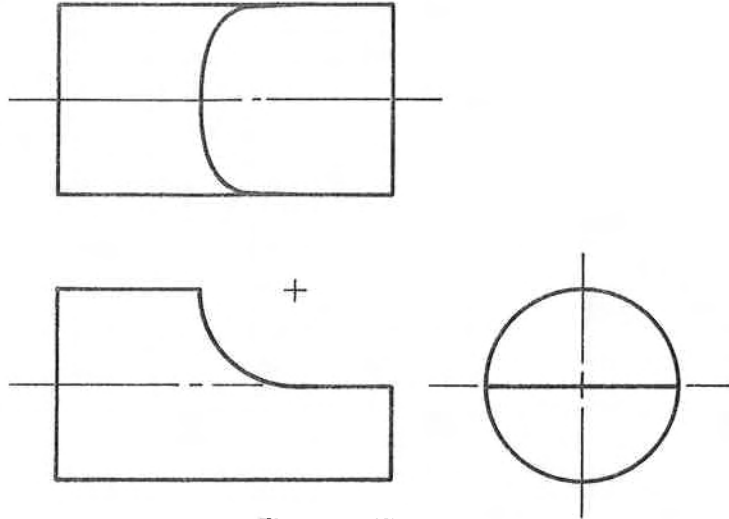


Figure 8-9(f)

7. Complete the top view by projecting necessary points from the front and right side views.

This procedure is exactly the same as that used in Section 8-4 to solve inclined cut problems. However, because of the difference in the kind of cut, the resulting ellipse in the top view is different.

8-6 CHAMFERS

Chamfers are machine cuts, usually at 45° , along the edges or corners of machined pieces. They are used to eliminate sharp, dangerous edges, to trim off material for clearance requirements, or to act as a kind of taper in aligning parts. They are not unique to cylinder problems and Figure 8-10 gives two examples of chamfers in noncylindrical pieces. Figure 8-11 is an example of cylindrical chamfers. The problem is to find the top view where the front and right side views are given. Only the chamfered sections are labeled since the rest of the solution has been previously explained (Section 8-1).

Consider line 2-3-4-5 in the right side view of Figure 8-12. It is an end view of a flat plane that was developed by machining away part of the cylinder and then chamfering the end. The chamfer creates two edge lines that show as concentric circles in the right side view and as parallel lines in the front view. This means that points 3 and 4 are in front of points 2 and 5 and that lines 2-3 and 4-5 are slanted in the top view. After defining points 2, 3, 4, and 5 in the front and side views, project them into the top view and draw lines 2-3, 3-4, and 4-5. There is no line 2-5. Why?

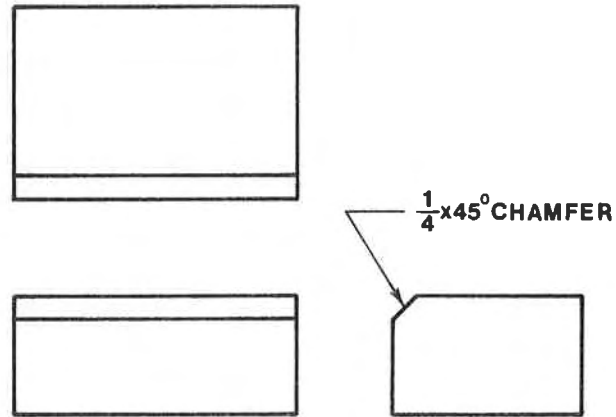
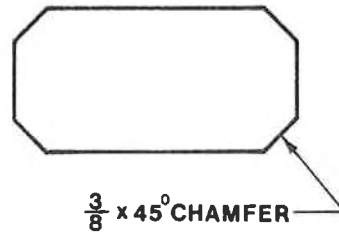


Figure 8-10 Chamfers on non-cylindrical shaped objects.

GIVEN: Front and side views.
PROBLEM: Draw the top-view.

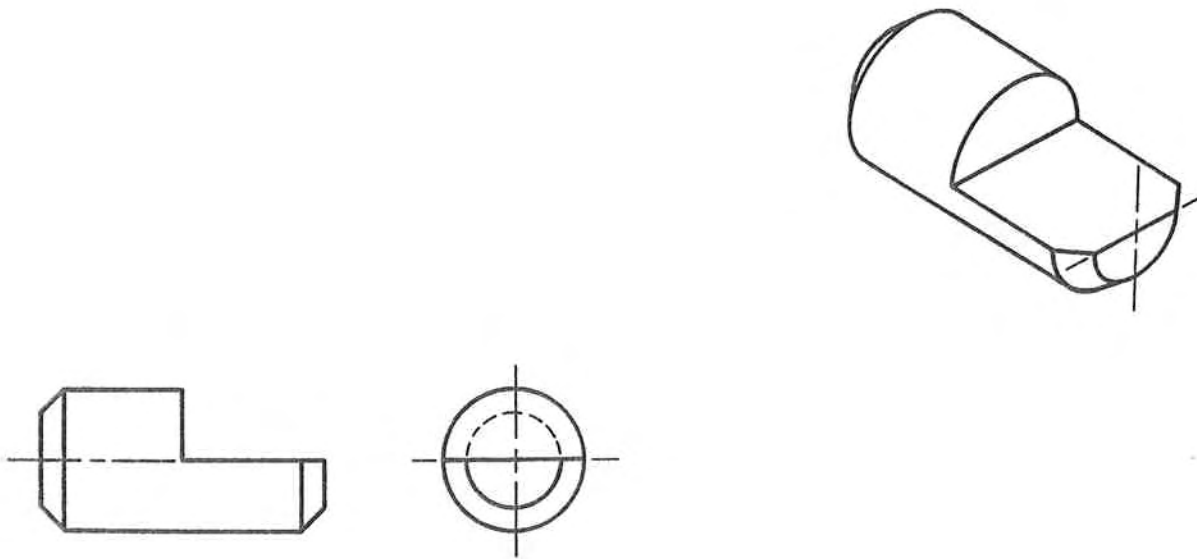


Figure 8-11 Cylinder with chamfers.

SOLUTION:

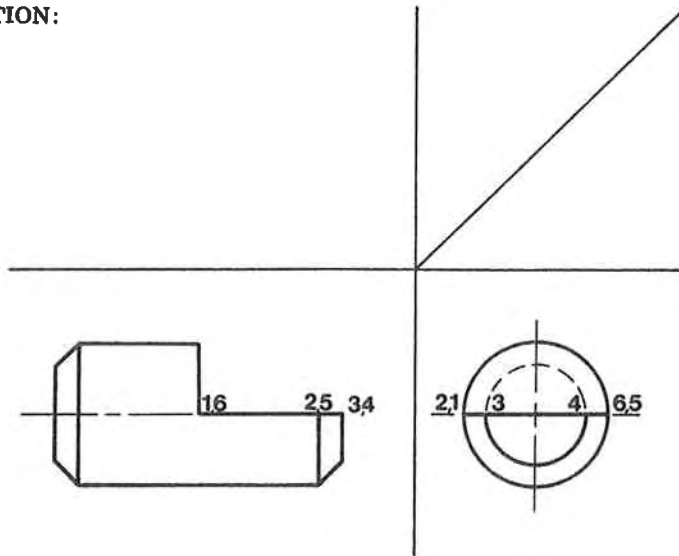


Figure 8-12(a)

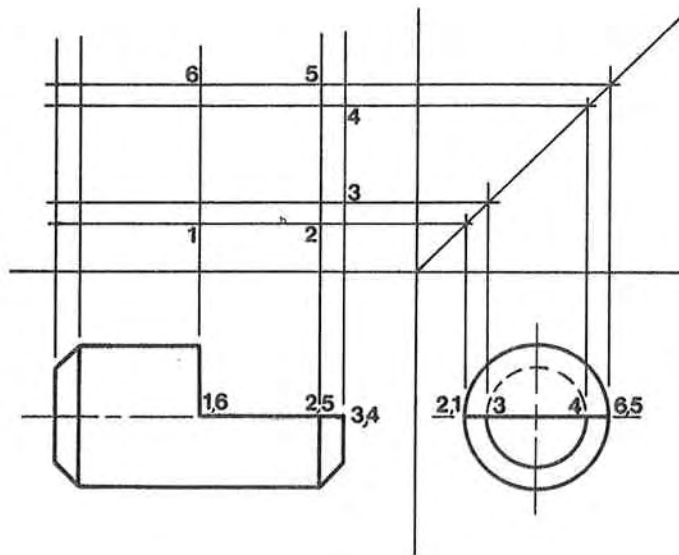


Figure 8-12(b)

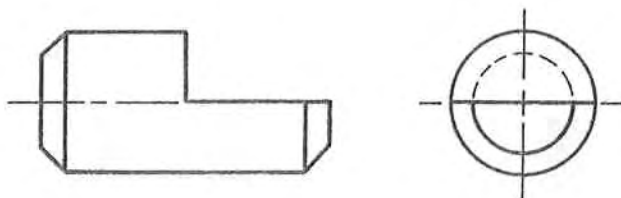


Figure 8-12(c)

8-7 HOLES

When holes are drilled in cylinders, holes create unique drawing and projection problems. Figure 8-13 is an example of a cylinder that has two holes drilled completely through from top to bottom. Detail A is an enlargement of the top surface and has been drawn twice scale to accent the elliptical shape generated by the round hole. Even at twice scale, the ellipse is almost flat. Thus, in most drawings the ellipse is neglected and is drawn as a straight line as shown in Figure 8-13. This irregularity is acceptable drafting practice since it does not affect the accuracy of the communication. A machinist needs only to know what size hole and where to put it, and the fact that a round drill generates a slight elliptical shape in an orthographic projection will not affect his method of drilling. The ellipse is an unimportant result of the drilling and may be omitted.

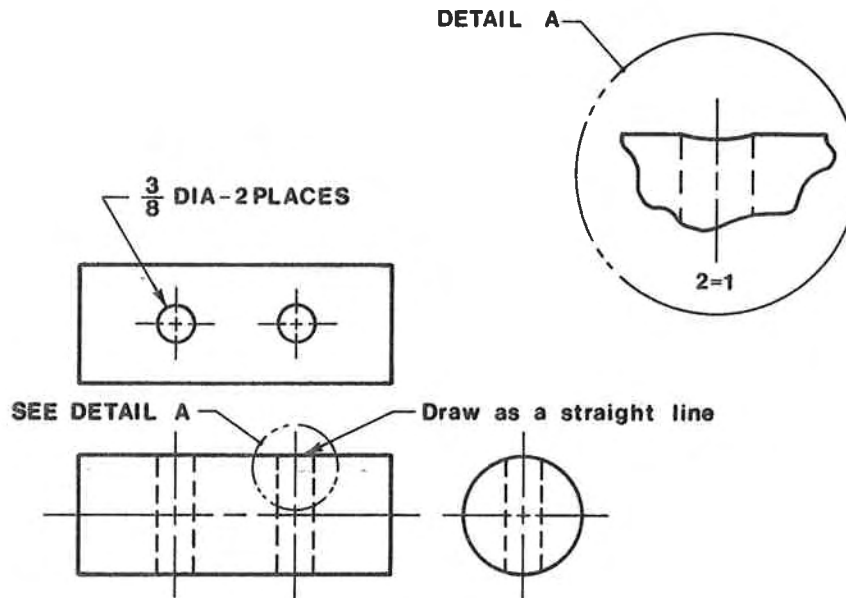


Figure 8-13 How to draw holes in cylinders.

This is not true if the hole is large. Where is the crossover point? When does a hole become large enough to require an ellipse to be drawn? There is no fixed rule to follow and the draftsman must use his own discretion depending on his particular situation.

8-8 ECCENTRIC CYLINDERS

Eccentric cylinders are two or more cylinders whose center points are not matched. One cylinder is off center in relation to the other. Some students feel that eccentric problems are created by instructors who are eccentric, but no research has been done to prove or, for that matter, disprove this theory.

Eccentric problems should be approached as separate and independent cylinder problems. Break down the problems into the sections that make them up and solve them separately; then rejoin them to form a composite solution. Figure 8-14 is an example of an eccentric cylinder problem that requires a top view when front and right side views are given. Figure 8-15 is the solution and was derived by the listed procedure:

GIVEN: Front and side views.
PROBLEM: Draw the front view.

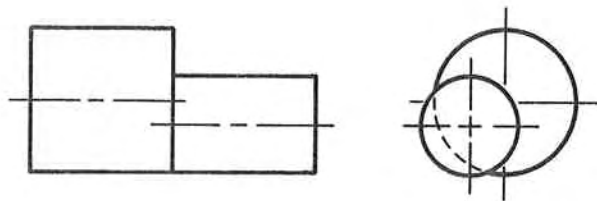
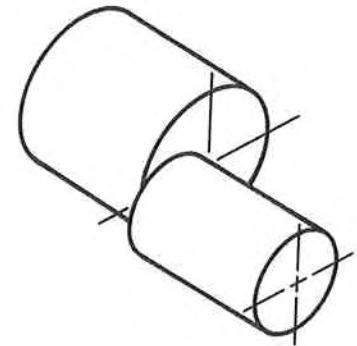


Figure 8-14 Eccentric cylinders.

SOLUTION:

1. Define the center line edge points 1, 2, 3, and 4 of the smaller diameter cylinder in the front and right side views.
2. Project points 1, 2, 3, and 4 into the top view.

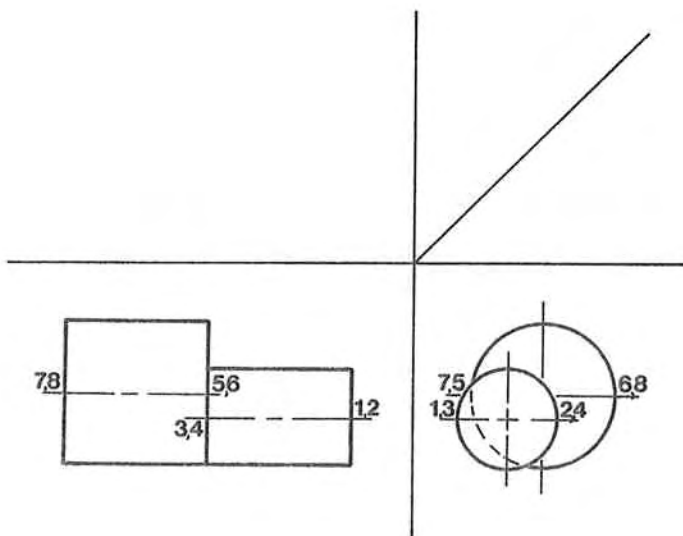


Figure 8-15(a)

3. Define the center line edge points 5, 6, 7, and 8 of the larger diameter cylinder in the front and right side views.

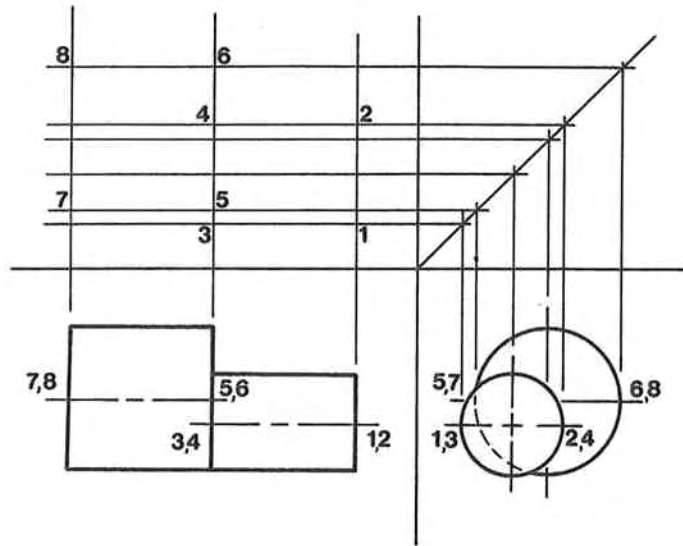


Figure 8-15(b)

4. Project points 5, 6, 7, and 8 into the top view.

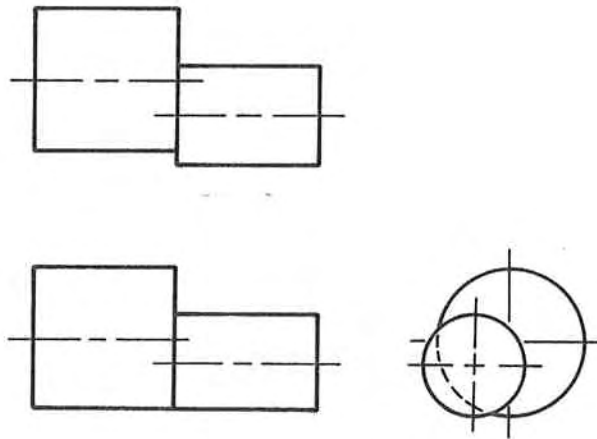


Figure 8-15(c)

5. Draw in the appropriate visible lines.

8-9 HOLLOW SECTIONS

Figure 8-16 is an example of a hollow cylinder. The problem is to find the top view when the front and right side views are given. Figure 8-17 is the solution and was arrived at by considering the outside and inside diameters as separate cylinders, solving them independently, and forming a composite solution. The following steps were used:

GIVEN: Front and side views.
 PROBLEM: Draw top view.

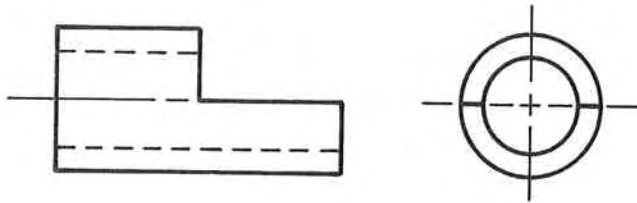
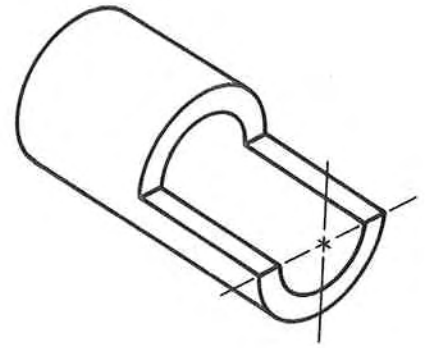


Figure 8-16 Hollow cylinders.

SOLUTION:

1. On the outside cylinder, define the horizontal center line edge points of the cut surface 1-2-7-8 in the front and right side views. In other words, consider the problem to consist only of a solid cylinder, cut directly on the horizontal center line (see Section 8-2).

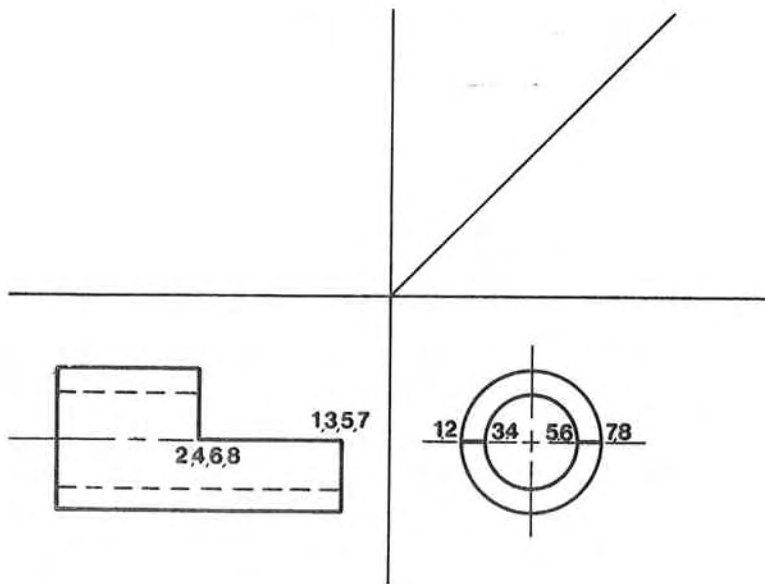


Figure 8-17(a)

2. Repeat step 1 for the inside cylinder, defining points 3, 4, 5, and 6.

3. Project points 1, 2, 3, 4, 5, 6, 7, and 8 into the top view.

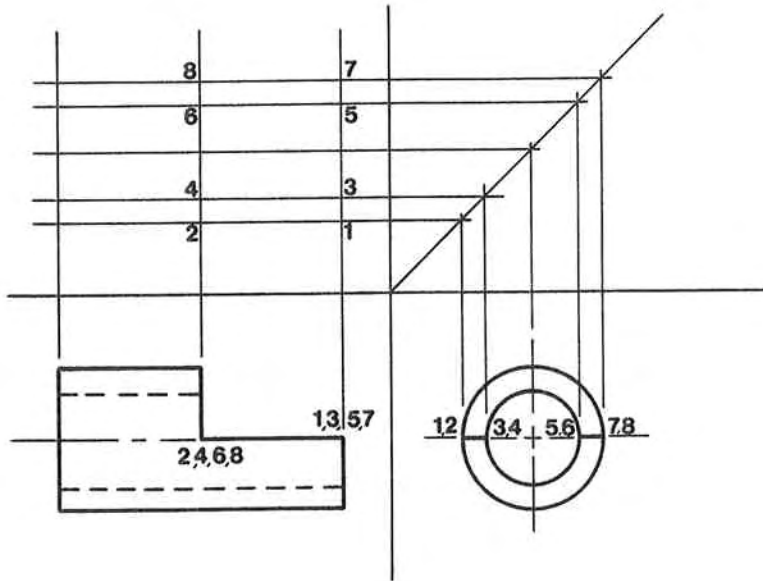


Figure 8-17(b)

4. Draw in the surfaces 1-2-3-4 and 5-6-7-8. Note that surfaces 1-2-6-5 and 3-4-6-7 are flat rectangles and, with the exception of the cylinder's ends, are the only flat surfaces in the problems.
5. Complete the top view by projecting necessary points from the front and right side views.

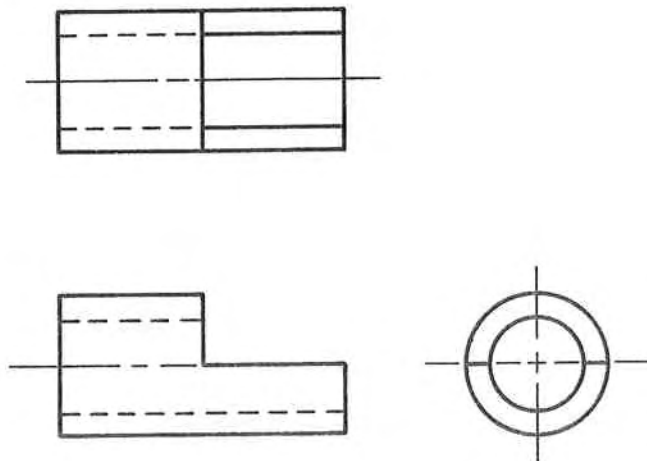
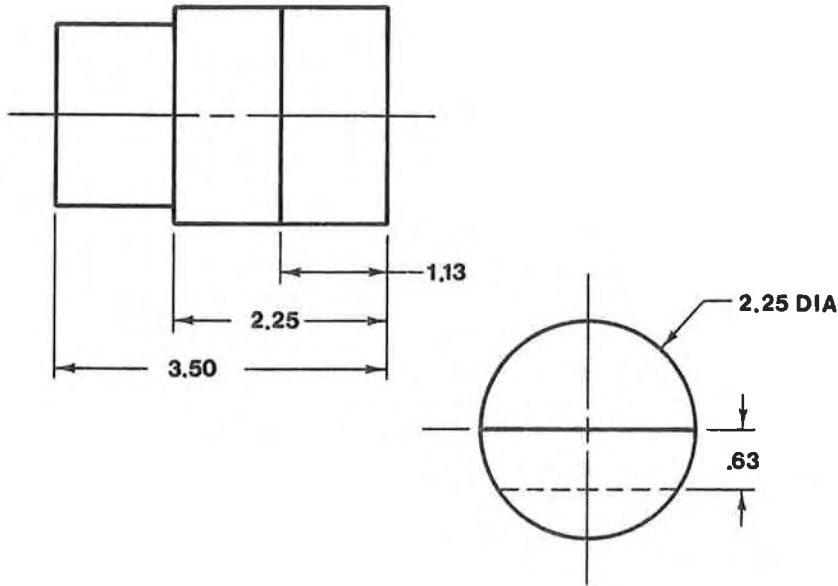


Figure 8-17(c)

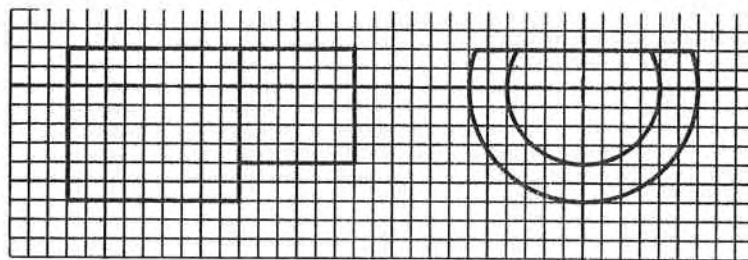
PROBLEMS

Draw three views (front, top, and right side) of the following objects. If two views are given, redraw the given views and add the missing third view. Make a freehand three-dimensional sketch of the object if requested by your instructor. If a three-dimensional picture is used to present the object, draw the front, top, and right side views. Each square on the grid pattern is 0.20 per side.

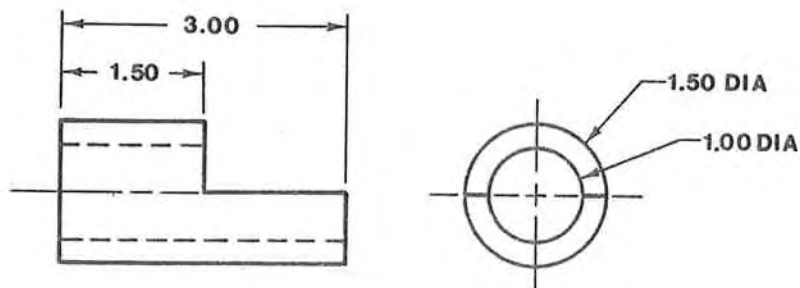
8-1



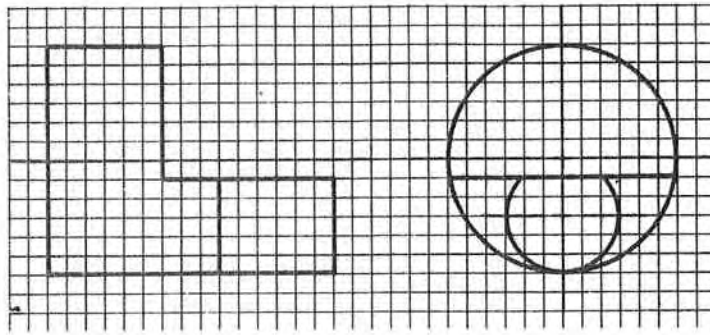
8-2



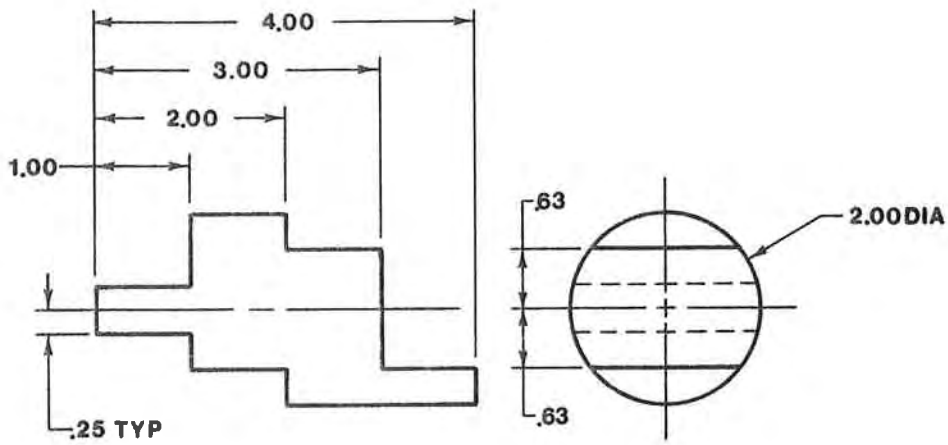
8-3



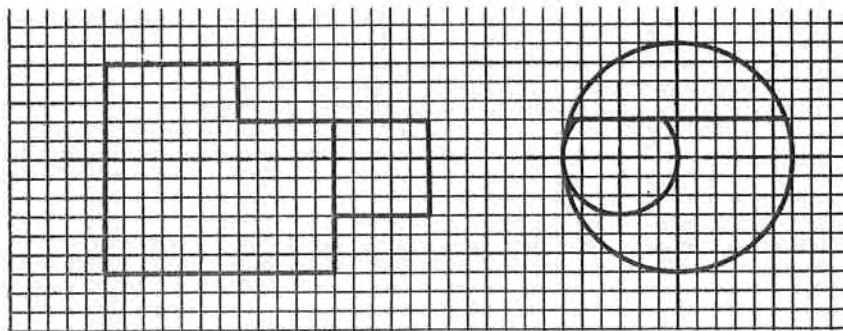
8-4



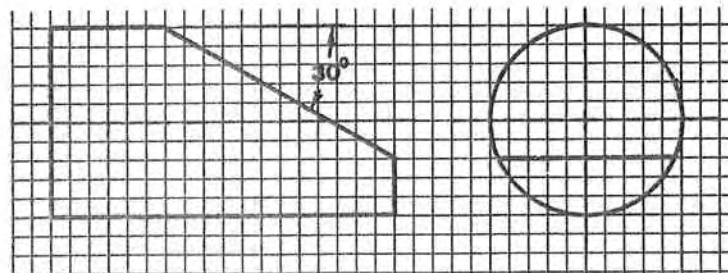
8-5



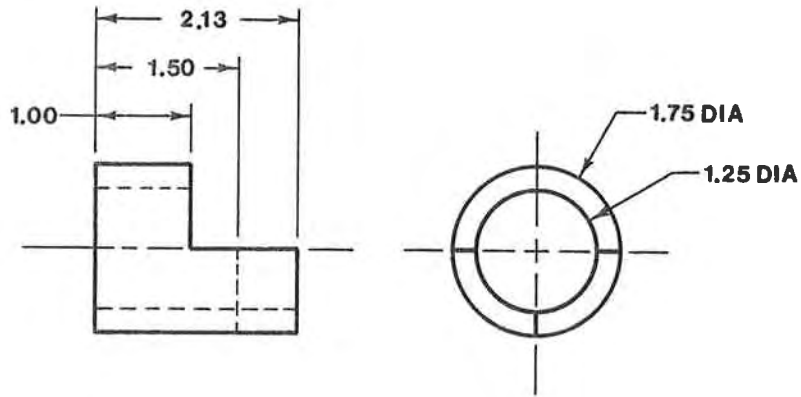
8-6



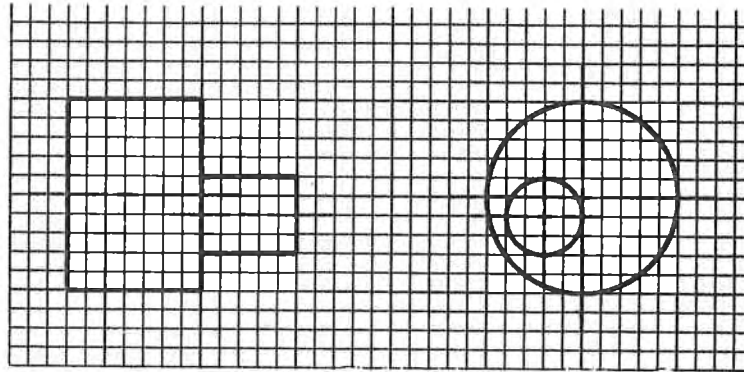
8-7



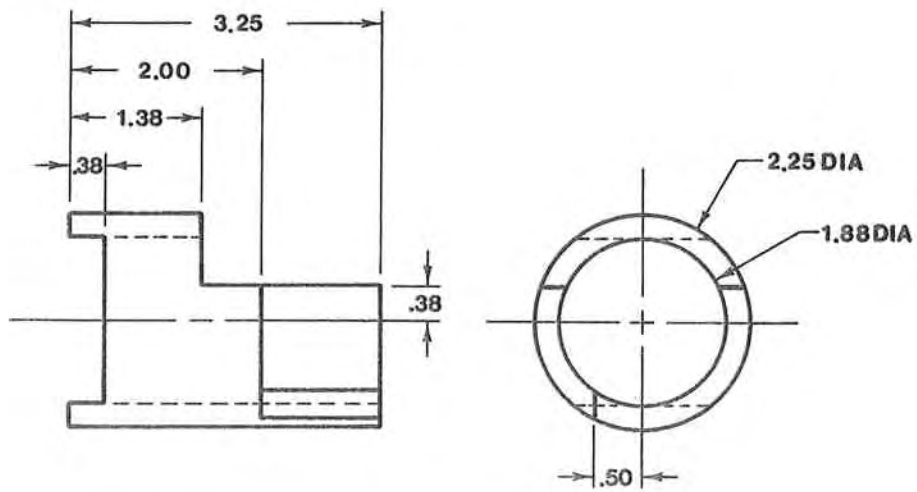
8-8



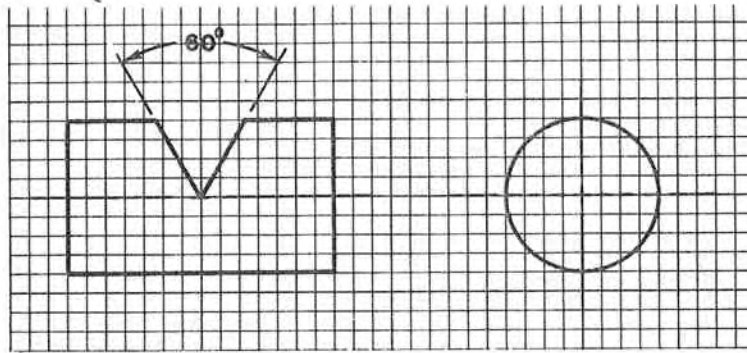
8-9



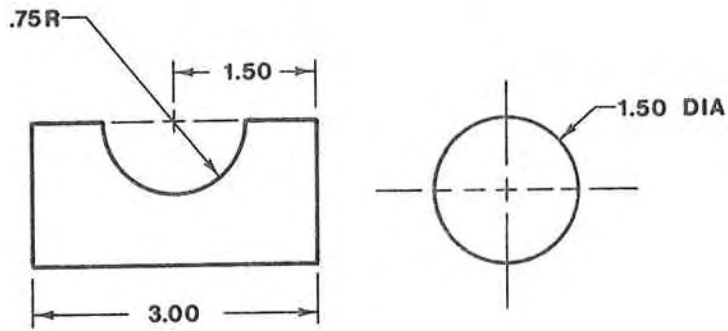
8-10



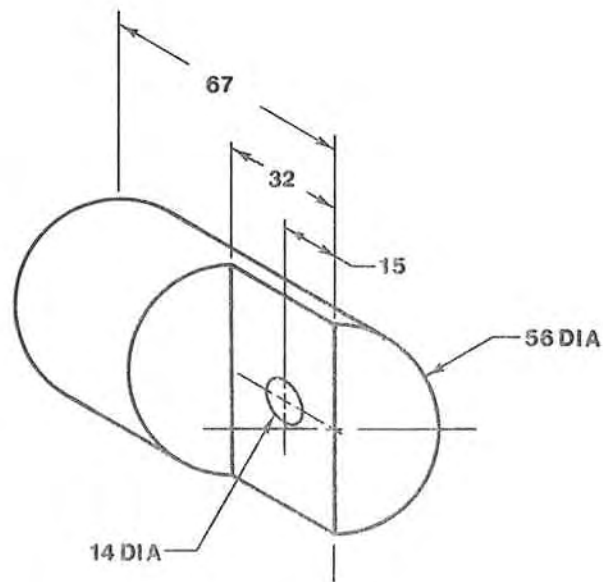
8-11



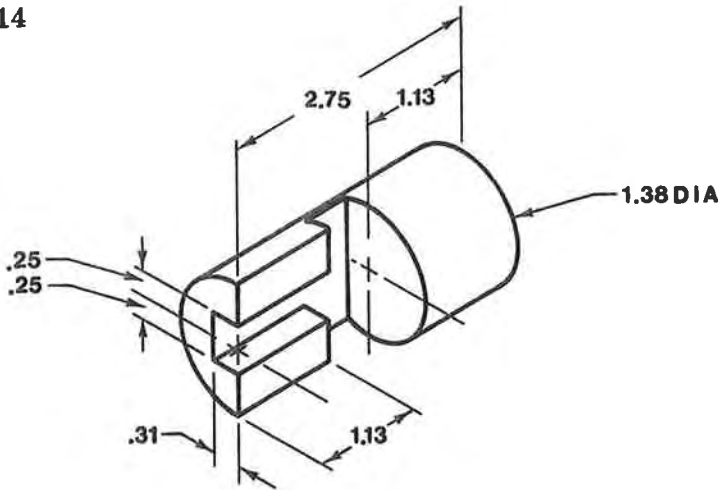
8-12



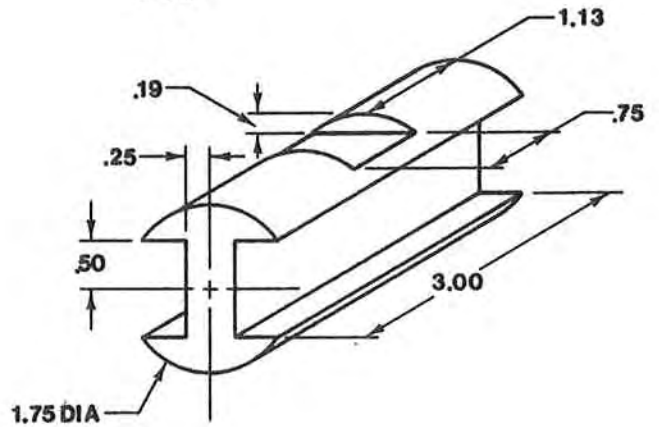
8-13 All dimensions are in millimeters.



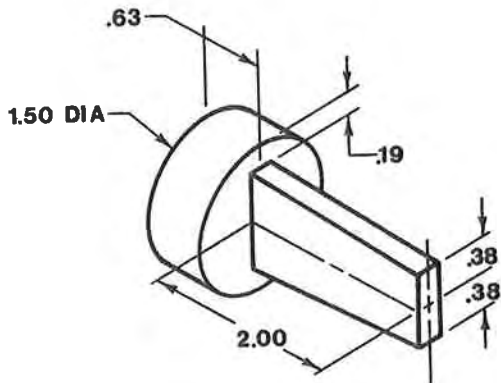
8-14



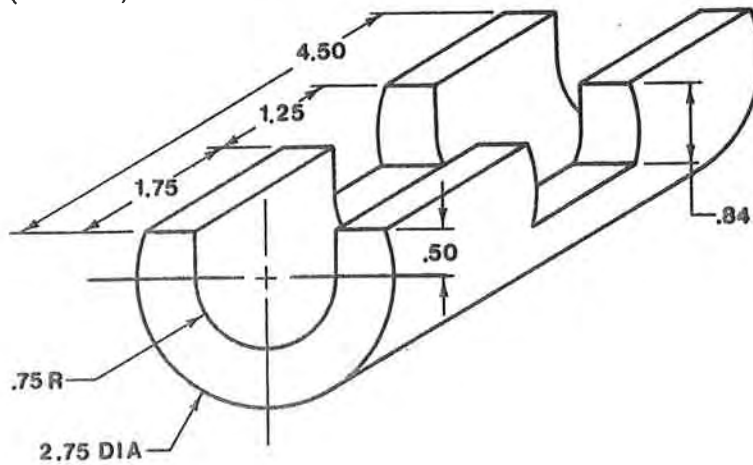
8-15



8-16



8-17 Use B-size paper (11 × 17).



CASTINGS 9

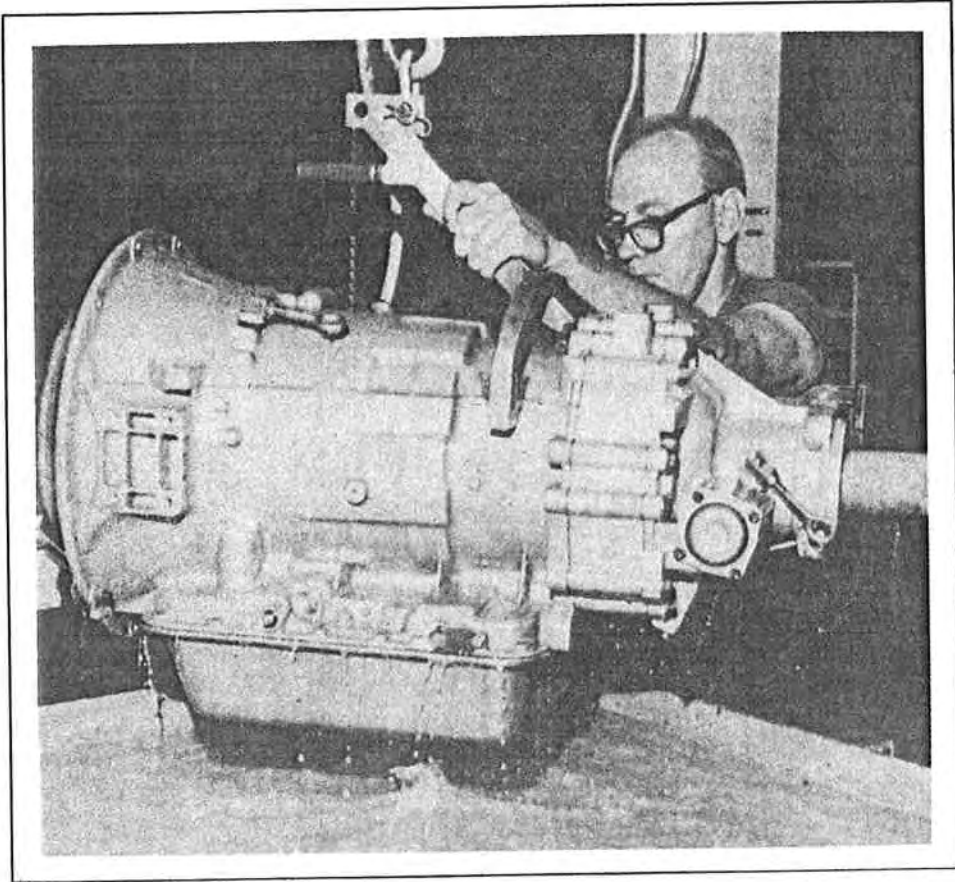


Figure 9-0 A five-range MT 650 automatic transmission being pressure tested. Photograph courtesy of Detroit Diesel Allison—a Division of General Motors Corp.

9-1 INTRODUCTION

Objects which are made using the casting process present unique drawing problems. Because edges of cast objects are not square (90°), they cannot appear as lines in orthographic views. Also, these nonsquare edges often intersect each other which results in many unusually shaped lines. This chapter will present the techniques used to draw cast objects and will show how rounded edges may be represented.

9-2 FILLETS AND ROUNDS

A fillet is a concaved-shaped edge. A round is a convex shaped edge. Figure 9-1 illustrates these definitions. The size of a fillet or round is usually specified on a drawing by a note such as:

ALL FILLETS AND ROUNDS $\frac{1}{8}R$

although they may be dimensioned individually.

From a drawing standpoint, fillets and rounds only appear in views taken at 90° to them, as shown in Figure 9-2. Note in Figure 9-2 that the lines that *seem* to represent edges represent surfaces. The actual edges are rounded and so do not appear in orthographic views unless they are shown in profile.

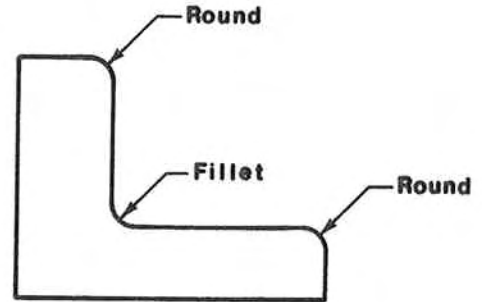
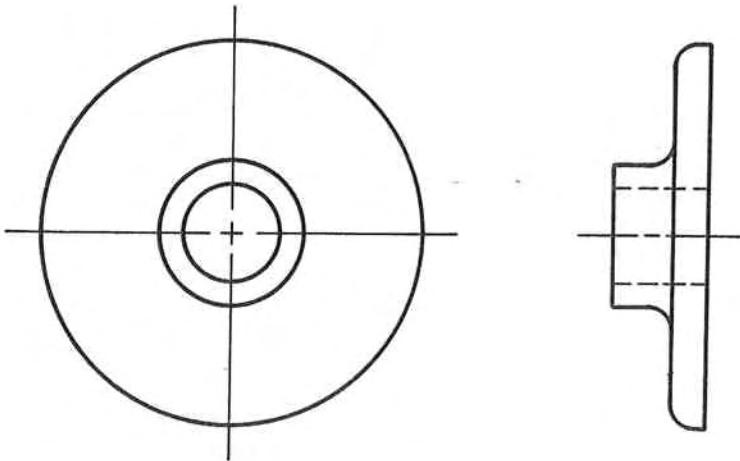


Figure 9-1 Fillets and rounds.



ALL FILLETS & ROUNDS $\frac{1}{4}R$

Figure 9-2 Orthographic views of a cast object.

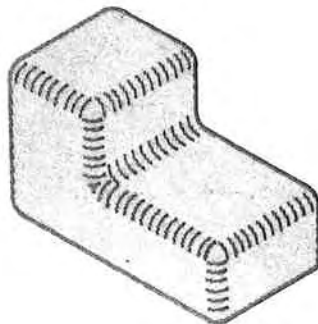
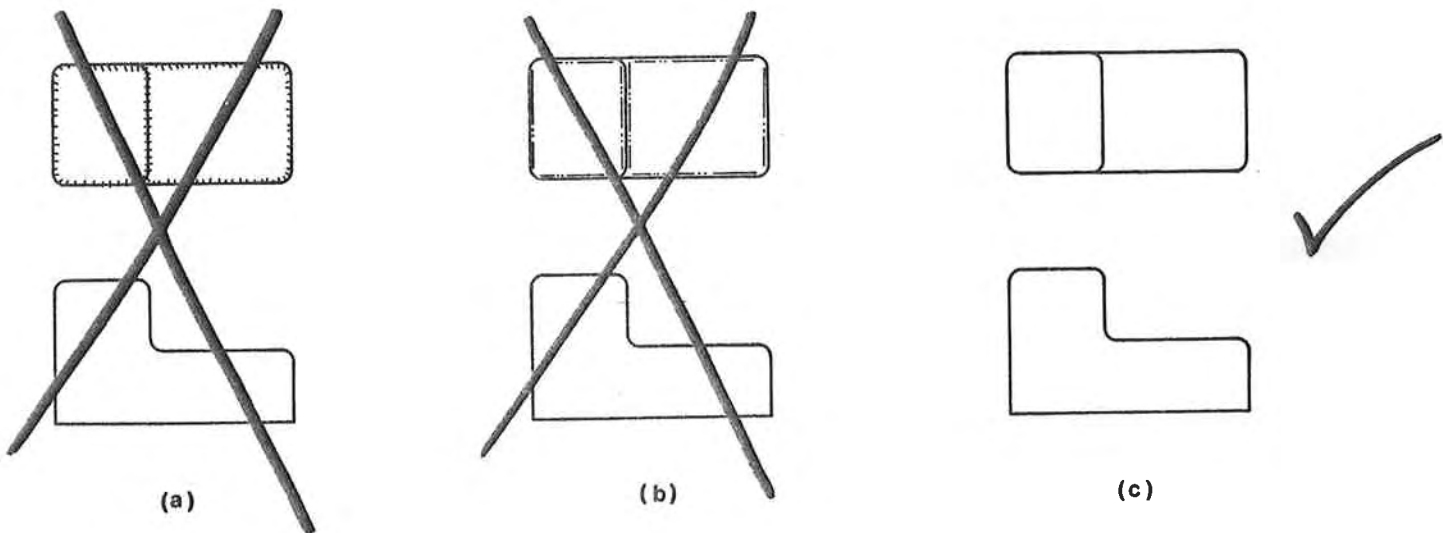
Most fillets and rounds are drawn by using a circle template because they are too small to be easily drawn with a compass. Remember that when you use a circle template the hole sizes are given in diameters, not radii. Therefore, be sure to convert the given fillet and round sizes to diameters before you draw them.

9-3 ROUND EDGE REPRESENTATION

When you draw cast objects, how do you properly represent rounded edges? Should the small curved lines, as shown in Figure 9-3(a) be used? Should the long, phantom lines, as shown in Figure 9-3(b), be used? Or should no lines be used, as shown in Figure 9-3(c)?

In general, the small curved lines and the phantom lines are only used to indicate a rounded edge in a pictorial drawing. They are not used in orthographic views. However, since representation practices vary from company to company, always check the company standards before you start a drawing.

Figure 9-3 No special shading or line work is required to represent the rounded edges of cast object.



9-4 RUNOUTS

A runout is the intersection of two or more rounded edges. Runouts appear on a drawing as curved sections at the end of the lines that represent surfaces. They generally turn out (that is, away from the surface lines), but this is not a hard, fast rule. Elliptical surfaces generate runouts that turn in, as illustrated in Figure 9-4. Each object must be judged individually as to which runout direction looks the most realistic.

Figure 9-5 shows several different examples of runouts. Draw runouts either freehand or by using a curve as a guide.

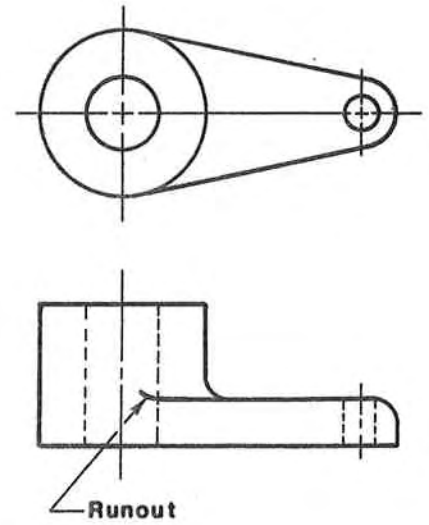


Figure 9-4 A drawing which includes a runout.

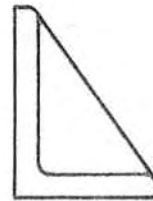
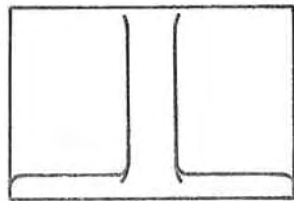
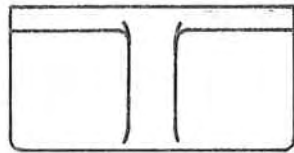
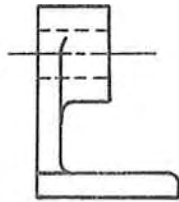
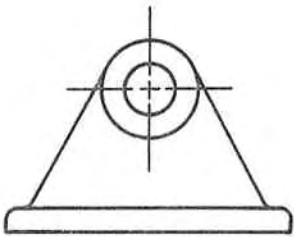
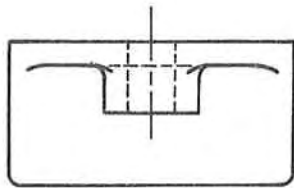


Figure 9-5 Example of two objects whose orthographic views include runouts.

9-5 SPOTFACES AND BOSSES

Spotfacing is a special machining operation that smooths out the otherwise rough surface finish found on cast objects. It is similar to counterboring, but during spotfacing the surface of the object is cut just deep enough to produce a machined quality finish.

Spotfacing is called out on a drawing by a note as shown in Figure 9-6. First, the drill diameter is given, then the drill depth, if any, and

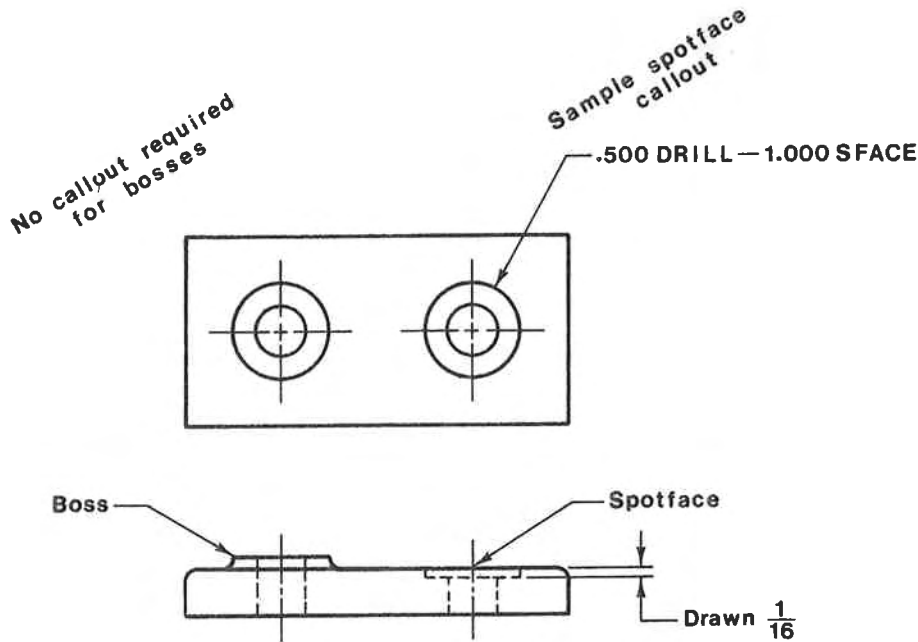


Figure 9-6 A drawing which includes a spotface and a boss.

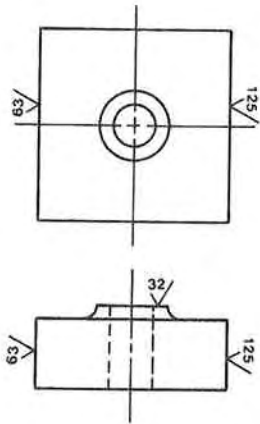
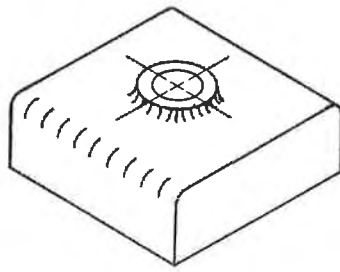
finally the diameter of the spotface. Spotface depth is *not* specified unless it is a design requirement. The machinist will cut just deep enough into the object to smooth out the surface.

When you draw a spotface, draw the spotface depth $1/16''$. This depth enables the drawing reader to clearly see the spotface and is convenient to draw. Other parts of the note are interpreted as shown in Figure 9-6.

A boss is a raised portion of a casting as shown in Figure 9-6. Bosses are usually added to castings because they can be easily machined (being higher than the rest of the cast surface). Bosses are usually as high as the given fillet and round size.

9-6 MACHINING MARKS

Machining marks are used to differentiate those surfaces on a casting which are to be machined. Figure 9-7 illustrates different machining marks and shows how they are used.



500√ = Rough

250√ = Coarse

125√ = Medium

63√ = Fine

32√ = Very fine

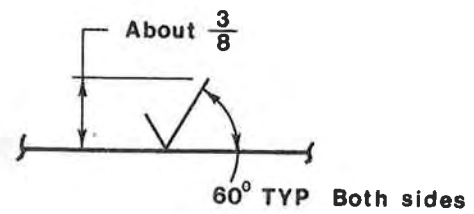


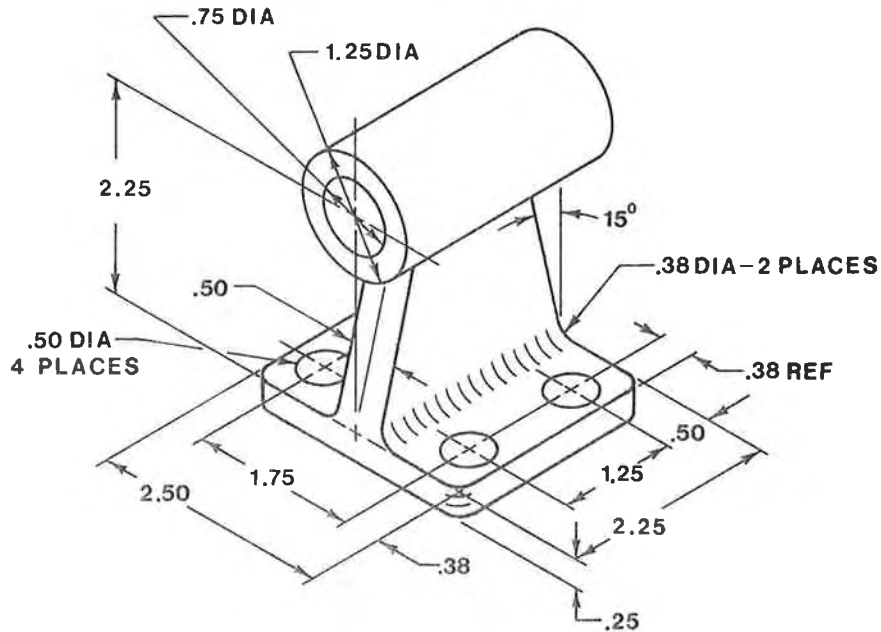
Figure 9-7 Machining marks are used to indicate the quality of the surface finish required.

PROBLEMS

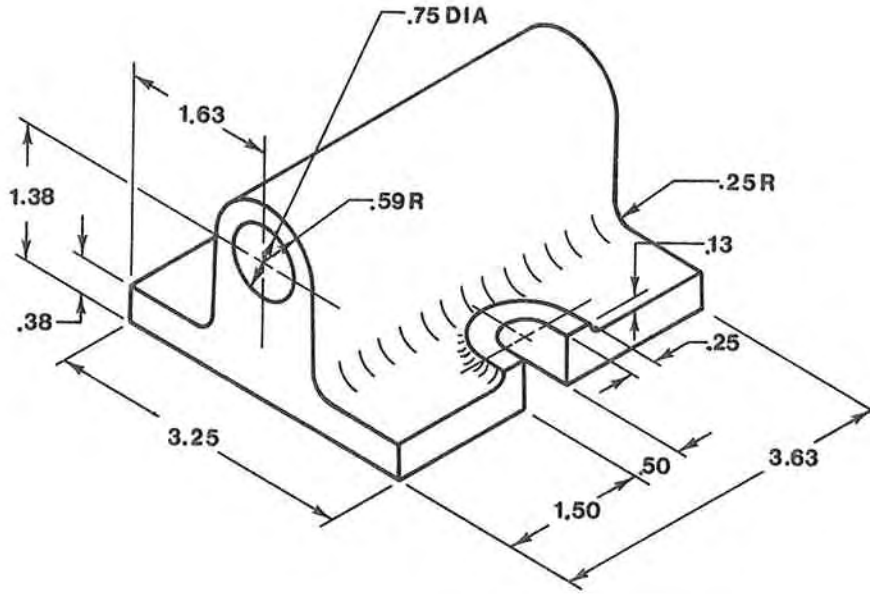
Draw three views (front, top, and side) of each of the following objects:

9-1

All fillets and rounds = $\frac{3}{16} R$

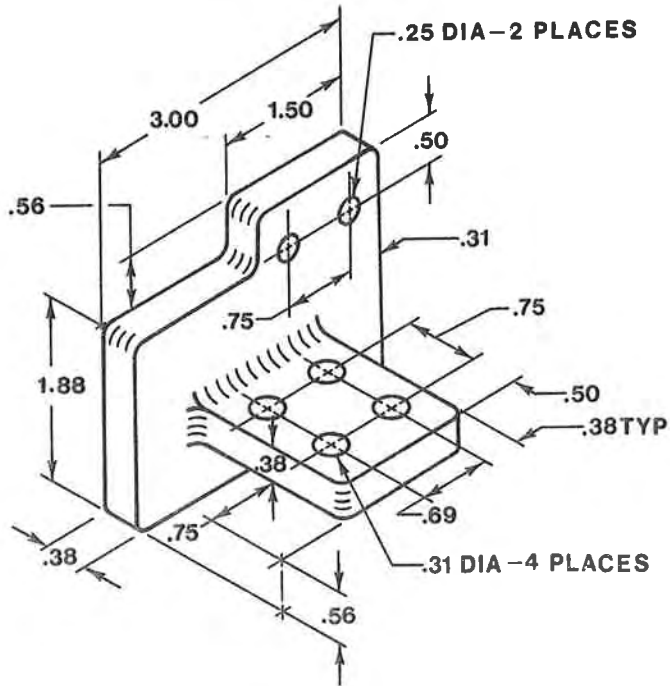


9-2



9-3

All fillets and rounds = $\frac{1}{8}$ R

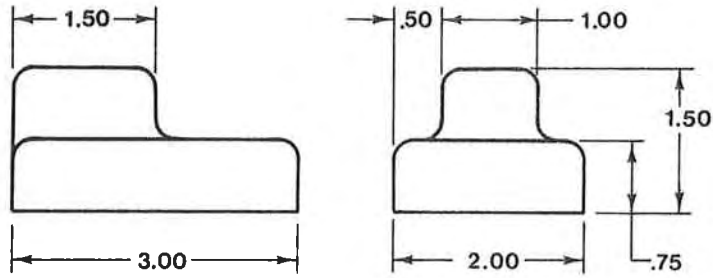


For the following problems, redraw the two given views and add the required missing view. Each square on the grid pattern is 0.20 per side.

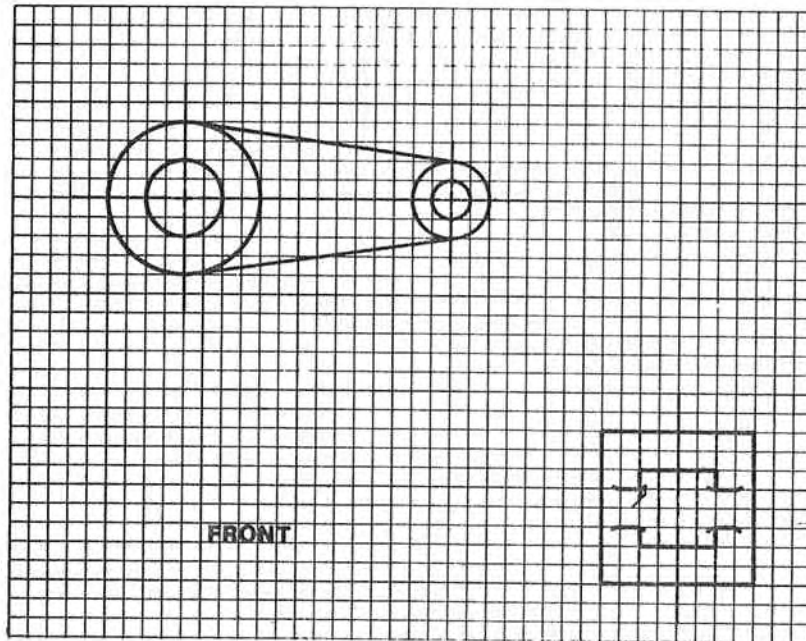
9-4

TOP

All fillets and rounds = $\frac{3}{16} R$



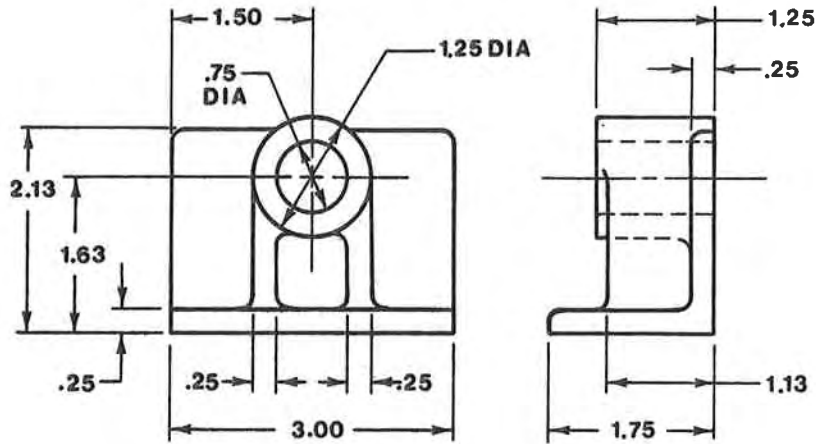
9-5



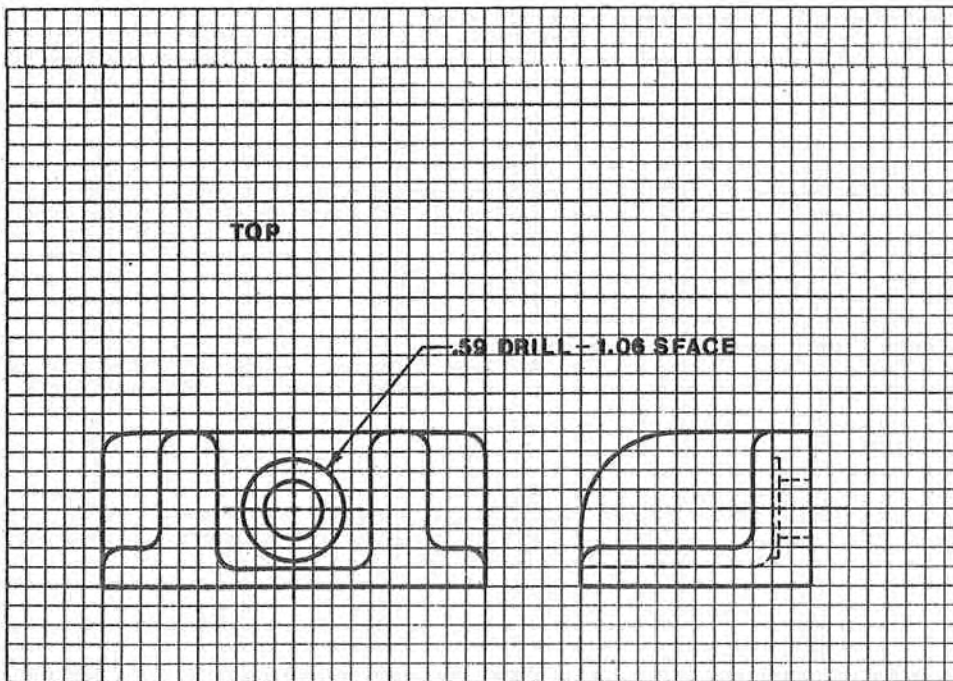
9-6

TOP

All fillets and rounds = $\frac{1}{8}$ R



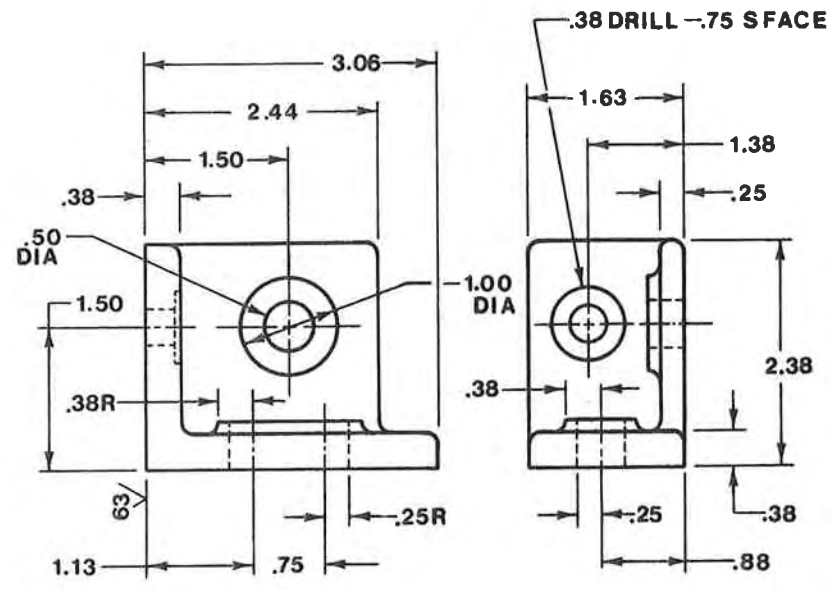
9-7



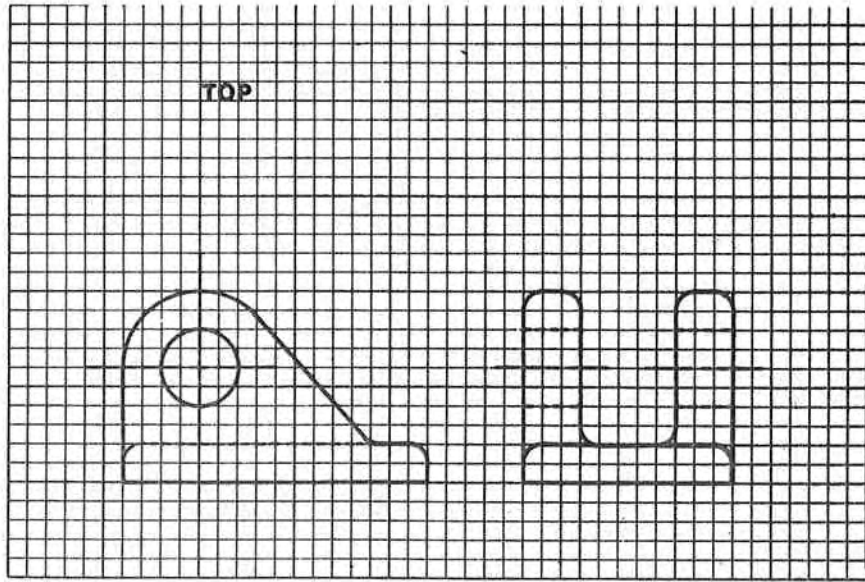
9-8

TOP

All fillets and rounds = $\frac{1}{8}$ R



9-9



SECTIONAL VIEWS 10

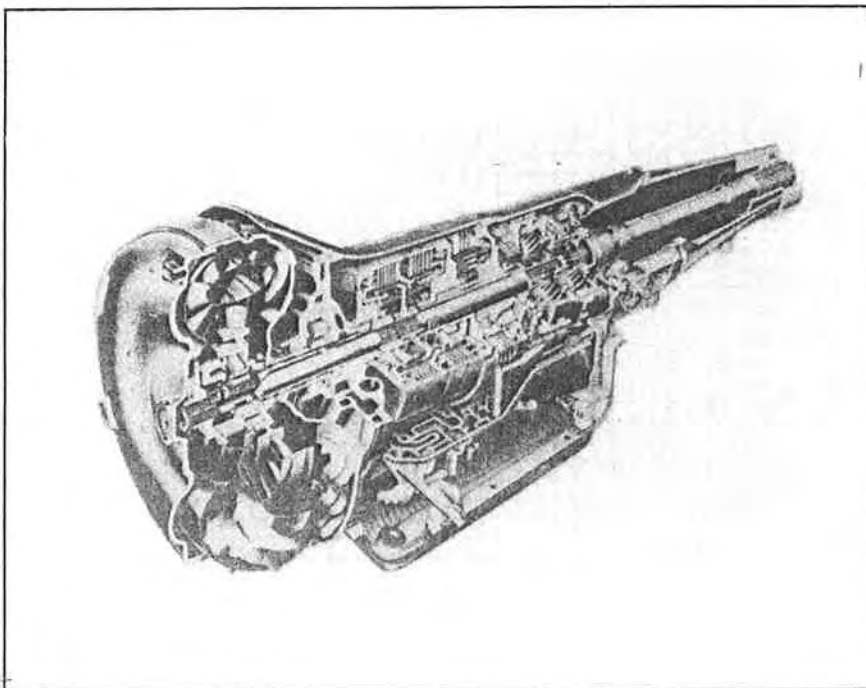


Figure 10-0 A model 400 Turbo Hydramatic. Photograph courtesy of General Motors Corp.

10-1 INTRODUCTION

Sectional views are used to expose internal surfaces of an object that would otherwise be hidden from direct view. Sectional views greatly add to the clarity of a drawing because they do not contain any hidden lines.

To help you understand the differences between section cuts and regular orthographic views, study Figures 10-1 and 10-2. In Figure 10-1 note the clarity of the internal profile of the object shown in the sectional view. In Figure 10-2 note that the sectional views are much easier to understand than are the regular orthographic views which contain many hidden lines. This does not mean that sectional views should be used instead of regular orthographic views. Sometimes sec-

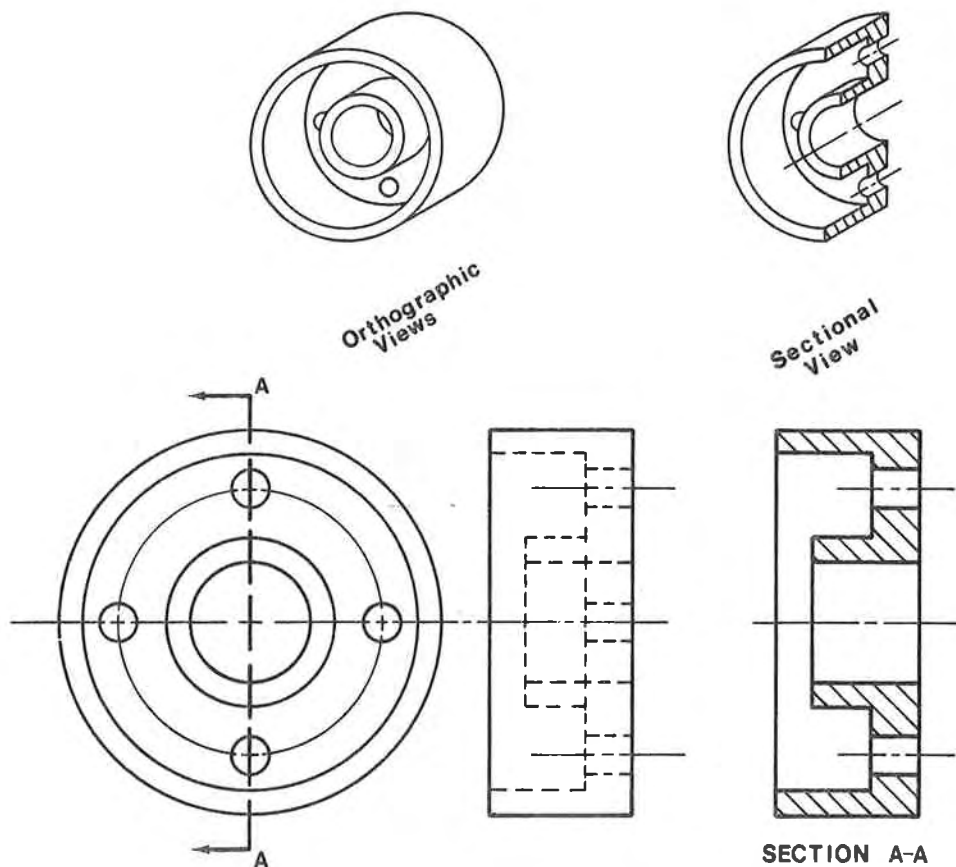


Figure 10-1 A comparison between a regular orthographic view and a sectional view.

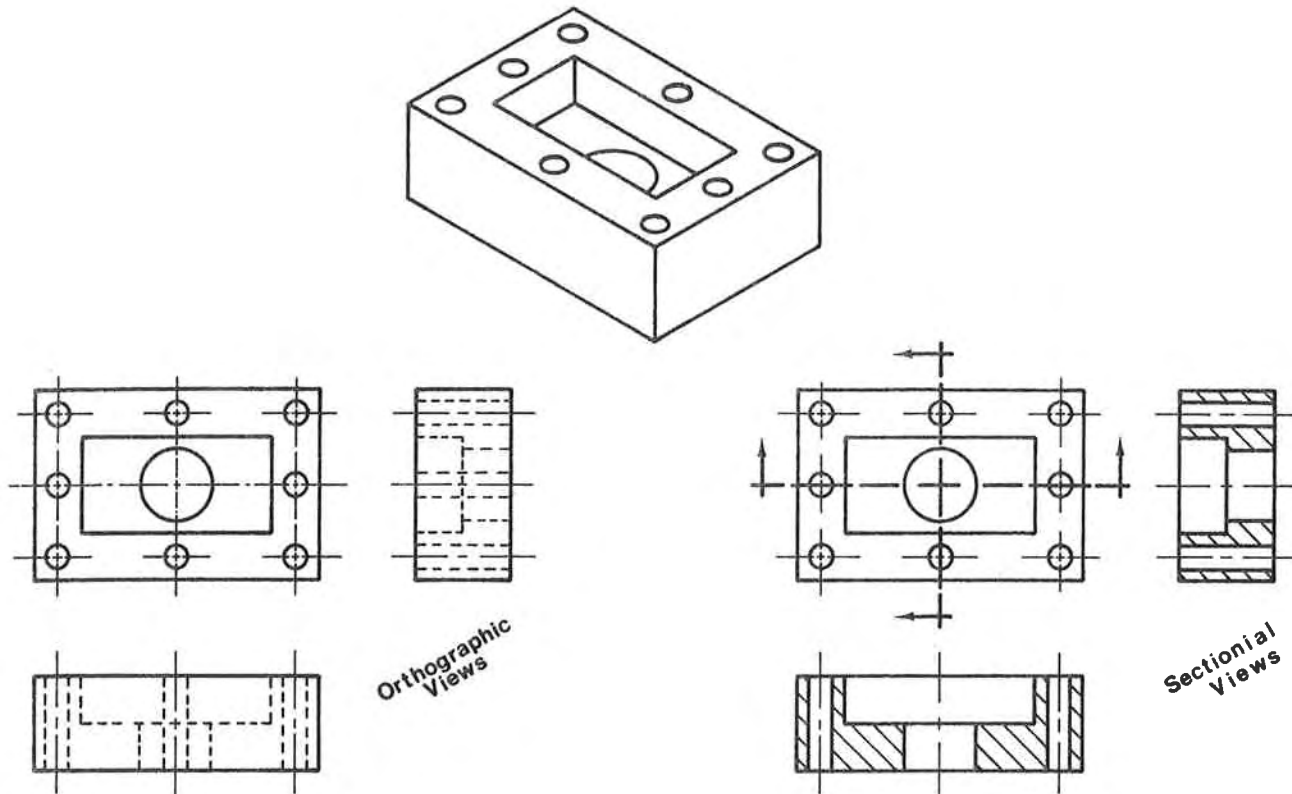


Figure 10-2 A comparison between regular orthographic views and sectional views.

tional views may be used to replace confusing regular orthographic views. At other times both views may be used. There are also many drawings that would not require section cuts at all. When and where to use a sectional view depends on the object being drawn. However, in any situation, your prime concern should be that your drawings are easily understood. Always be as clear and direct as possible in the views that you present.

10-2 CUTTING PLANE LINES

Cutting plane lines are used to define the line along which an object is to be cut. They are drawn by using either of the two configurations shown in Figure 10-3. They should be drawn by using very heavy and very black lines—as heavy and black, if not more so, than visible lines.

Cutting plane lines need not go directly through an object but may be offset as shown in Figures 10-4 and 10-5. Cutting plane lines are offset so that several internal surfaces may be shown in the same sectional view. The fact that a cutting plane line is offset does not appear in the sectional view. There should be no lines in the sectional view to indicate that the cutting plane line has changed direction.

The arrowheads of a cutting plane line indicate the direction in which to observe the sectional view. The actual section view should be

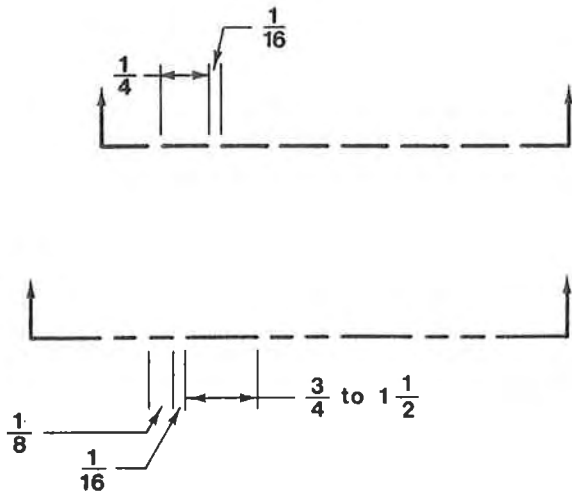


Figure 10-3 Cutting plane line configurations.

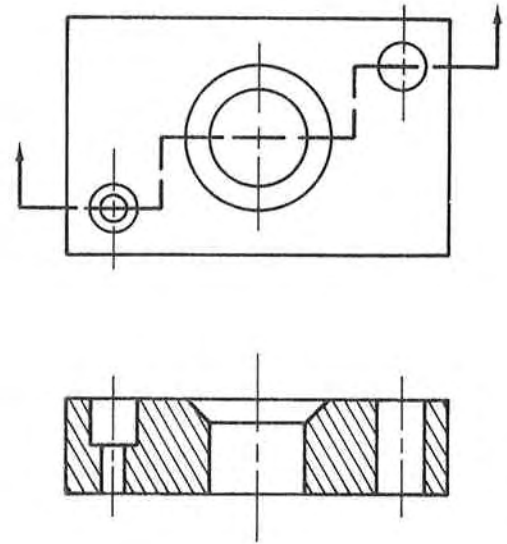


Figure 10-4 An offset cutting plane line.

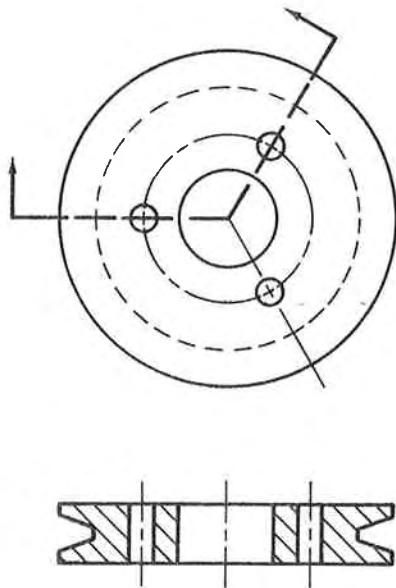


Figure 10-5 An offset cutting plane line.

located behind the arrowheads or, if absolutely necessary, in alignment with the cutting plane line as illustrated in Figure 10-6. Under no circumstances should the sectional view be placed ahead of the cutting plane line arrowheads.

To help you visualize this convention, think of yourself as standing on the sectional view looking at the object being drawn. The cutting plane line arrowheads should point in the direction in which you are looking—away from the sectional view.

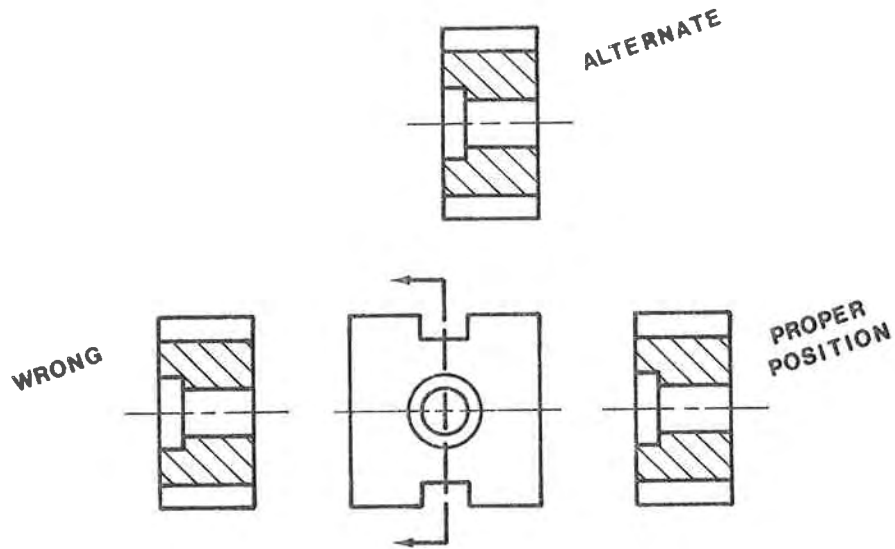


Figure 10-6 Sectional view locations relative to the cutting plane line.

10-3 SECTION LINES

Section lines are used to indicate where, in a sectional view, solid material has been cut. There are many different section line patterns (a different pattern for each building material), but the most common pattern is the one shown in Figure 10-7. The lines are thin and black (about one-half as thick as visible lines) and are drawn at any inclined angle (45° is most often used).

When two or more parts are cut by the same cutting plane line, the section cut lines must be varied to indicate clearly the different parts. Section lines may be drawn at different angles or with different spacing as is illustrated in Figure 10-8.

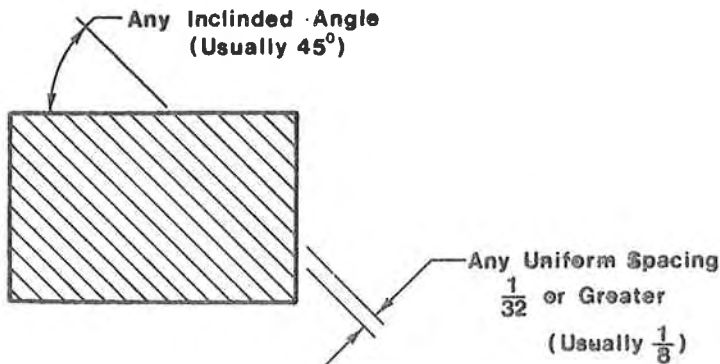


Figure 10-7 Section lines.

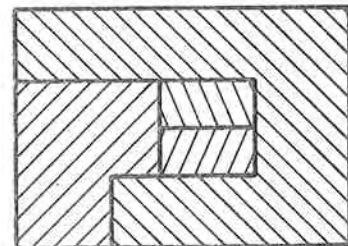


Figure 10-8 Four different objects in the same sectional view.

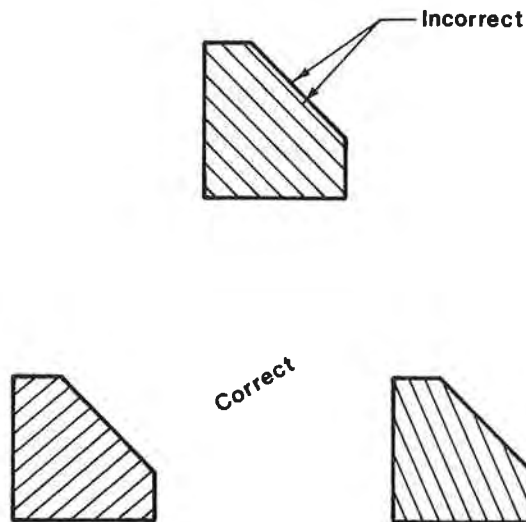
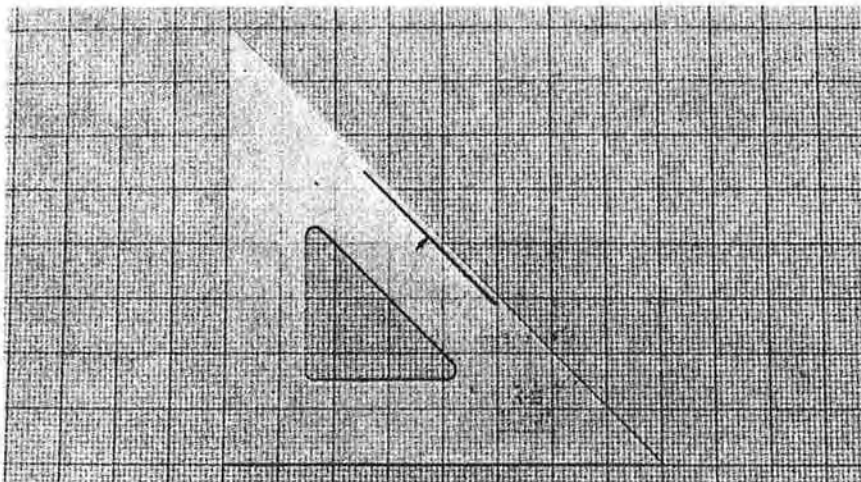


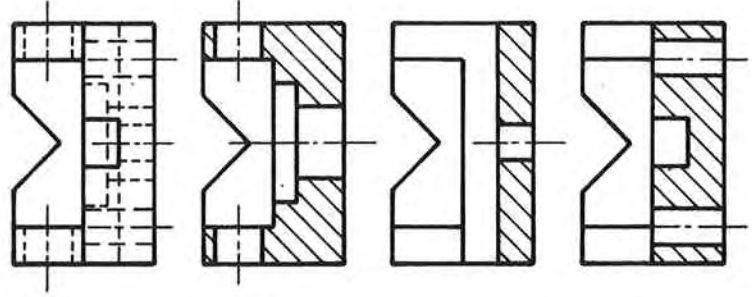
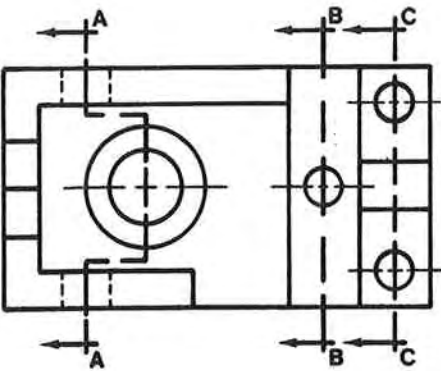
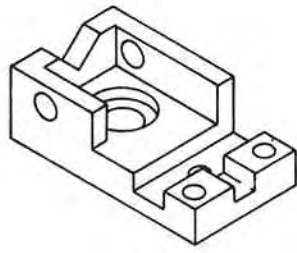
Figure 10-9 The correct alignment of section lines.

Do not draw section lines so that they are parallel to any surface in the object. For example, the upper right corner of the object pictured in Figure 10-9 is a 45° surface. It is wrong to draw section lines at 45° , parallel to the 45° surface. The lines must be drawn at another angle so that they are not parallel to the 45° surface.

There are several techniques draftsmen use to draw section lines. One is to use an Ames Lettering Guide. Another is to slip a piece of graph paper under the drawing, align it as desired, and then trace the lines. Another technique is to scribe a line onto a 45-45-90 triangle as shown in Figure 10-10. Scribe the guide line $1/8''$ from and parallel to the edge of the triangle. If desired, several lines may be scribed.

Figure 10-10 A 45-45-90 triangle which has a line scribed along the longest edge (see arrow). This scribed line is parallel to and $1/8$ from the edge of the triangle. Use the scribed line to align the triangle when drawing section lines.





SECTION A-A SECTION B-B SECTION C-C

Figure 10-11 Multiple sectional views.

10-4 MULTIPLE SECTIONAL VIEWS

It is possible to take many sectional views through the same orthographic view. Figure 10-11 demonstrates this by showing three sectional views, each taken through a different position of the same top view. Note how each sectional view is placed behind the arrowheads of the cutting plane line. As many sectional views as are necessary for clear definition of the object being studied may be shown.

Although hidden lines are not shown in sectional views, visible lines are shown. Note, for example, that the V formation located on the back left surface of the object appears in all three sectional views. Any surface that may be directly seen, even if it is not located directly on the path of the cutting plane line, must be shown. For example, the tall center portion of the object shown in Figure 10-12 appears in section

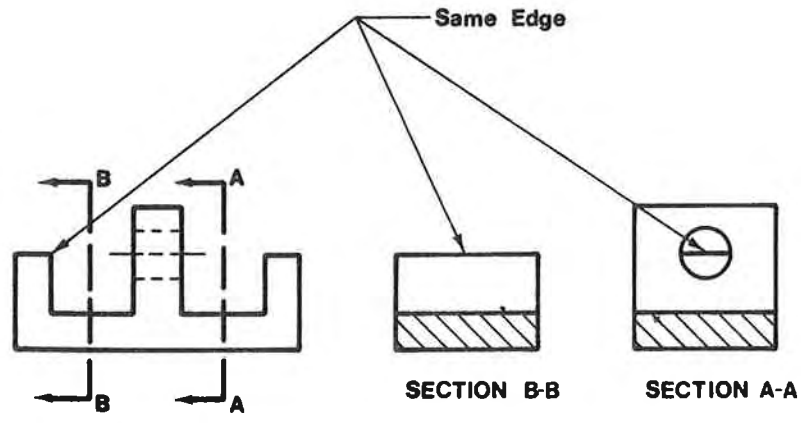


Figure 10-12 Multiple sectional views.

A-A because it may be directly seen. The shorter end section cannot be directly seen and, therefore, is not shown. However, note that part of the shorter left end section may be directly seen through the hole and, because it may be seen, it must be shown in the sectional view. Since in section B-B we are beyond the tall center section, it will be omitted in the sectional view.

10-5 REVOLVED SECTIONAL VIEWS

It is sometimes possible to save drawing a separate sectional view by drawing a sectional view directly on the regular orthographic view. This sectional view is called a *revolved sectional view* and is illustrated in Figure 10-13. A revolved sectional view is used to define the shape of an object that has a constant shape.

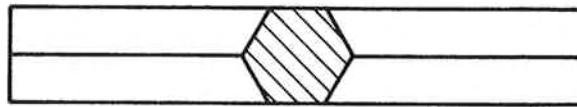


Figure 10-13 Revolved sectional views.

Figure 10-14 illustrates another revolved sectional view. This time the object has been broken open and the revolved sectional view has been placed between break lines. Either revolved sectional view (Figure 10-13 or Figure 10-14) is acceptable.

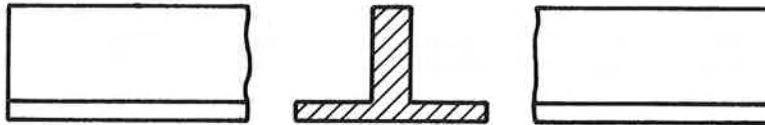


Figure 10-14 A revolved sectional view.

10-6 HALF SECTIONAL VIEWS

Regular orthographic views and sectional views may be combined within the same orthographic view to form a half sectional view. Figure 10-15(a) shows a half sectional view. Note that the two views are separated by a center line and that each half is drawn independently of the other. The regular orthographic part of the view shows hidden lines, but the sectional view part does not. Half sections are particularly useful for drawing symmetrical objects.

Study the cutting plane line in Figure 10-15(a) and note how the left arrowhead is placed directly on the center line. Compare this with the cutting plane line of Figure 10-15(b) and then compare the differences in the resultant sectional views. By drawing the cutting plane line as shown in Figure 10-15(b), we eliminate the need to draw all hidden lines on the left side of the sectional view. Both Figures 10-15(a) and 10-15(b) are acceptable ways of drawing half sectional views.

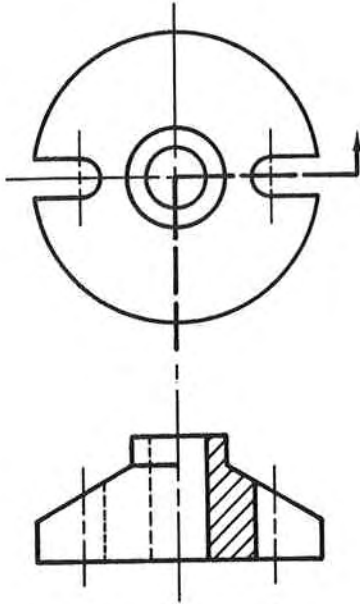


Figure 10-15(a) A half sectional view.

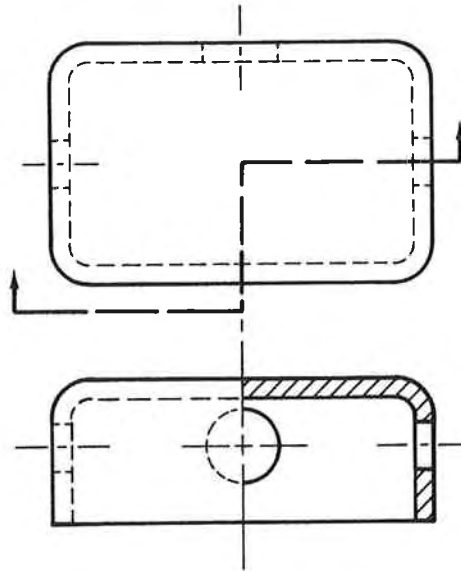


Figure 10-15(b) A half sectional view.

10-7 BROKEN OUT SECTIONAL VIEWS

Sometimes less than a full or half sectional view is sufficient to clarify some internal surfaces of an object. In Figure 10-16, for example, the internal surfaces are symmetrical both vertically and horizontally. That is, the left and right halves are exactly the same as the top and bottom halves. Therefore, in this example we only need to show a small piece of the internal surfaces to give the reader a good idea of the entire internal shape of the object. We do this by using a broken out sectional view as shown in Figure 10-16.

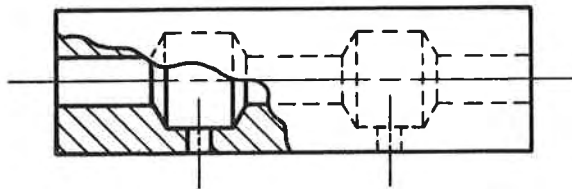


Figure 10-16 A broken out sectional view.

Broken out sectional views are sectional views drawn on a regular orthographic view and are created by theoretically breaking off a part of the external surface of the object, thereby exposing some of the internal surfaces to direct view. When you break open the object, use a break line to outline the place where the external surfaces have been broken. A cutting plane line is not required.

Figure 10-17 is another example of a broken out sectional view.

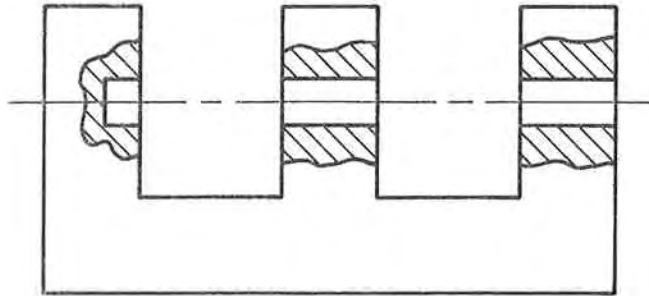


Figure 10-17 A broken out sectional view.

10-8 PROJECTION THEORY

The projection theory presented in Chapter 4 and continued throughout this book is also applicable to sectional views. Figure 10-18 illustrates its application.

Most sectional views are drawn without the aid of projection theory, but as with regular orthographic views, projection theory is very helpful in checking lines.

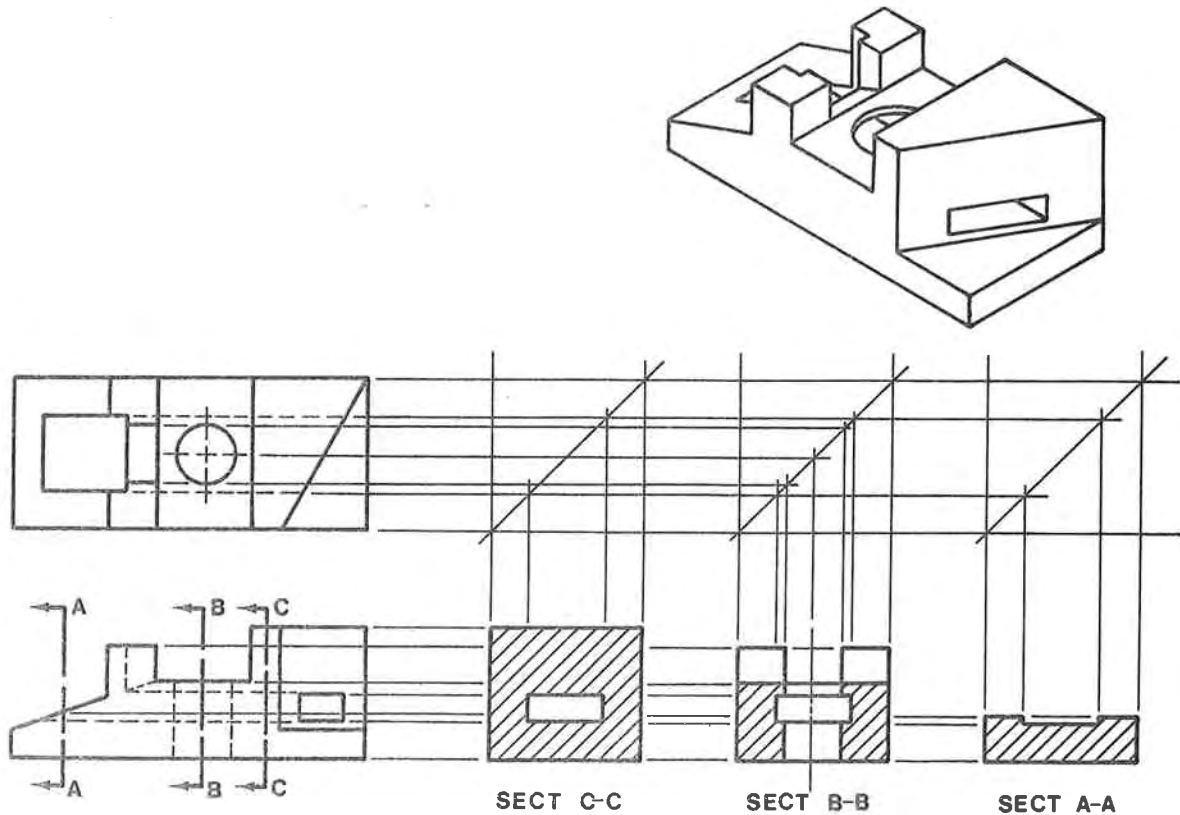


Figure 10-18 A multiple sectional view problem solved using projection theory.

10-9 HOLES IN SECTIONAL VIEWS

A common mistake that is made in drawing holes in a sectional view is to omit the back edge of the hole. Even if a hole is cut in half in a sectional view, the back edges must be shown in the sectional view. Figure 10-19, which shows a counterbored hole, uses an isometric drawing, a regular orthographic view, and a sectional view. In each view the arrows point to approximately the same point on the back edge of the hole. Note how lines that represent the back edges of the hole appear in the sectional view. When you draw holes in a sectional view, make sure that the back edge of the hole is represented.

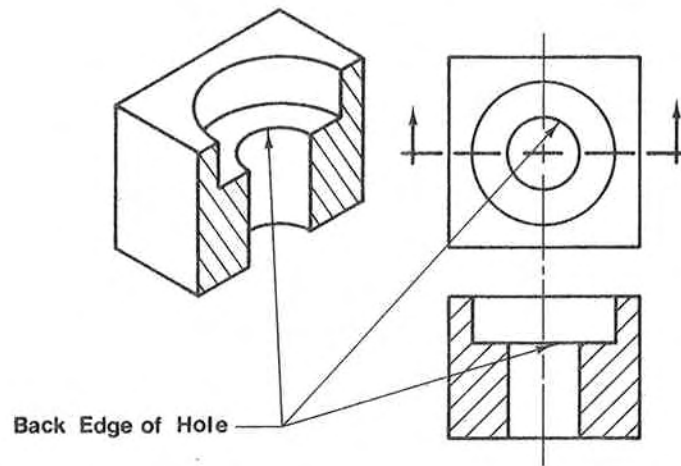


Figure 10-19 A hole in a sectional view.

10-10 AUXILIARY SECTIONAL VIEWS

Auxiliary sectional views may be created in the same way that auxiliary views are created (see Chapter 11). Use the cutting plane line to define the angle at which the view is to be taken and be sure to include sectioning lines where material has been cut. Either complete or partial auxiliary sectional views may be drawn. Figures 11-8 and 11-9 illustrate two auxiliary sectional views.

10-11 DIMENSIONING SECTIONAL VIEWS

Sectional views are very helpful in presenting clear, well-defined dimensions. In Chapter 6 we learned that it is considered poor practice to dimension to hidden lines. Yet, there are many objects that contain so many internal surfaces that it is impossible to dimension without referring to hidden lines. By drawing sectional views, we open up to

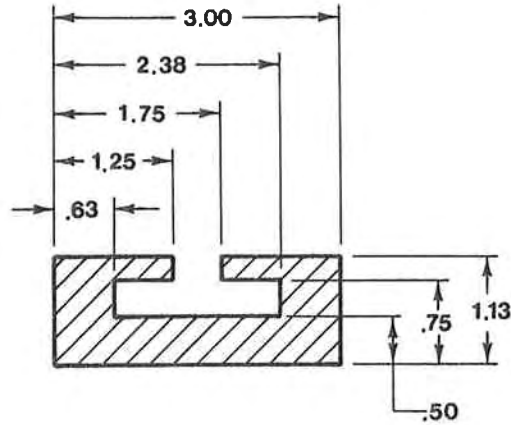


Figure 10-20 An example of a dimensioned sectional view.

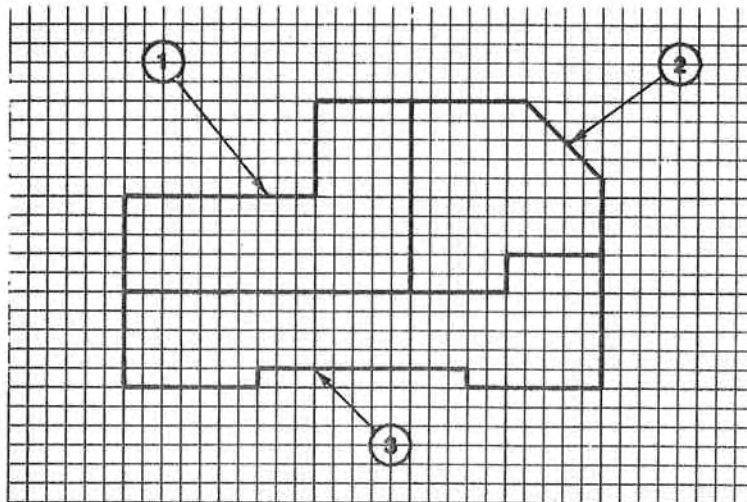
direct view the internal surfaces, thereby changing hidden lines to solid lines which, in turn, give us solid, well-defined lines to dimension to.

Figure 10-20 illustrates how a sectional view may be dimensioned. Note that the extension lines cross over the section lines. Also note the small gap between the end of the extension line and the line that it is defining on the object.

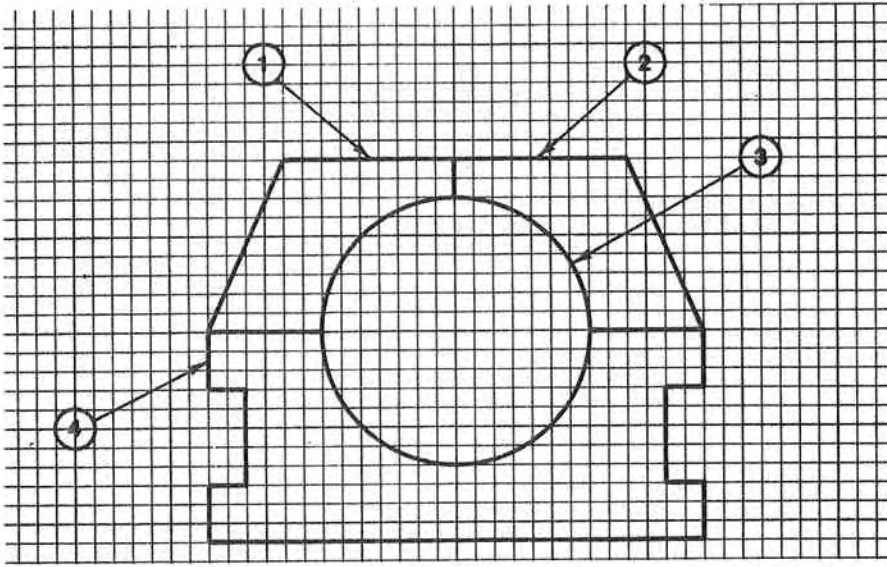
PROBLEMS

Assume that the following are sectional views of several different objects. Redraw the sectional views and add section lines. Each square on the grid is 0.20 per side.

10-1

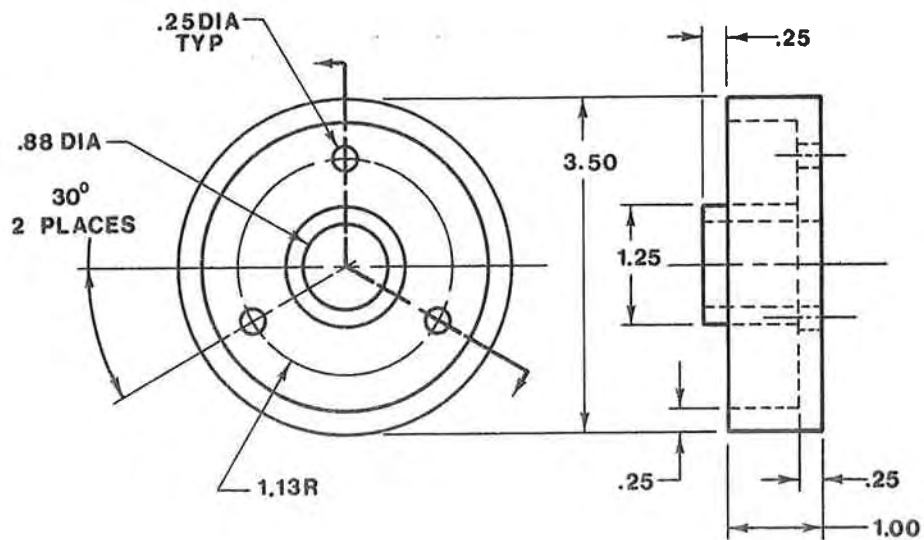


10-2

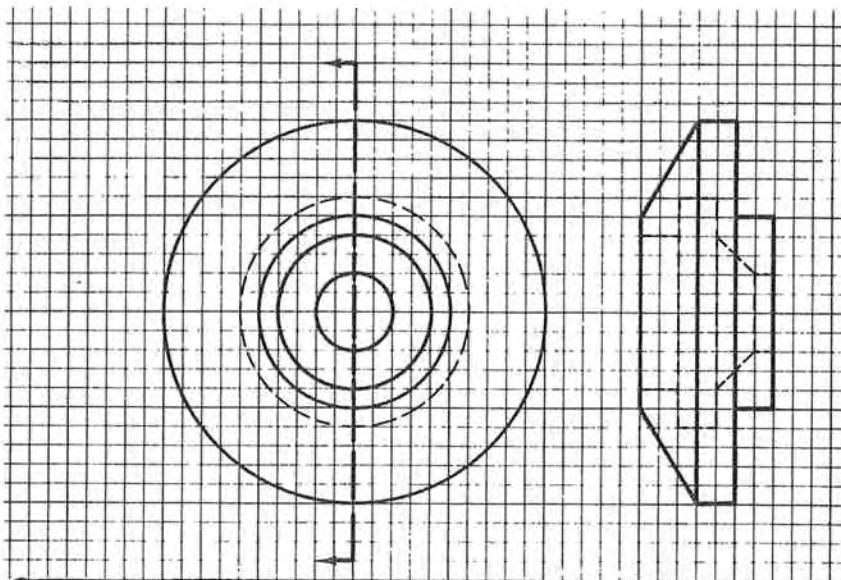


Redraw the front view and replace the side view with a sectional view. Each square on the grid is 0.20 per side.

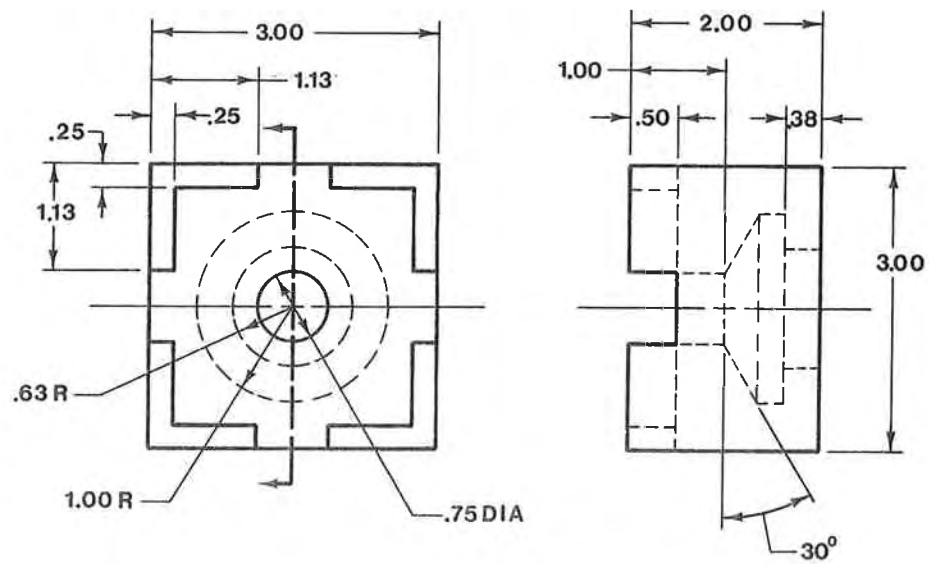
10-3



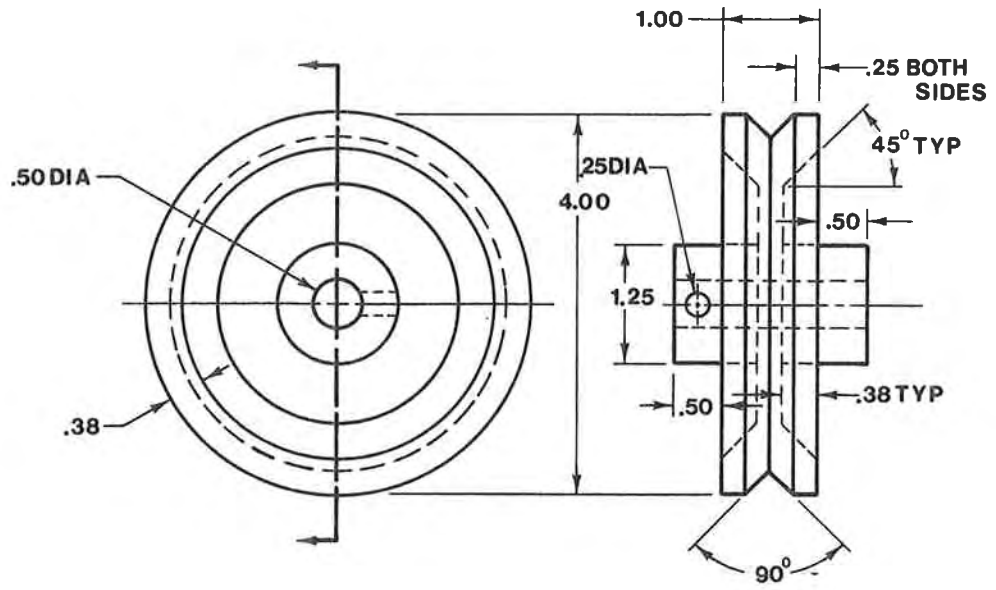
10-4



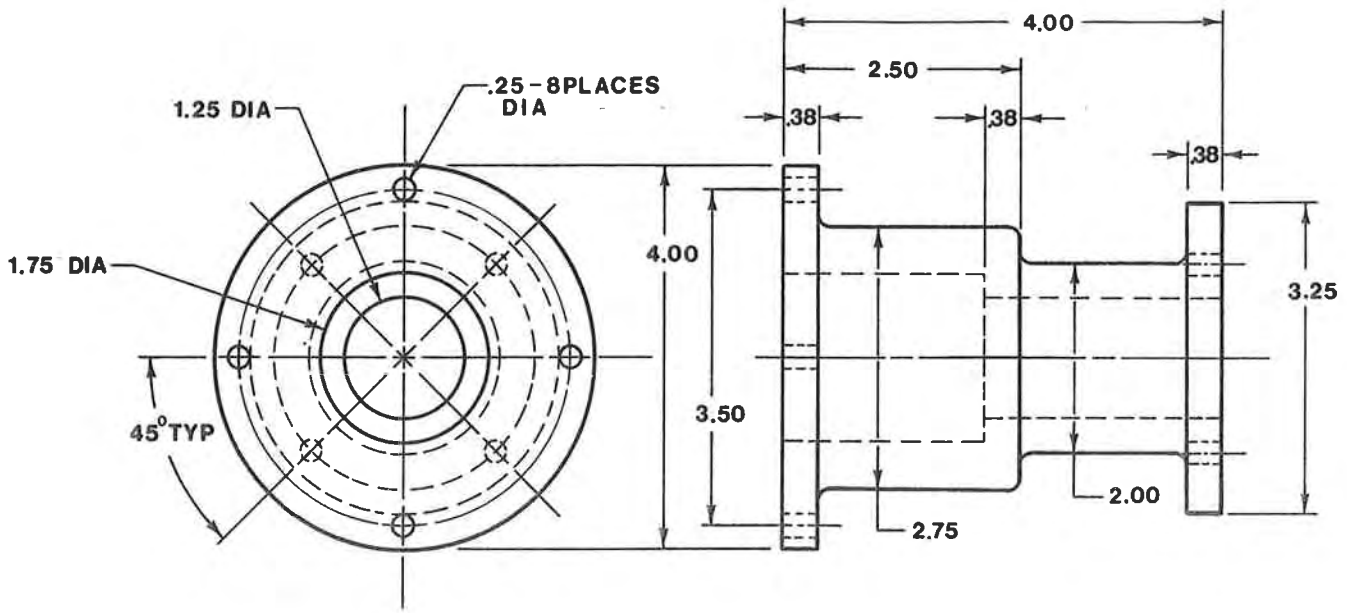
10-5



10-6

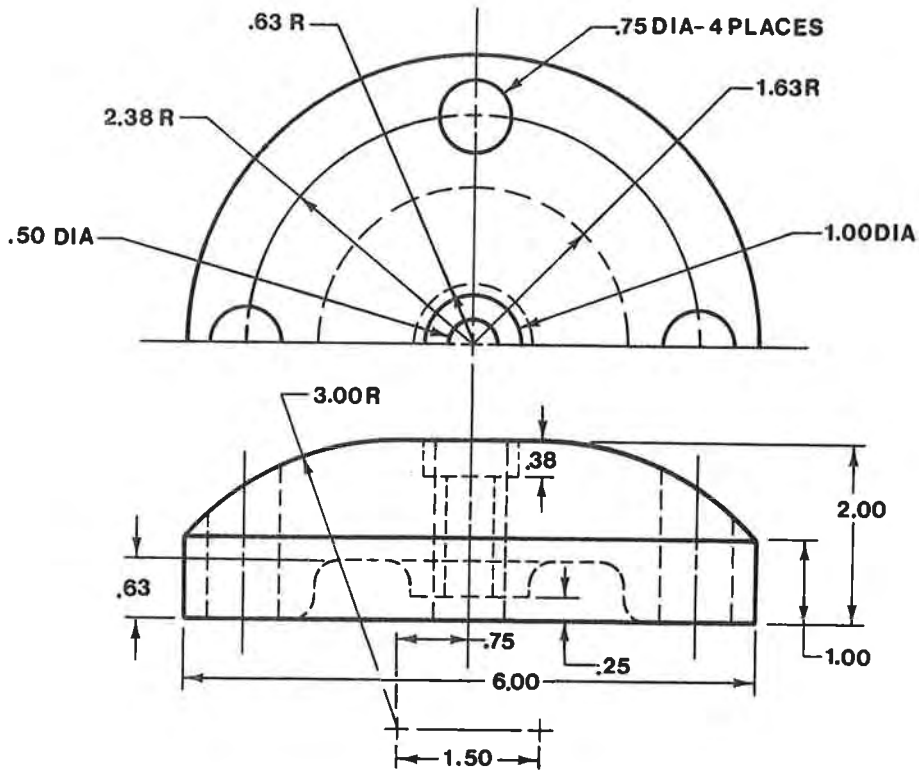


10-7

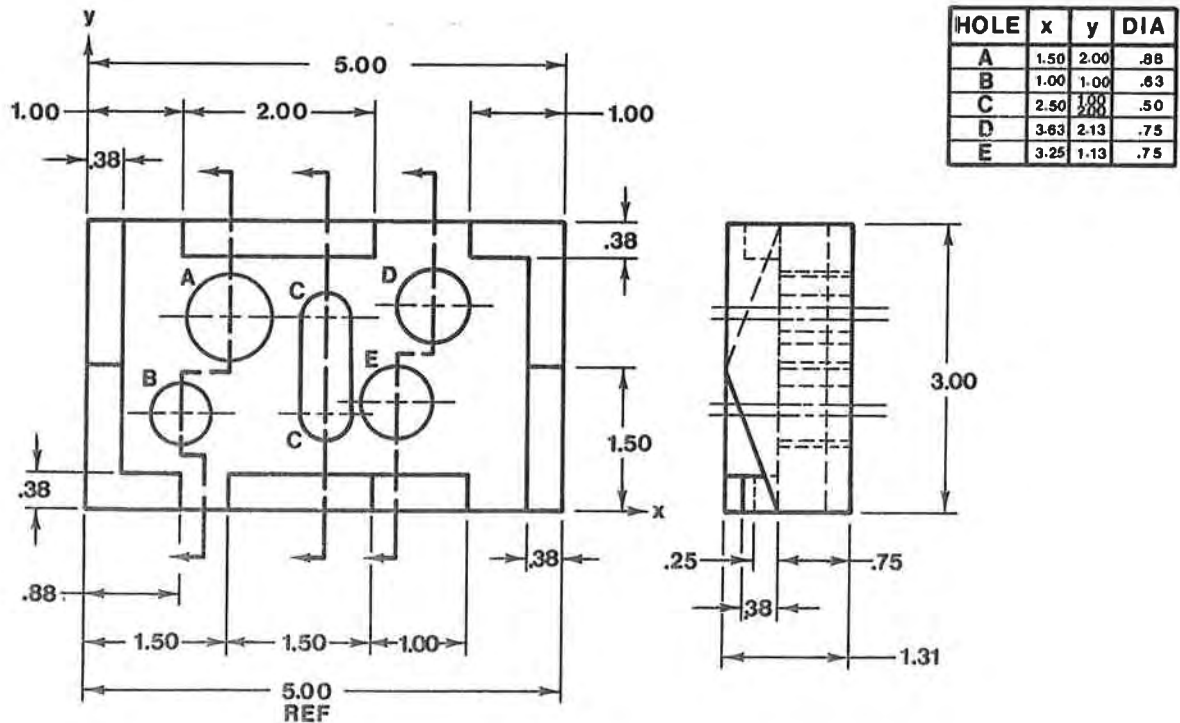


ALL FILLET AND ROUNDS = $\frac{1}{8}R$

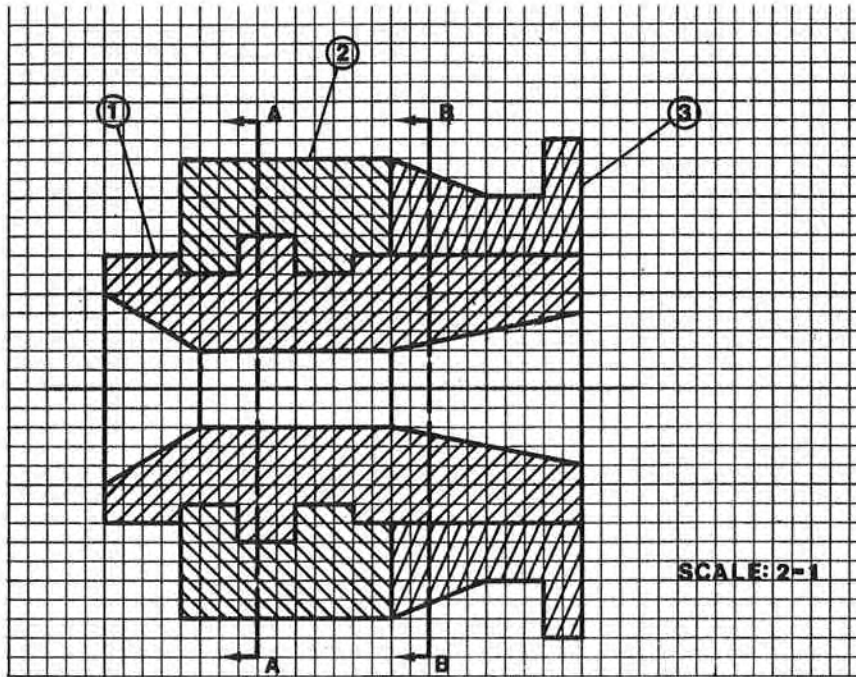
10-8 Redraw the top view and replace the front view with a sectional view.



10-9 Redraw the front and side views and add the appropriate sectional views.

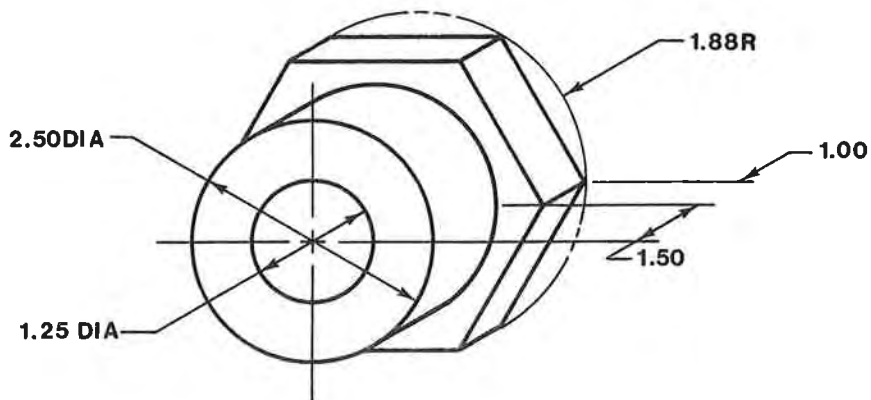


10-10 Redraw the following sectional view and add the appropriate sectional views. Assume that all the pieces are round. Each square on the grid is 0.20 per side.

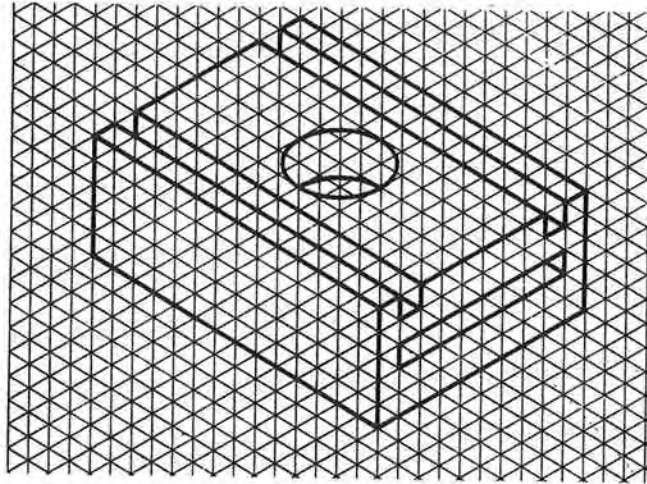


Draw a front view and sectional view of the following. Each triangle on the grid pattern is 0.20 per side.

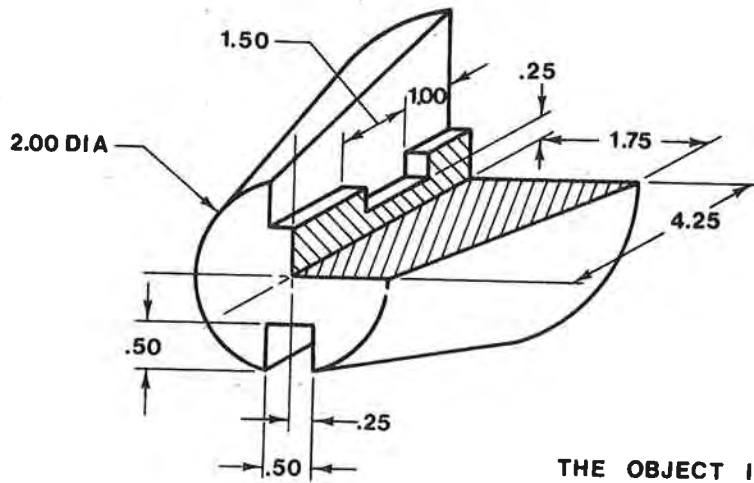
10-11



10-12

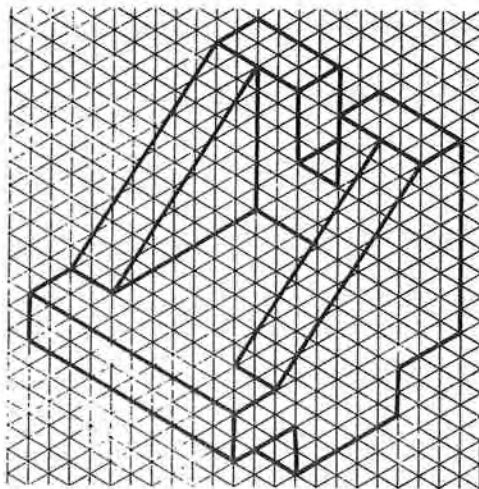


10-13

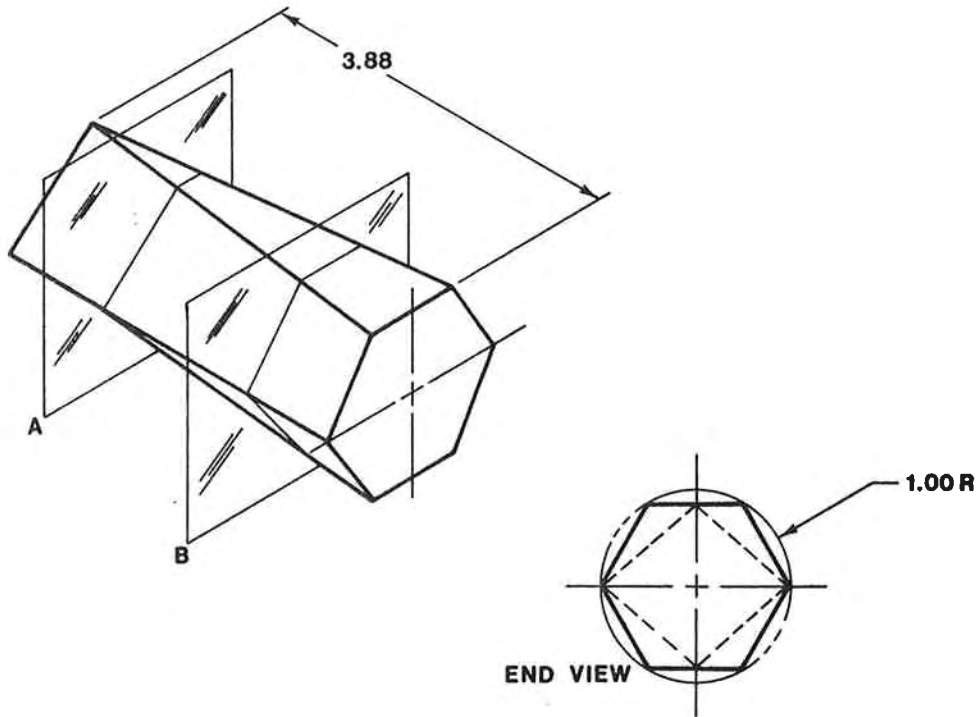


THE OBJECT IS
SYMMETRICAL

10-14



- 10-15** Draw a front and side view of the following object. Then draw two sectional views, one as defined by cutting plane A and one as defined by cutting plane B. Cutting plane A is located 1.25 from the left end of the object. Cutting plane B is located 1.00 from the right end.



AUXILIARY VIEWS 11

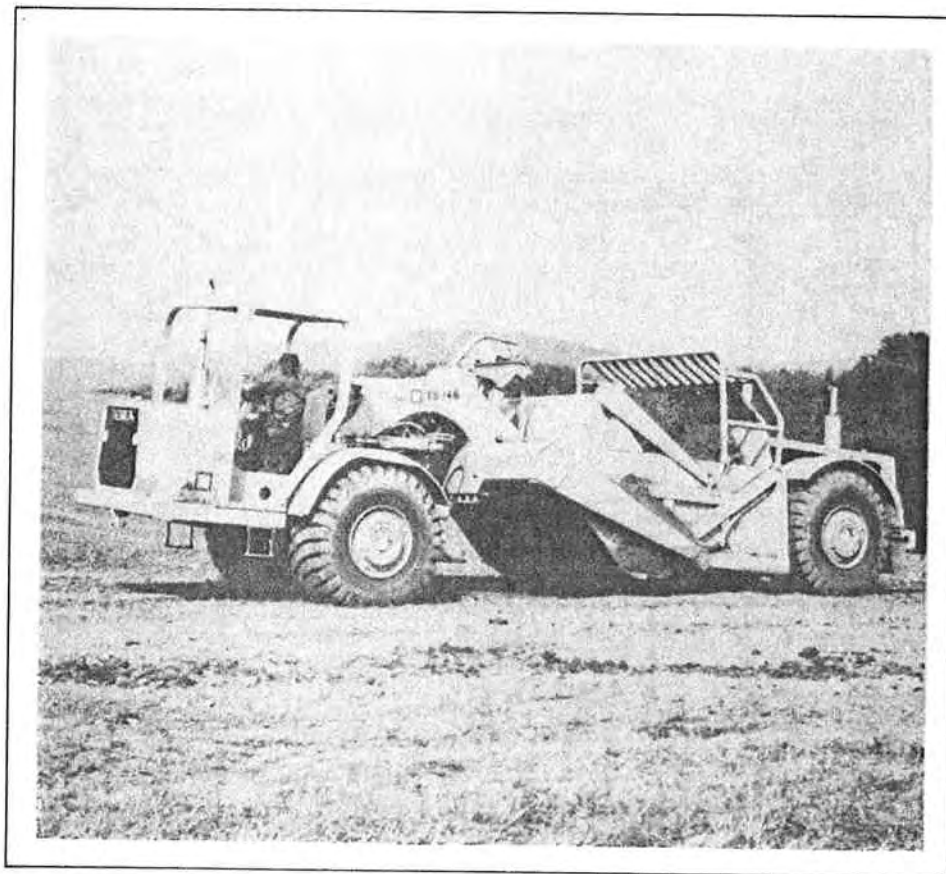


Figure 11-0 Photograph courtesy of TEREX Division, General Motors Corp.

11-1 INTRODUCTION

Auxiliary views are any orthographic views other than the three principal views. They are usually drawn to show the true shape of a surface that otherwise would appear distorted in the normal front, top, and right side view format. For example, in Figure 11-1 neither the true shape of surface 1-2-3-4 or the true shape of the $\frac{1}{2}$ " diameter hole is shown in any of the given views. This means that even though three views of the object are presented, from a *visual* standpoint, the drawing is incomplete and therefore unsatisfactory.

Figure 11-2 shows the same object that was shown in Figure 11-1, but this time using only two orthographic views: a front view and an auxiliary view. The auxiliary view is an orthographic view taken perpendicular to surface 1-2-3-4. This two-view drawing is actually more effective in its presentation of the object than is the three-view drawing. Thanks to the auxiliary view, it defines the true shape of surface 1-2-3-4 and the $\frac{1}{2}$ " diameter hole as well as all other necessary information.

Deciding when and where to use auxiliary views depends on the object being presented and on how its individual surfaces are positioned. Always use auxiliary views to add clarity to your drawings and thereby to make the technical information you are presenting easier to understand.

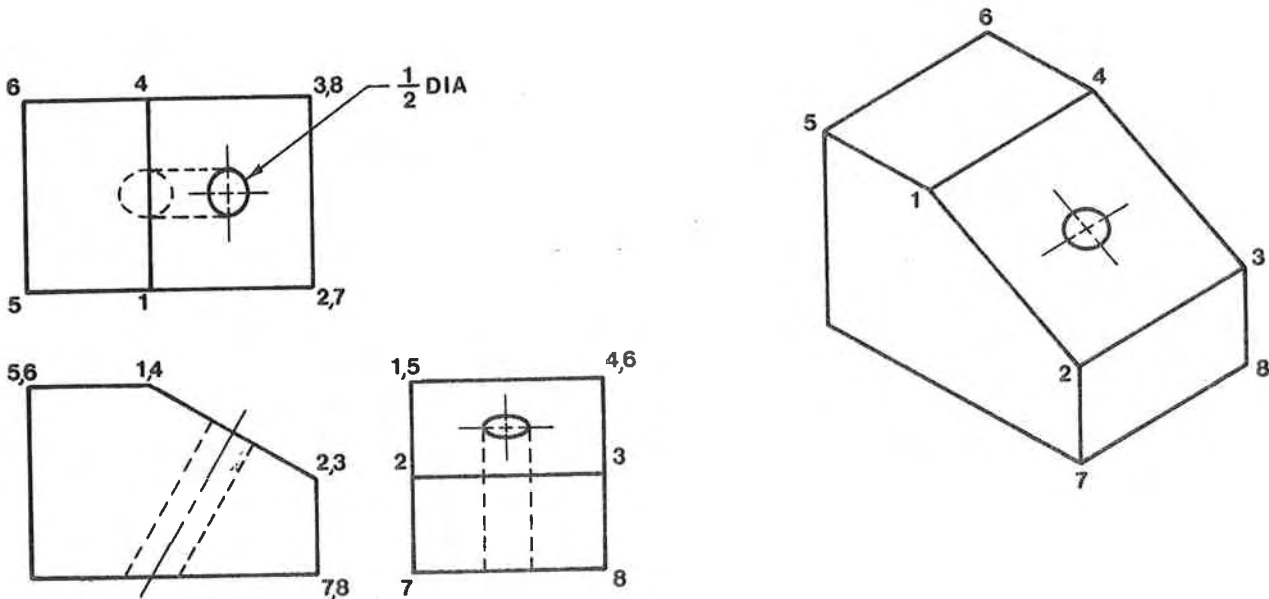


Figure 11-1 Three views of an inclined surface.

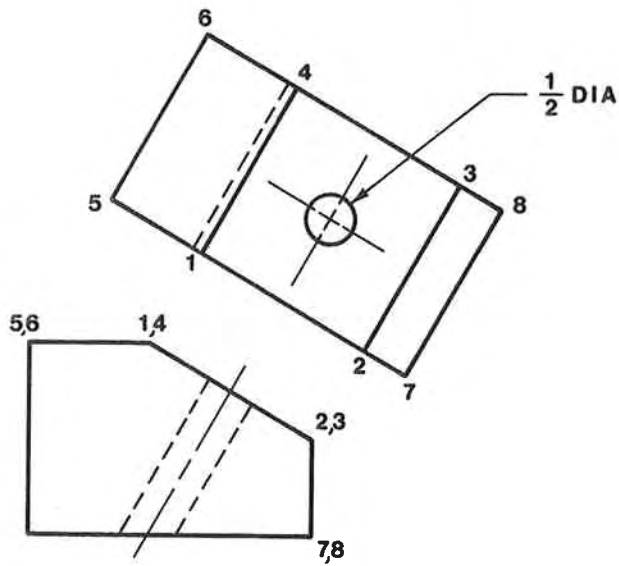


Figure 11-2 A front view and an auxiliary view of the object presented in Figure 11-1.

11-2 REFERENCE LINE METHOD

Two methods may be used to create auxiliary views: the reference line method, explained in this section, and the projection theory method, explained in the next section. Figure 11-3 is a sample problem in which you are given two views and are asked to create an auxiliary view that clearly presents surface 1-2-3-4-5. Figure 11-4 is the solution and was derived by using the reference line method as follows:

GIVEN: Front and side views.

PROBLEM: Draw an auxiliary view using the reference line method.

GIVEN: Front and side views.

PROBLEM: Draw an auxiliary view using the projection theory method.

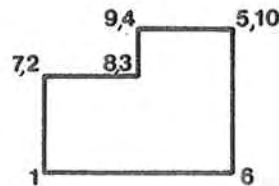
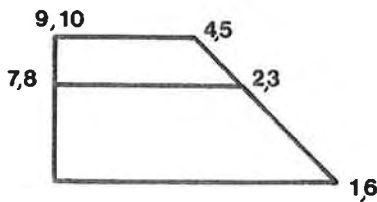
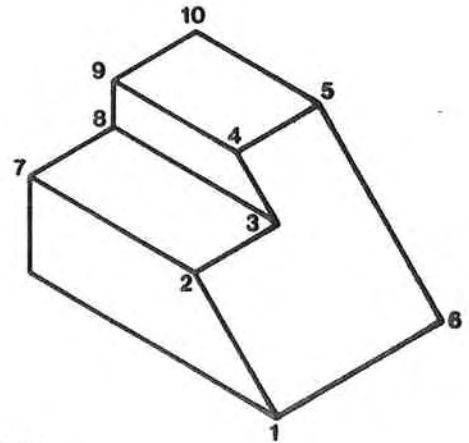


Figure 11-3

SOLUTION: Using the reference line method:

1. Draw a vertical line between the front and right side views and draw a line parallel to surface 1-2-3-4-5-6. Define the vertical line as reference line 1. Define the line parallel to surface 1-2-3-4-5 as reference line 2.

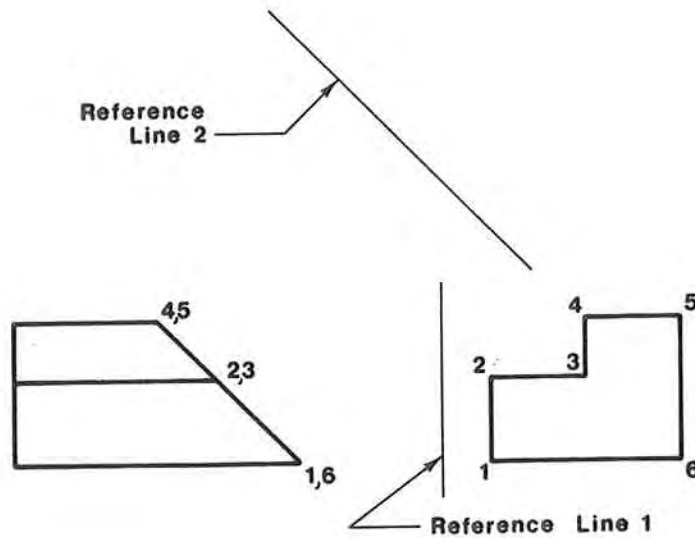


Figure 11-4(a)

2. Label points 1, 2, 3, 4, 5, 6, and any other points you feel you'll need in both the front and right side views.
3. Project all points in the front view into the auxiliary views by drawing very light lines perpendicular to reference line 2 from the front view points into the area where the auxiliary view will be.

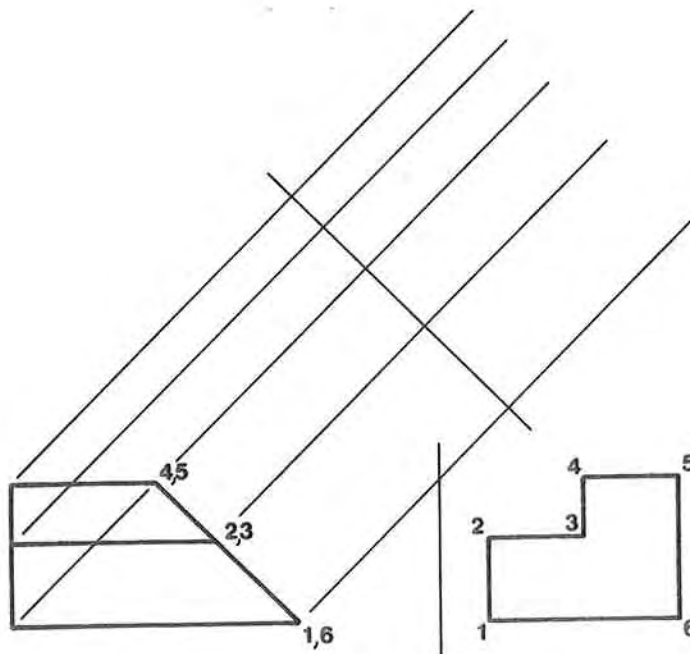


Figure 11-4(b)

4. Using either dividers or a compass, transfer the points from the right side view to the auxiliary view by transferring the perpendicular distance from reference line 1 to the point, to reference line 2 along the appropriate point projection line created in step 3. This is possible because the distance between reference line 1 and the right side view and the points is the same as the distance between reference line 2 and the auxiliary view. Label all points in the auxiliary view.

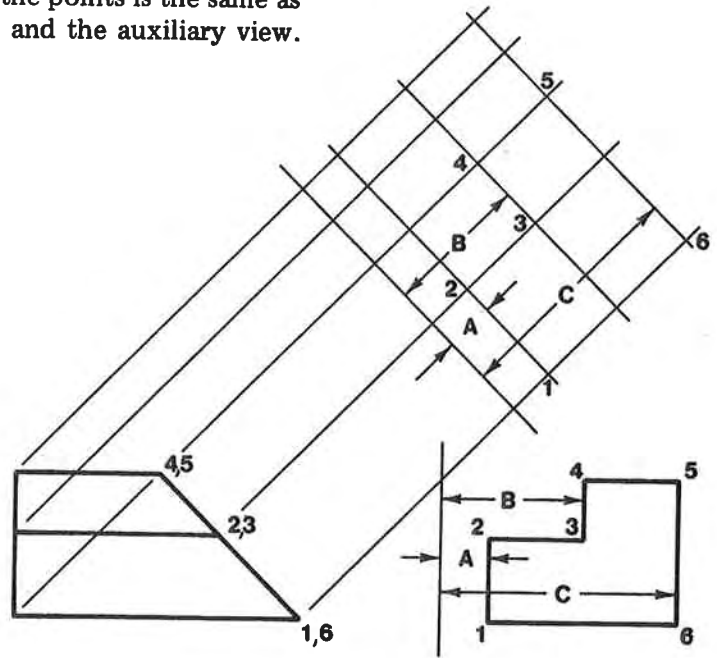


Figure 11-4(c)

5. Lightly draw in the auxiliary view by lightly connecting the appropriate points. Check your work.
6. Erase all excess lines, point labels, and smudges and draw in all lines to their final configuration and color.

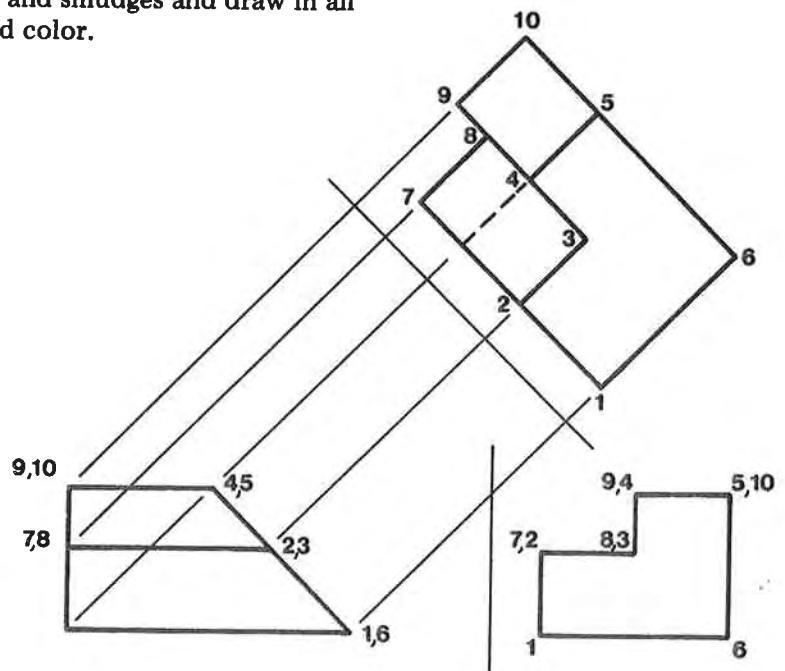


Figure 11-4(d)

Note that surfaces 4-5-9-10 and 2-3-8-7 are distorted in the auxiliary view.

Figures 11-5 and 11-6 are further examples of auxiliary views drawn by using the reference line method.

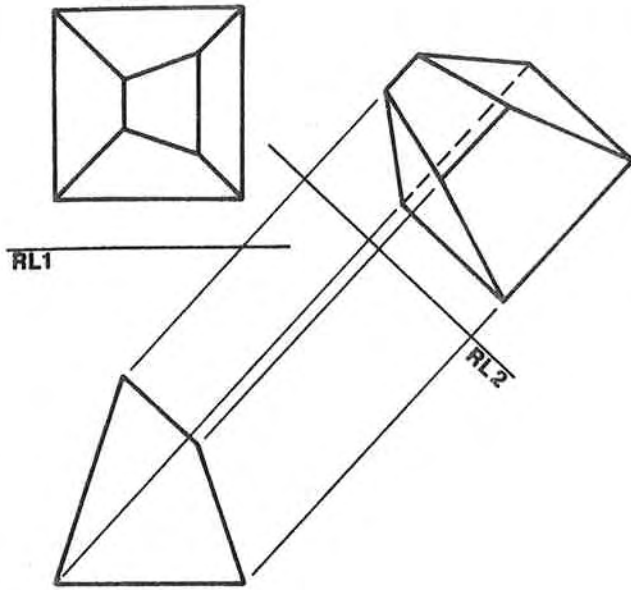


Figure 11-5 An auxiliary view created using the reference line method.

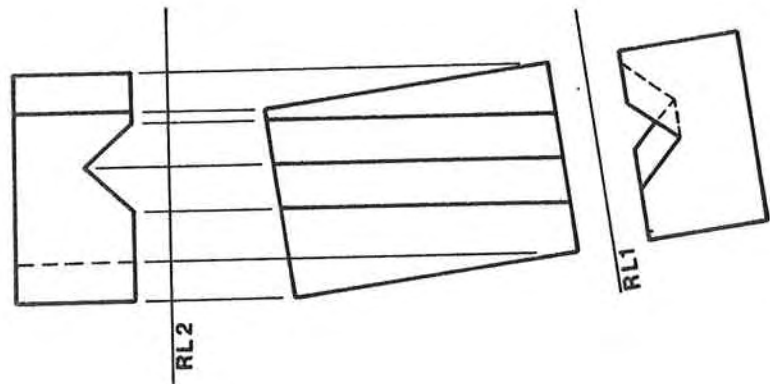


Figure 11-6 An auxiliary view created using the reference line method.

11-3 PROJECTION THEORY METHOD

The projection theory presented in Chapter 4 may also be applied to auxiliary views. The problem of Figure 11-3 is again presented, but this time it is solved by using the projection theory method. The solution is illustrated in Figure 11-7 and was derived by using the following procedure:

SOLUTION: Using the projection method:

1. Draw a vertical line between the front and right side views and draw a line parallel to surface 1-2-3-4-5-6. Draw the lines so that they intersect. Label the intersection point 0. Through point 0 draw two more lines: one perpendicular to the vertical line (therefore a horizontal line) and one perpendicular to the line drawn parallel to surface 1-2-3-4-5-6.

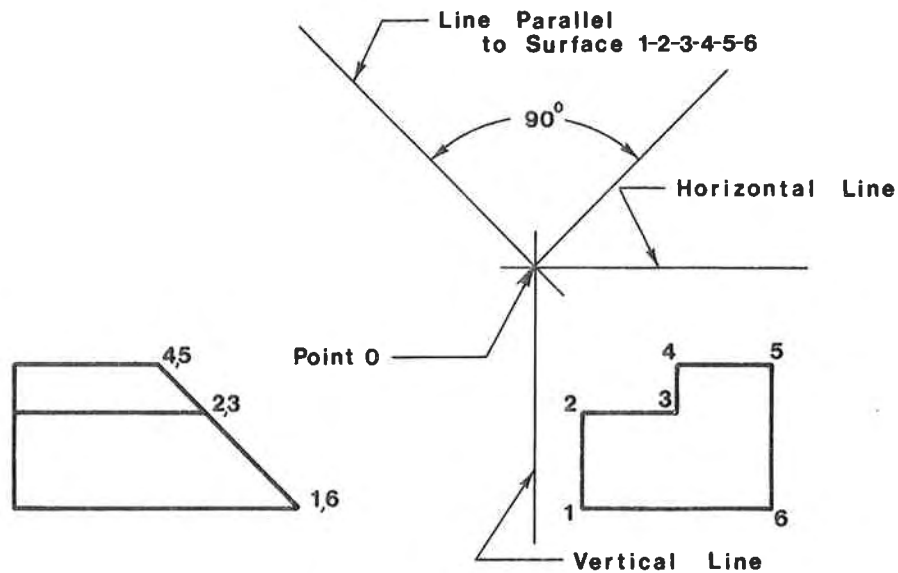


Figure 11-7(a)

2. Project the points labeled in the side view into the area where the auxiliary view will be by first drawing vertical projection lines from the points to the horizontal line drawn in step 1. Then, using a compass set on point 0, draw projection arcs which will continue the vertical projection lines from the horizontal line to the line perpendicular to the line parallel to surface 1-2-3-4-5-6. Continue the projection lines parallel to surface 1-2-3-4-5-6 as shown.

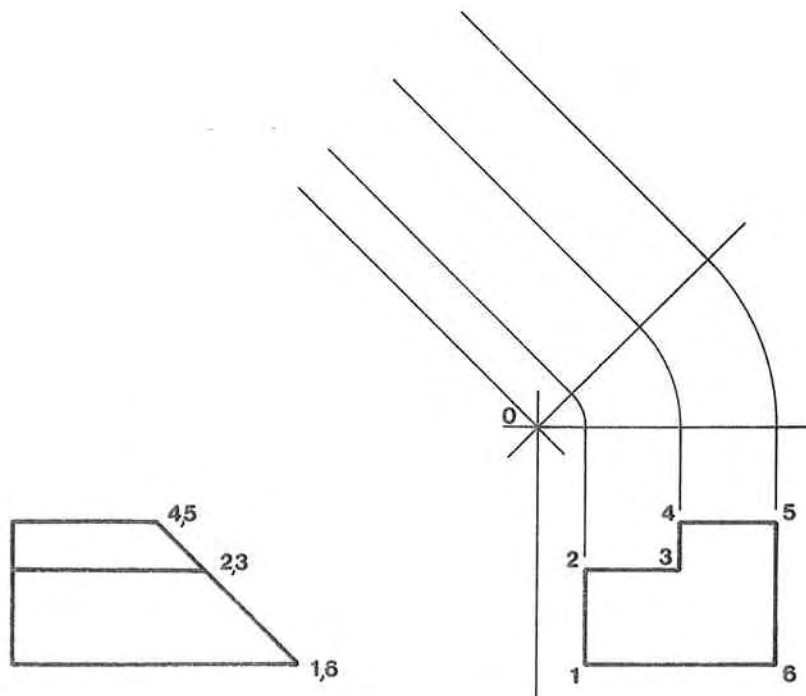


Figure 11-7(b)

- Project the points from the front view by drawing lines perpendicular to the line drawn parallel to surface 1-2-3-4-5-6. Label the intersections of these projection lines with the ones drawn in step 2 with the appropriate numbers.

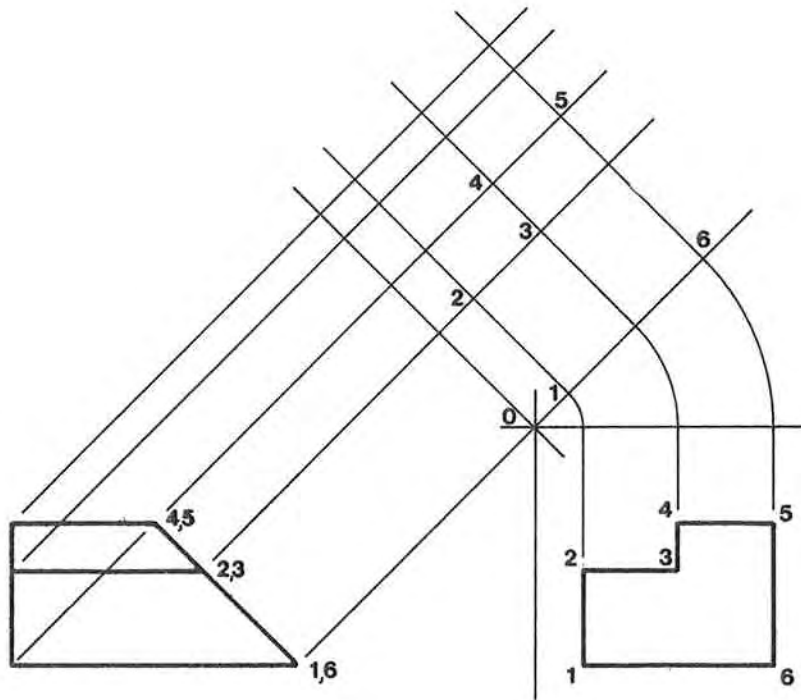


Figure 11-7(c)

- Erase all excess lines, point labels, and smudges and draw in all lines to their final configuration and color.

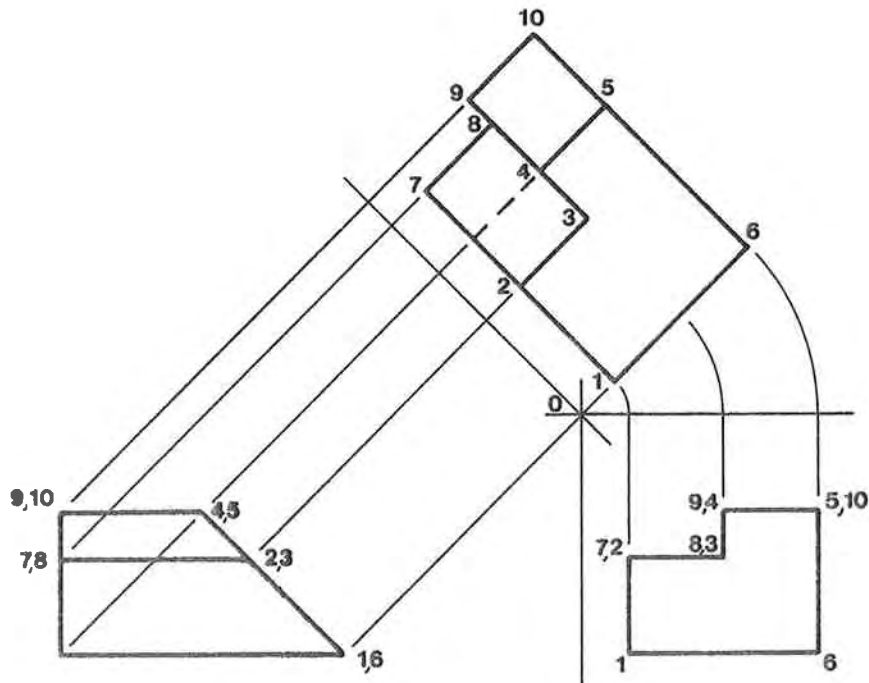


Figure 11-7(d)

Note that the solution derived by the projection theory method is exactly the same as the solution derived by the reference line method. Either method will generate an accurate answer and the choice of which method to use depends on the preference of the individual draftsman.

11-4 AUXILIARY SECTIONAL VIEWS

Auxiliary sectional views are a combination of an auxiliary view and sectional view. They are orthographic views taken through an object at an angle defined by a cutting plane line. They adhere to the same rules and format given for sectional views in Chapter 10, and they are drawn for the same reasons: to expose surfaces that are hidden from direct view in the regular front, top, and right side views.

Figure 11-8 is an example of a drawing that contains an auxiliary sectional view. Figure 11-9 is an example of a drawing that contains a partial auxiliary sectional view. Either the reference line or projection line method may be used to create auxiliary sectional views.

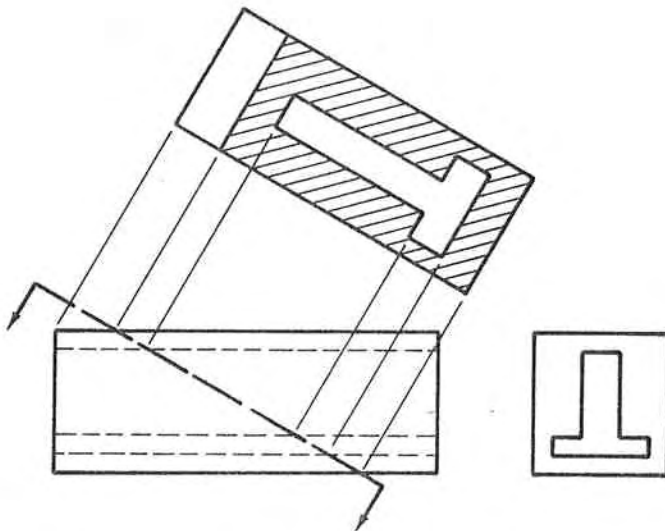


Figure 11-8 An auxiliary sectional view.

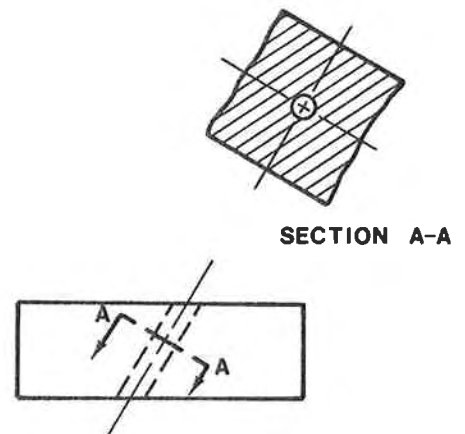


Figure 11-9 A partial auxiliary sectional view.

11-5 PARTIAL AUXILIARY VIEWS

Auxiliary views are helpful in clarifying drawings, but their use does have drawbacks. For example, surface 1-4-6-5 which appeared true size in the top view of Figure 11-1 appears distorted in the auxiliary view in Figure 11-3. The same is true of surface 2-7-8-3. By trying to create a view that will clarify one surface, we have distorted two other views. To eliminate distortion in the principal views, we have created auxiliary views which in turn have created other distortions.

The solution is to use partial auxiliary views. Figure 11-10 shows the same object that was shown in Figures 11-1 and 11-2 and was drawn using a front view and a partial auxiliary view. As the name

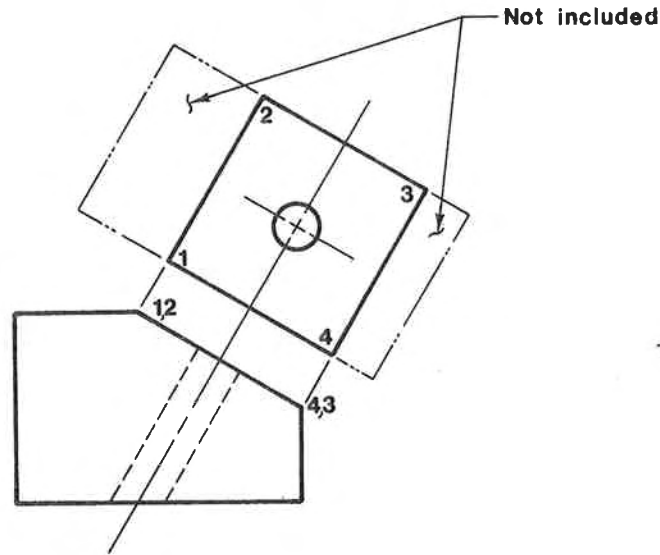


Figure 11-10 Front and partial auxiliary views of an object.

implies, a partial auxiliary view is only part of a complete auxiliary view. Partial auxiliary views enable you to limit your auxiliary view to one specific surface or part of a surface, thereby eliminating the need to draw surfaces that have become distorted in the auxiliary views.

If only one complete surface is shown in the partial auxiliary view, as is the case in Figure 11-10, break lines need not be shown. If however, part of a surface or more than one surface is to be drawn, break lines are shown.

11-6 SECONDARY AUXILIARY VIEWS

It is sometimes necessary to draw an auxiliary view of an auxiliary view. This occurs when the first auxiliary view does not completely define or does not clearly present the surface being studied. For example, Figure 11-11 shows a front, top, right side, and auxiliary view of an object that contains an oblique surface (surface 1-2-3). Despite the great number of views taken of the object, none of the given views shows the true shape of surface 1-2-3. To present a true shape of surface 1-2-3, we must use a secondary auxiliary view.

The true shape of surface 1-2-3 will only be shown in an orthographic view taken at exactly 90° to the surface. To help you visualize this concept, think of an airplane in flight. If the airplane is flying directly away from you, parallel to your line of sight (0°), it will give little or no indication of its true speed. It will simply seem to slowly disappear. If, however, the airplane is flying directly across your line of vision (90°), it will give a correct indication of its true speed. Similarly, only when a line or a plane is directly across your line of vision (an orthographic view taken at exactly 90° to your line of vision) can you see its true shape.

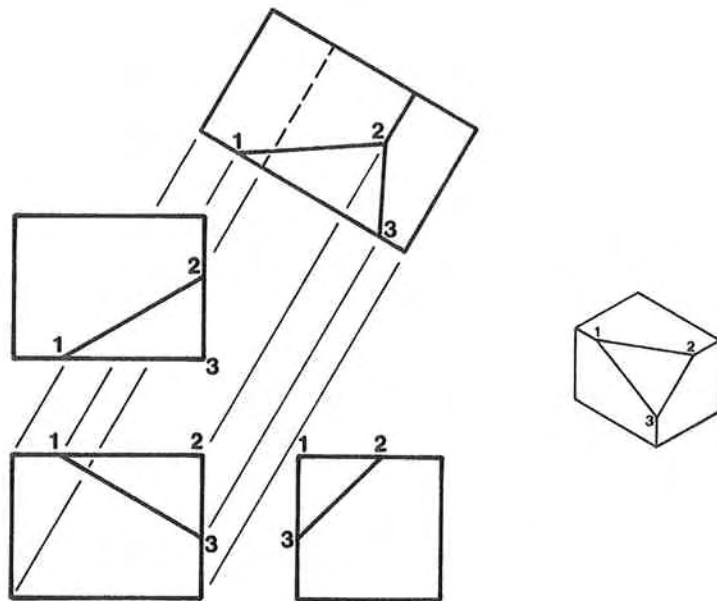


Figure 11-11 What is the true shape of surface 1-2-3? None of these views define it.

But how can we be assured that our secondary auxiliary view is taken at 90° to the surface? If we want our secondary view to be 90° to a surface, the first auxiliary view must be taken 0° to the surface because each auxiliary view will be 90° to the previous one.

To draw an auxiliary view that is at 0° to the surface (an end view of the surface), we must identify a true length line on the surface. A true length line is the only line on the surface whose angle relative to the principal plane lines we know exactly. Because we know the exact angle of a true length line relative to the principal plane lines, we know the angle at which to draw an auxiliary view which will be an end view of the line and therefore an end view of the surface in which the line is located.

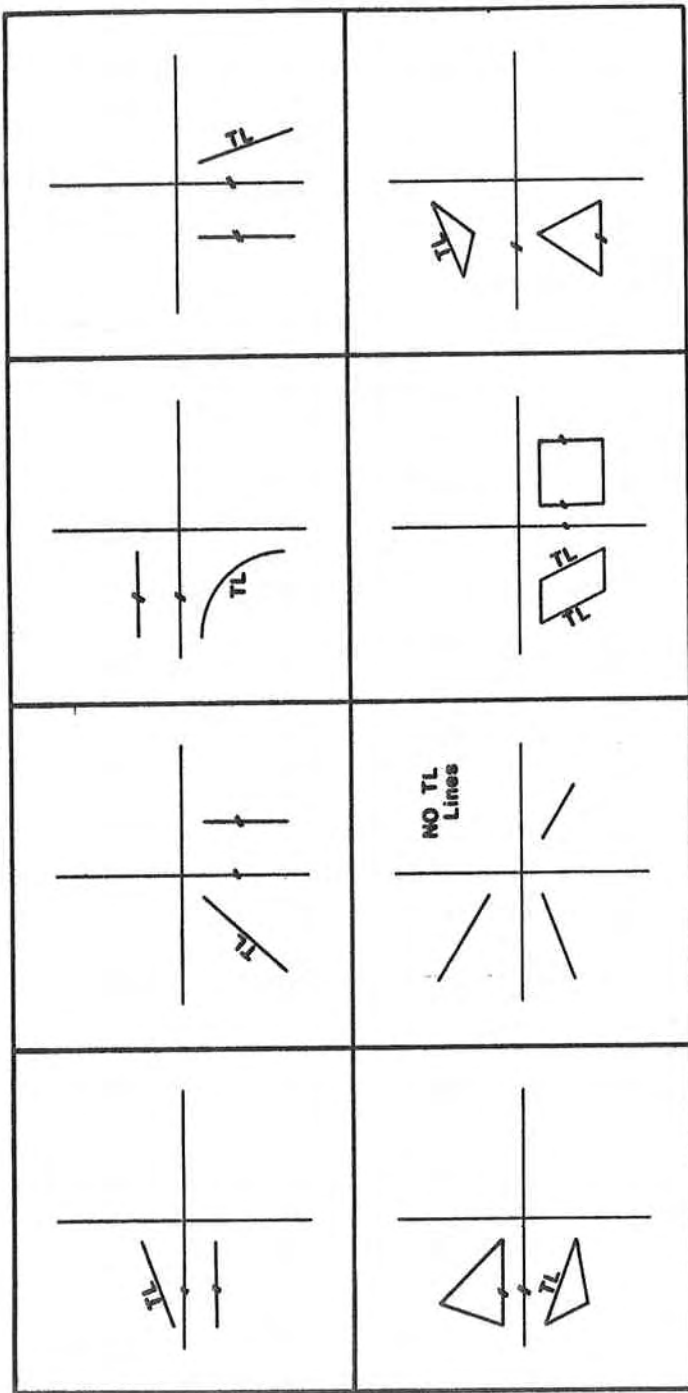
A true length line is found by the following axiom:

An orthographic view of a line shows the true length (TL) of that line if one of the other orthographic views of that line is parallel to one of the principal plane lines.

Axiom 11-1

Figure 11-12 illustrates this axiom. Note that so long as one of the given orthographic views is parallel to one of the principal plane lines, the other view of the line is a true length. If none of the views of the line is parallel to either principal plane line, then none of the given views is a true length. Also note that because one of the lines in a surface is true length, it does not mean that all the other lines in the surface are true length.

In the example of Figure 11-11, line 1-2 is true length in the top view, line 1-3 is true length in the front view, and line 2-3 is true length in the right side view. We could use any one of these lines to generate an auxiliary view that is 0° to the surface 1-2-3. Line 1-2 was used for this example.



/ Indicates lines which are Parallel

Figure 11-12 How to identify true length lines.

Figure 11-13 is the solution to the problem presented in Figure 11-11 and was derived by using the following procedure:

SOLUTION:

1. Identify in one of the given views a true length line. In this example line 1-2 meets the criterion set by axiom 11-1.

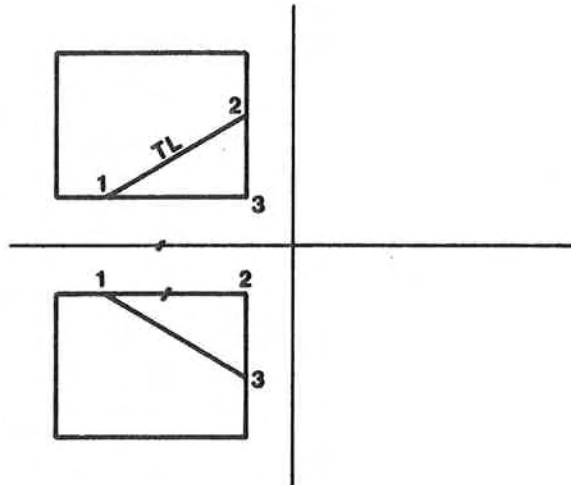


Figure 11-13(a)

2. Extend line 1-2 and draw lines parallel to the extension of line 1-2 throughout the other known points on the surface.

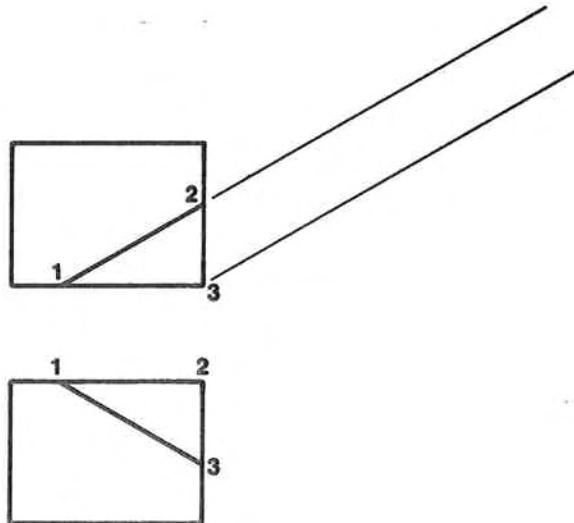


Figure 11-13(b)

3. Draw in the principal plane line between the two given views and label it reference line 1. Also draw a line somewhere along the extension lines drawn in step 2. The line must be perpendicular to those lines. Label it reference line 2.

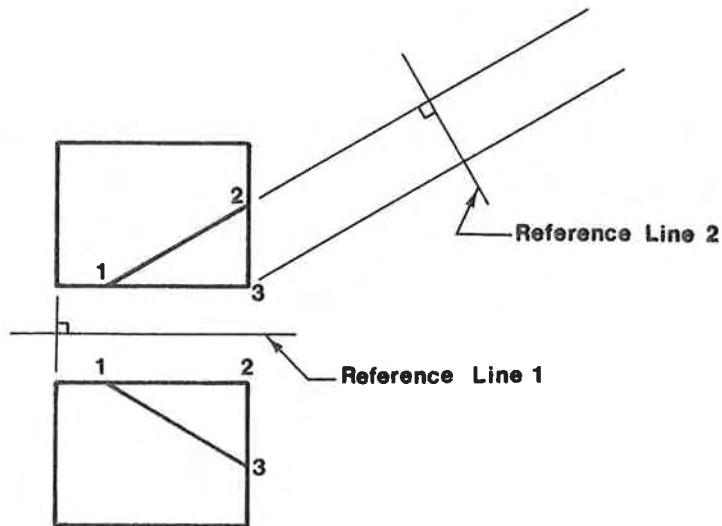


Figure 11-13(c)

4. Measure the distance from reference line 1 to point 1 in the view that contains line 1-2 parallel to the principal plane line. Transfer this distance to reference line 2 as shown. Make sure that you transfer the distance to the line that was originally extended through point 1. Do the same with all other points in the surface. Measure the distance from the point to reference line 1, and then transfer this distance to reference line 2 as shown.

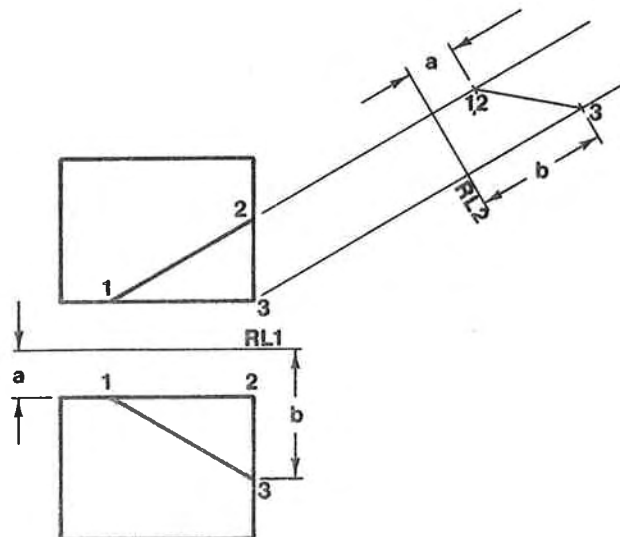


Figure 11-13(d)

- Using appropriate point numbers, label the first auxiliary view you have now generated.

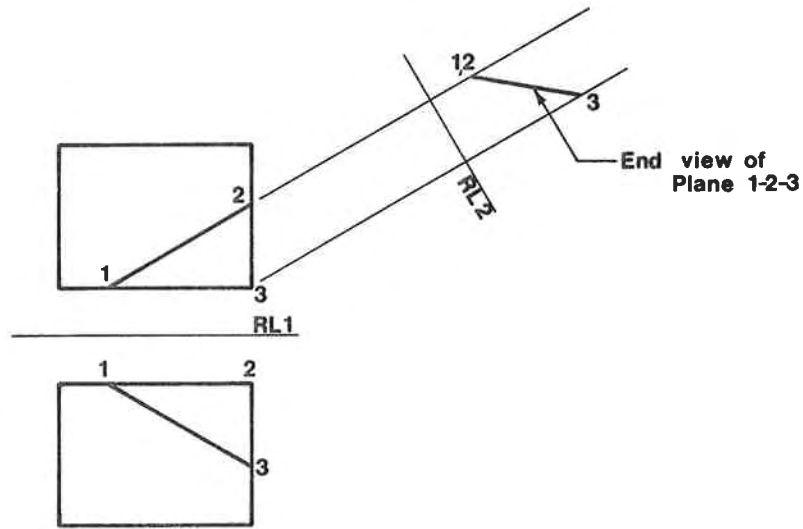


Figure 11-13(e)

- Draw lines perpendicular to the auxiliary view through all points on the surface as shown. Draw a line parallel to the end view of the surface and label it reference line 3.

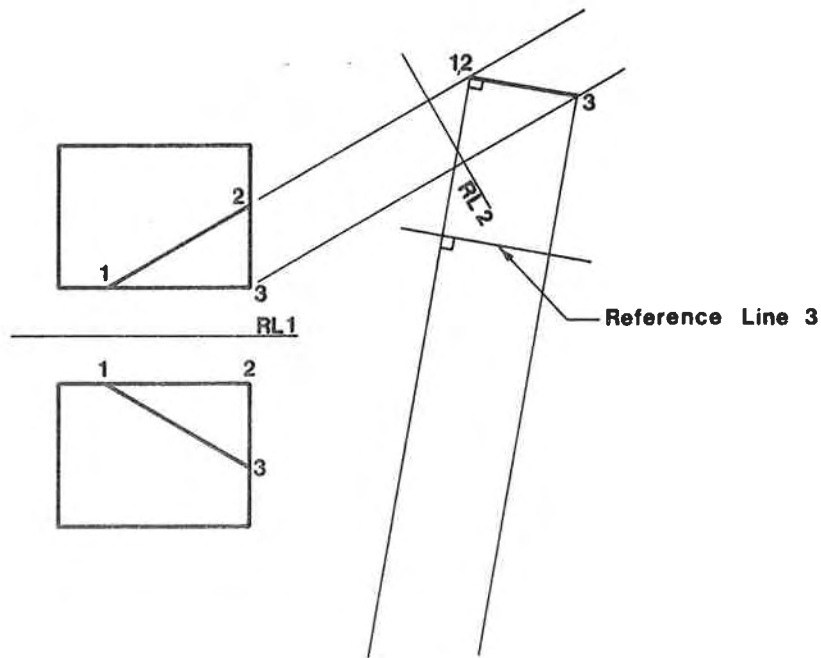


Figure 11-13(f)

7. Measure the distance from reference line 2 to point 1 in the view in which line 1-2 appeared true length. Transfer this distance to reference line 3 as shown. Do the same with all other points in the surface.
8. Label the secondary auxiliary view of the surface with the appropriate point numbers and darken in all lines to the final color and configuration. Leave on all construction lines unless you are specifically told to erase them. This will make it easier for someone to check or follow your work.

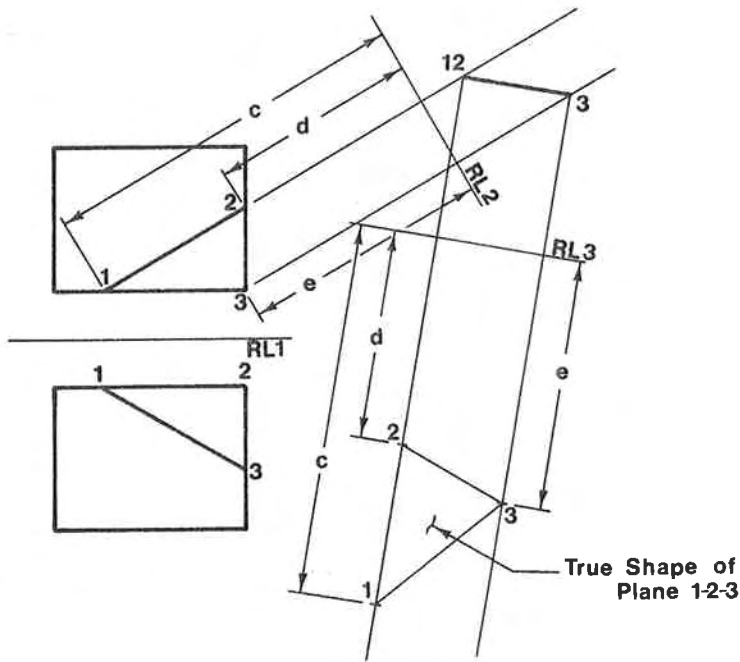


Figure 11-13(g)

Figure 11-14 is the solution to the problem stated in Figure 11-11, except that in Figure 11-14 line 2-3 was used to generate the first auxiliary view. The problem was solved by using the procedure outlined for Figure 11-13. Note that the true shape of surface 1-2-3 is exactly the same as that generated in Figure 11-13. Study and carefully verify how each point was transferred from reference line to reference line.

Sometimes none of the given lines that define a surface is of true length. This does not mean that a secondary auxiliary view of the surface cannot be created. It simply means that we have to create a true length line from the given information and then proceed as before. For example, the surface 1-2-3 pictured in Figure 11-15 contains no true length lines and yet the problem asks us to find the true shape of that surface which we know can only be accomplished through a secondary auxiliary view.

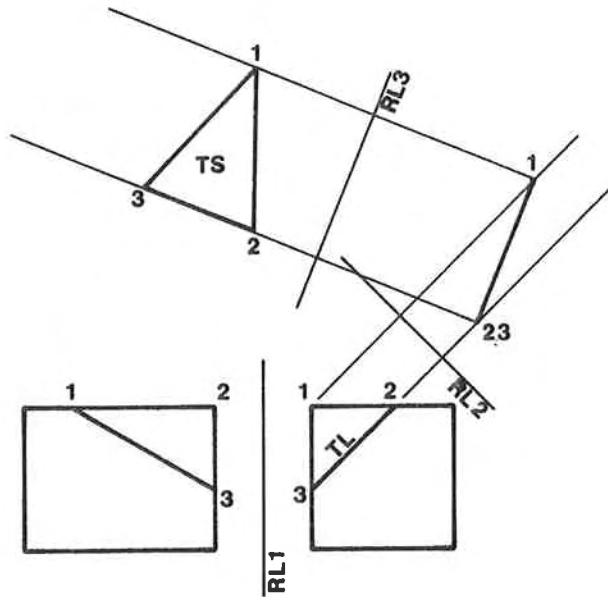


Figure 11-14 The true shape of plane 1-2-3 found by using the true length view of line 2-3.

GIVEN: Front and top views.

PROBLEM: Draw the true shape of plane 1-2-3.

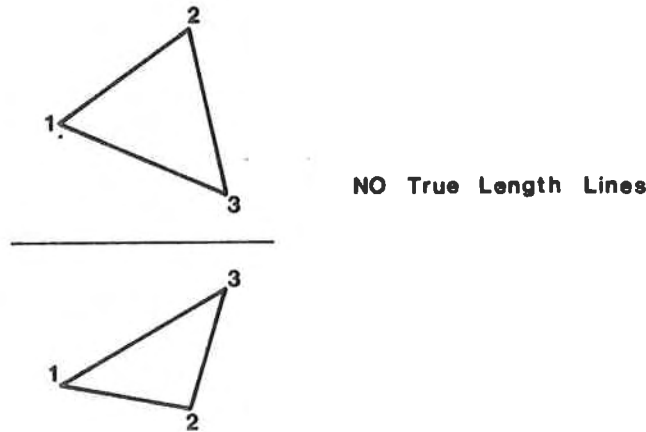


Figure 11-15

To create a true length line in surface 1-2-3, first draw a line in one of the views that is parallel to one of the principal plane lines. Then project this line into the other view of the surface. In this example the new line was labeled 1-x where point x lays along the known line 2-3. To project point x from the top view into the front view, draw a line parallel to the line drawn between the two known point 1's and perpendicular to the principal plane line from point x in the top view to a

point of intersection with line 2-3 in the front view. The solution to the problem is completed as previously outlined based on the true length line 0-x. Figure 11-16 is the solution to the problem stated in Figure 11-15.

SOLUTION:

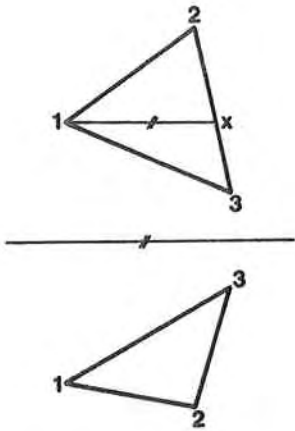


Figure 11-16(a)

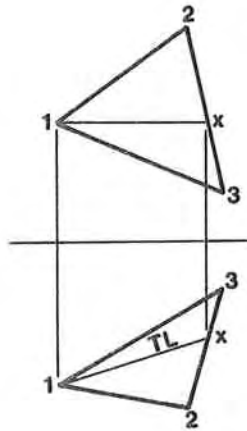


Figure 11-16(b)

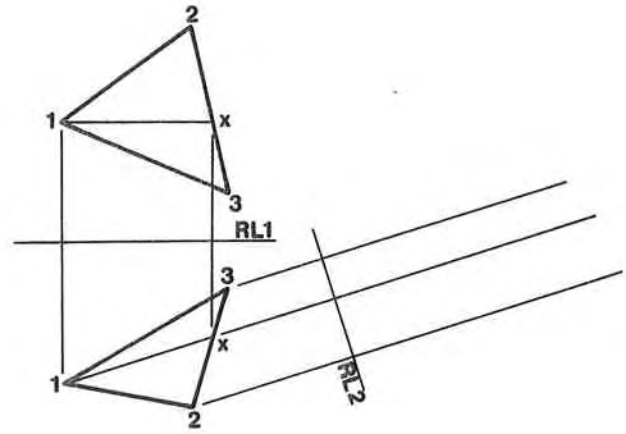


Figure 11-16(c)

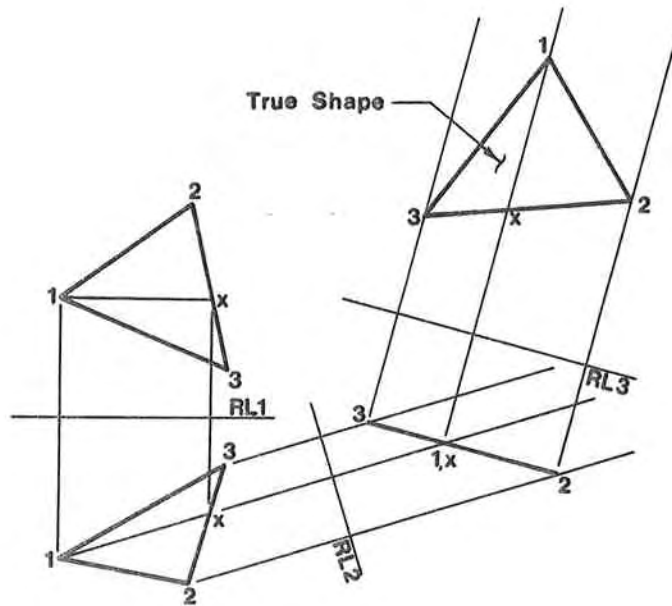
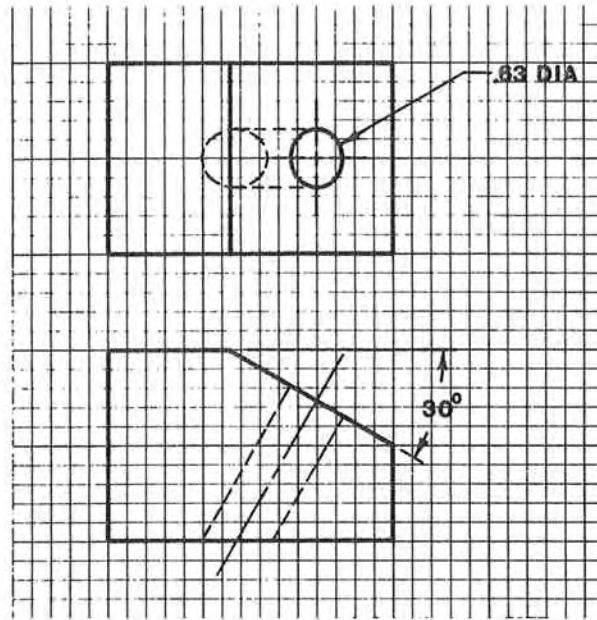


Figure 11-16(d)

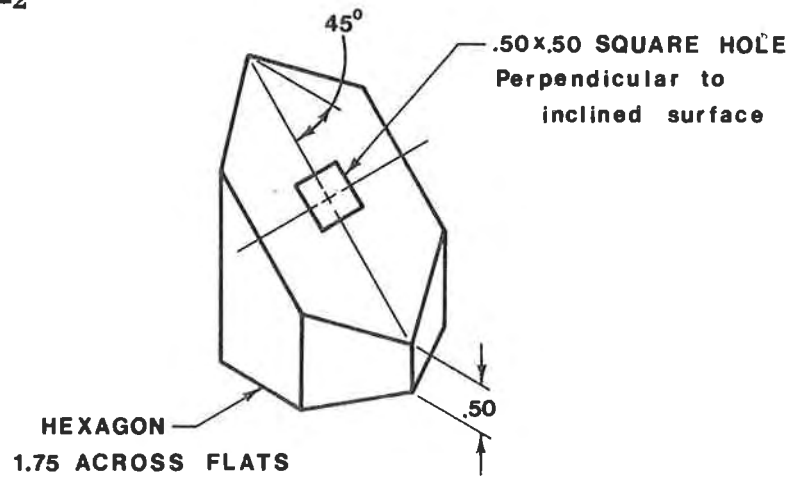
PROBLEMS

Redraw the following objects and add the appropriate auxiliary views:

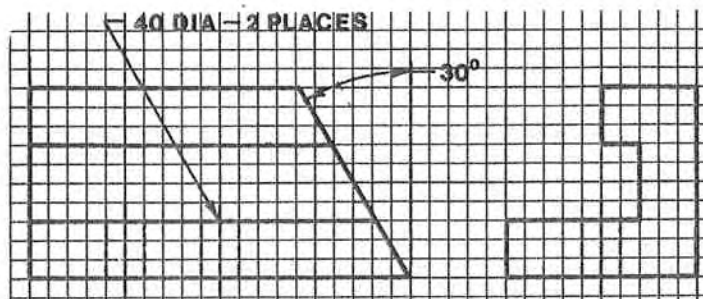
11-1



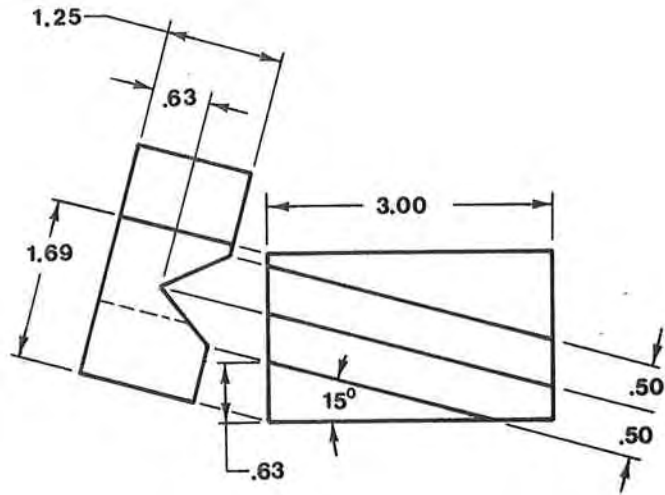
11-2



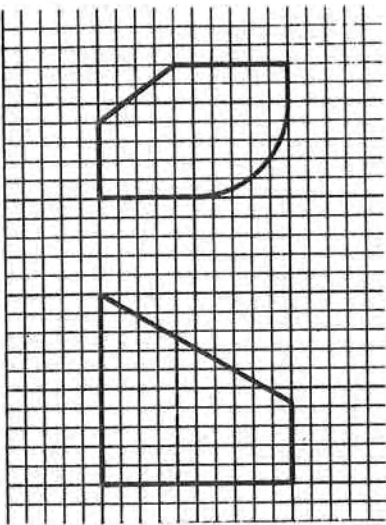
11-3



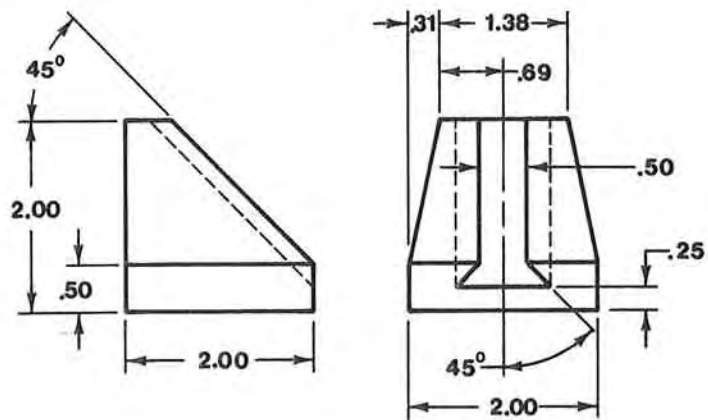
11-4



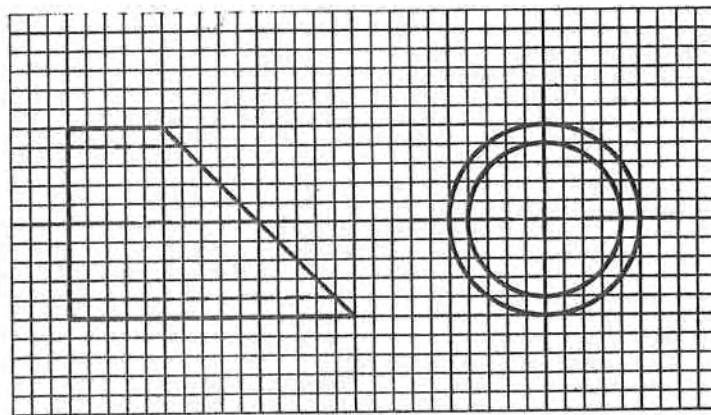
11-5



11-6

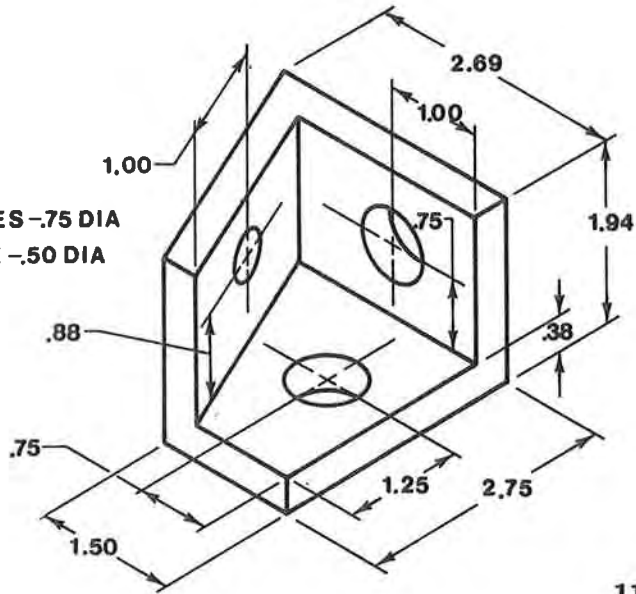


11-7

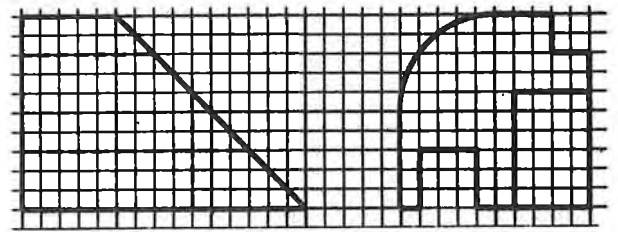


11-8

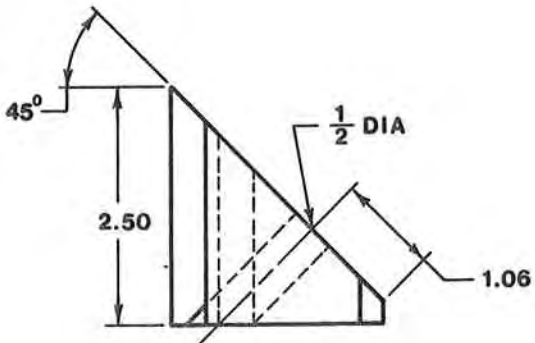
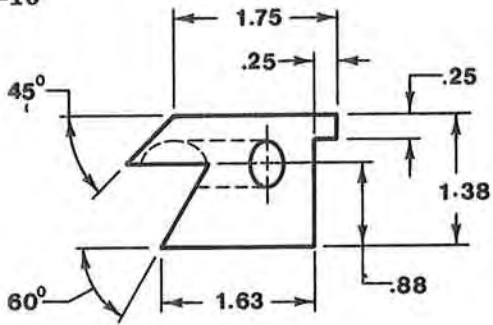
2 LARGE HOLES -.75 DIA
1 SMALL HOLE -.50 DIA



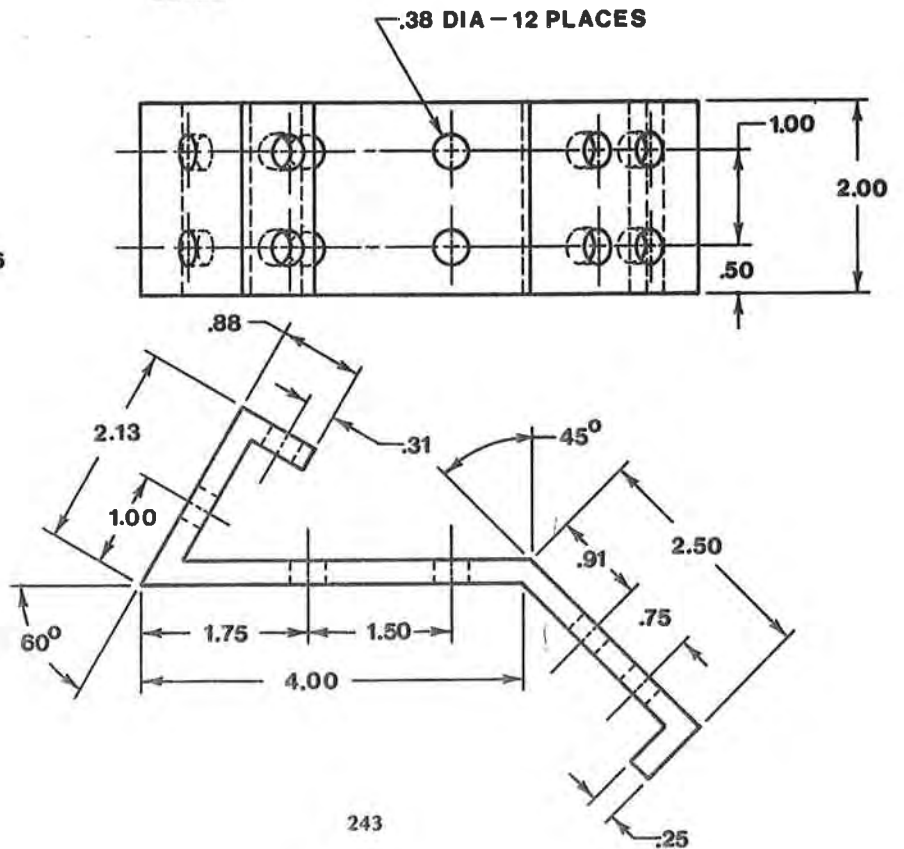
11-9



11-10

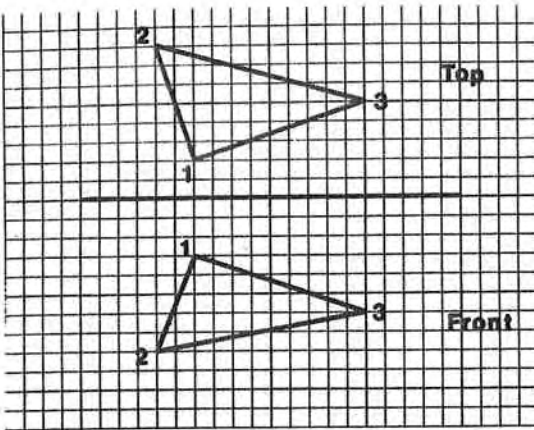


11-11

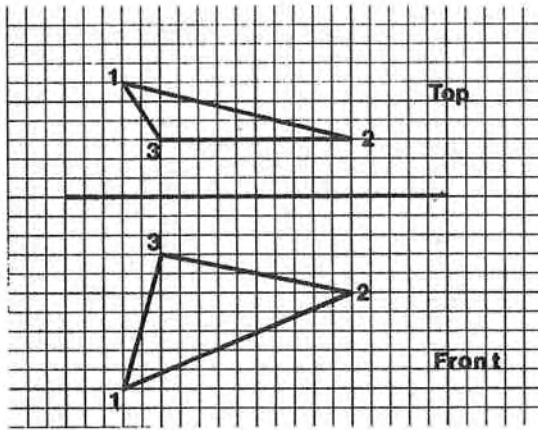


Using a secondary auxiliary view, derive the true shape of the following planes. Each square of the grid is 0.20 per side.

11-12

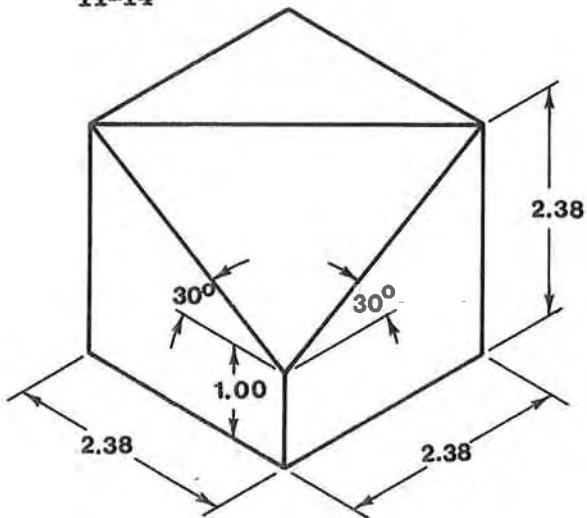


11-13

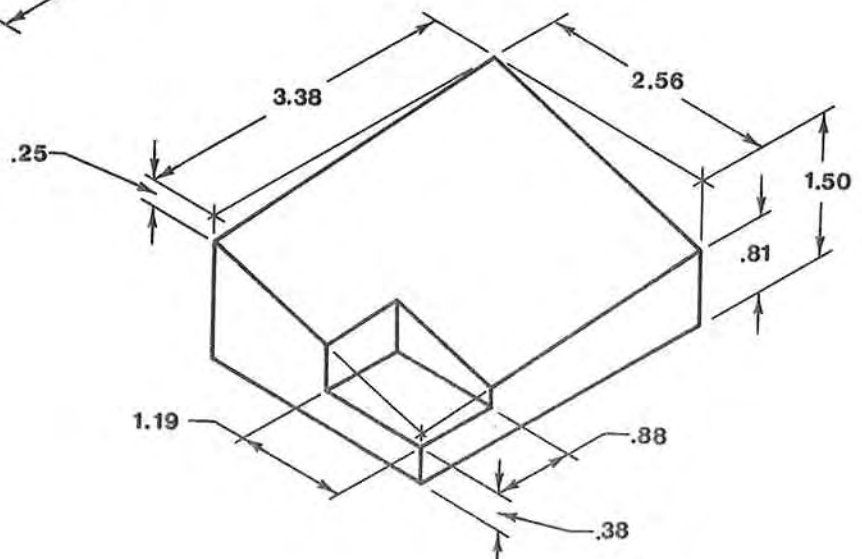


Draw sufficient views to completely define the following objects. In each case, include a secondary auxiliary view of the oblique surface.

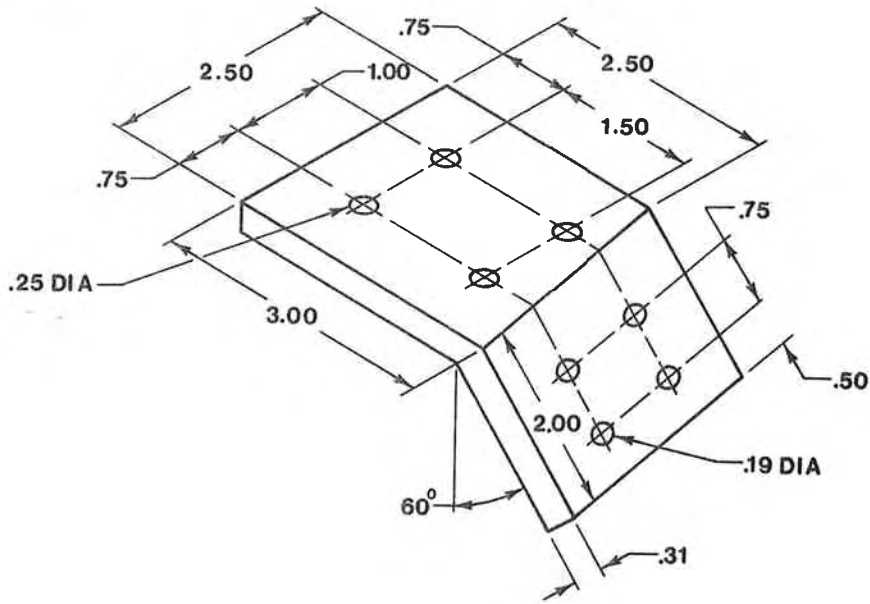
11-14



11-15



11-16



FASTENERS 12

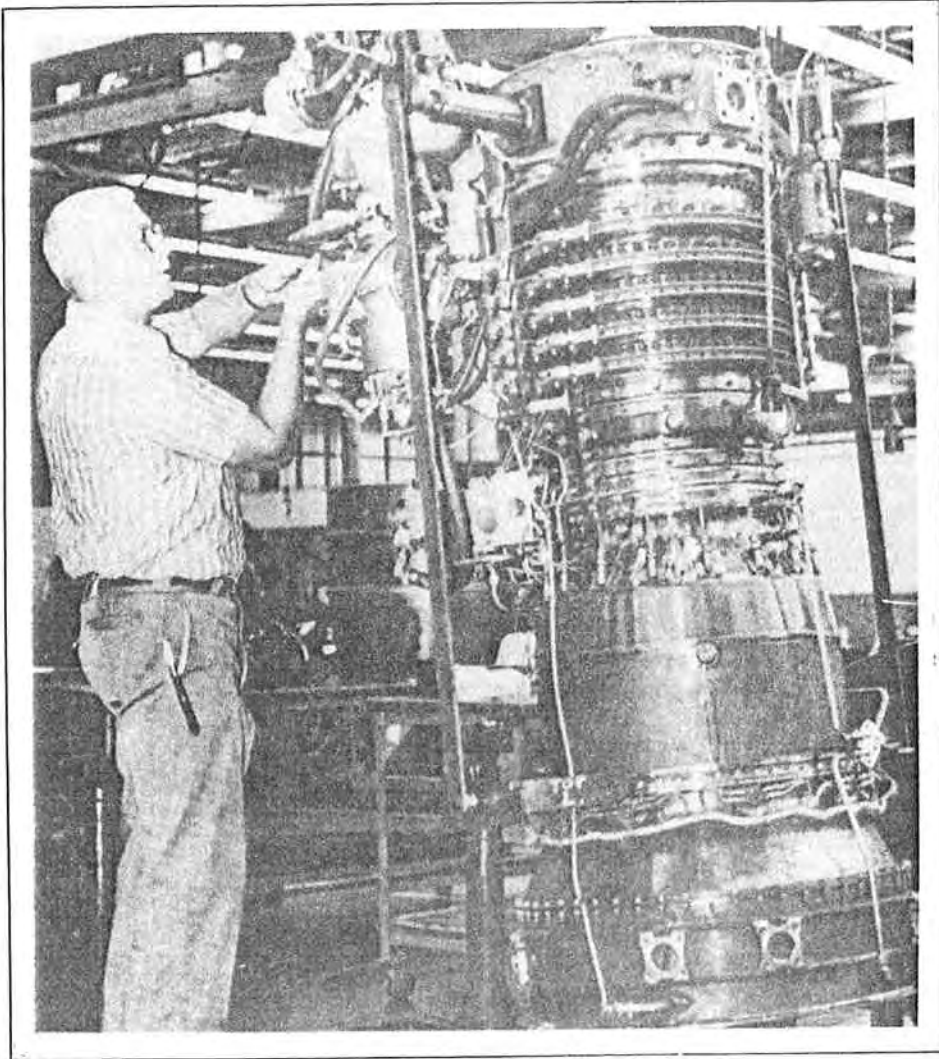


Figure 12-0 Photograph of an Allison 501-M62B turboshaft engine courtesy of Detroit Diesel Allison Division of General Motors Corp.

12-1 INTRODUCTION

There are two basic fasteners: mechanical and nonmechanical. Mechanical fasteners include bolts, rivets, and screws and, from a design standpoint, they are usually stronger, easier to work with, and more easily replaced than nonmechanical fasteners. Nonmechanical fasteners include glues, epoxies, tapes, and so on, and they are usually less expensive, lighter, and require less installed space than do mechanical fasteners.

This chapter deals exclusively with mechanical fasteners. Nonmechanical fasteners are not drawn, but they are noted on a drawing as shown in Figure 12-1. Mechanical fasteners, however, have specific representations that must be clearly and accurately drawn.

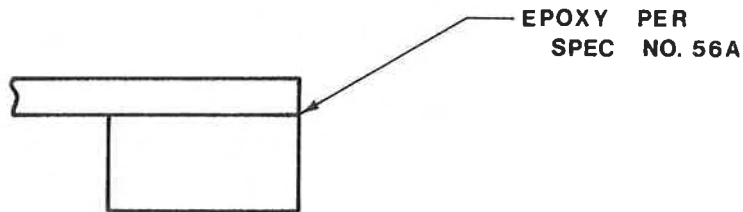


Figure 12-1 A call out for a nonmechanical fastener.

12-2 THREAD TERMINOLOGY

Figure 12-2 illustrates some of the basic terms used to describe a thread. These terms are common to all kinds of threads and will be referred to throughout the chapter.

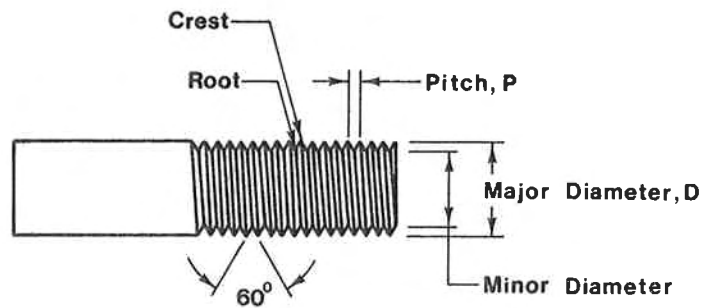


Figure 12-2 Some basic terms used to describe a thread.

The pitch of a thread is equal to 1 over the number of threads per inch.

$$P = \frac{1}{\text{Number of threads per inch}} \quad (12-1)$$

A thread made with 20 threads per inch, for example, has a pitch of 0.05".

$$P = \frac{1}{20} = 0.05''$$

A thread with eight threads per inch has a pitch of 0.125".

$$P = \frac{1}{8} = 0.125''$$

12-3 THREAD NOTATIONS

Figure 12-3 shows a typical thread notation and a definition of each term. The terms *major diameter* and *threads per inch* (pitch) have already been explained in Section 12-2 and Figure 12-2. The terms *thread category* and *class of fit* require further explanation.

Threads are generally manufactured to either National Coarse or National Fine standards, although there are several other categories of thread standards (Unified Extra Fine, for example). These standards are internationally agreed upon manufacturing specifications that result in products of uniform quality and interchangeability. From a drawing standpoint, there is no difference between any of the standards, for they all use the same representations.

Class of fit refers to the way in which two threads match each other. There are four categories: classes 1, 2, 3, and 4. The higher the number, the better quality the match-up. Class 1 is a very sloppy fit; class 2 is the most commonly manufactured fit and is generally acceptable in most design situations; classes 3 and 4 are rarely specified because they are very exact and very expensive.

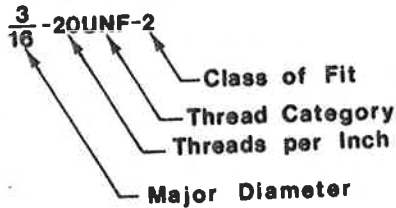


Figure 12-3 The definition of a thread notation.

12-4 THREAD REPRESENTATION

There are three ways to represent threads on a drawing: detailed, schematic, and simplified. From a drawing standpoint, each representation has advantages and disadvantages. The detailed representation is very easy for the reader to understand, but it is very time-consuming to draw. The simplified representation is very easy to draw, but to the uneducated reader, it is very confusing. The schematic representation is a compromise—fairly easy to draw and fairly easy to read, but it is still inexact and time-consuming. The representation chosen will depend on the specific shop or drafting requirements applicable.

Simplified Representation (Figure 12-4):

- (a) Define the major diameter, thread length, and shaft length of the desired thread.

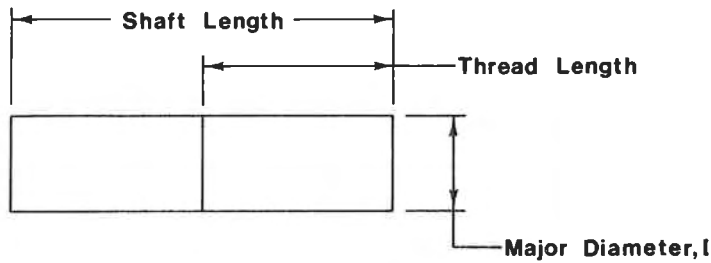


Figure 12-4(a) Simplified thread representation.

- (b) Draw a 45°-chamfer 1/16 or 1/8 long on the end of the threaded portion of the shaft. The choice of 1/16 or 1/8 depends on which looks better.

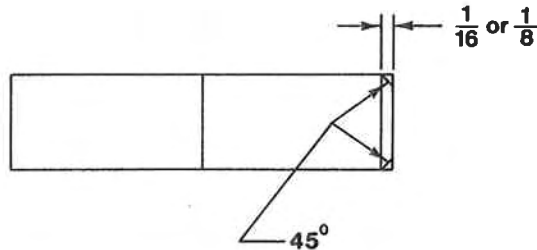


Figure 12-4(b)

- (c) Draw hidden lines as shown. If you used 1/16 in step (b), then use it here. If you used 1/8, then use 1/8.

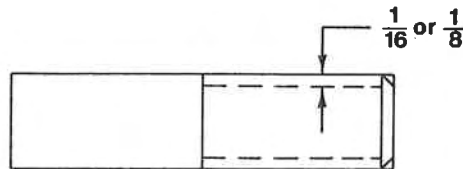


Figure 12-4(c)

- (d) Darken in the visible lines and add the appropriate thread call out.

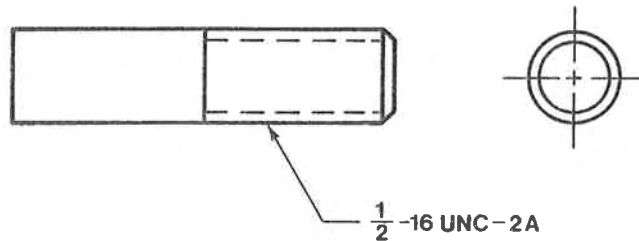


Figure 12-4(d)

Schematic Representation (Figure 12-5):

- (a) Define the major diameter, thread length, and shaft length of the desired thread.

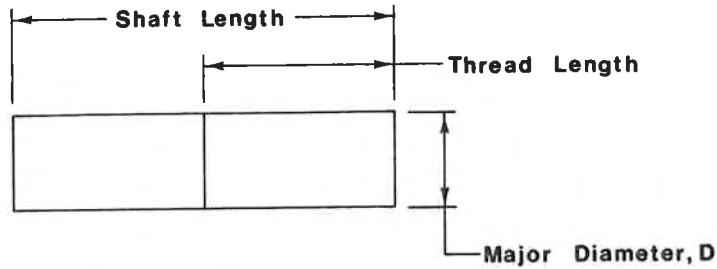


Figure 12-5(a) Schematic thread representation.

- (b) Draw parallel lines as shown. Draw these lines extremely lightly because they will be erased later. The choice of $1/16$ or $1/8$ depends on which looks better.

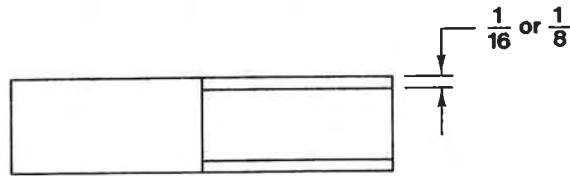


Figure 12-5(b)

- (c) Draw lines perpendicular to the lines drawn in step (b) as shown. If $1/16$ was used in step (b), space them $1/16$ apart. If $1/8$ was used in step (b), space them $1/8$ apart.

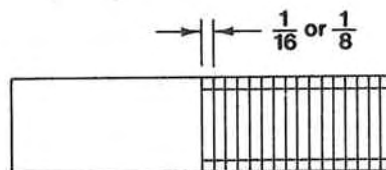


Figure 12-5(c)

- (d) Draw 45° -chamfers at the threaded end of the shaft as shown. Draw lines parallel to and halfway between the lines drawn in step (c). Start and end these lines as they intersect the lines drawn in step (b).

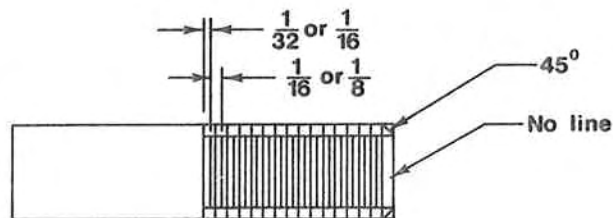


Figure 12-5(d)

- (e) Darken the lines created in step 4 and all visible lines as shown. Add the appropriate thread call out.

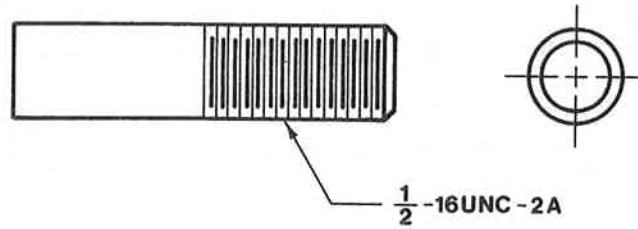


Figure 12-5(e)

If desired, the spacing of the lines drawn in step (c) may be made exactly equal to the thread pitch.

Detailed Representation (Figure 12-6):

- (a) Define the major diameter, thread length, and shaft length of the desired thread.

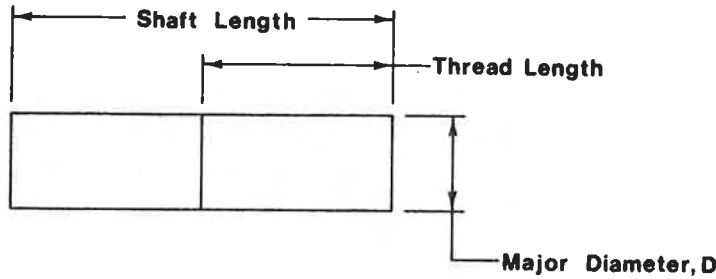


Figure 12-6(a) Detailed thread representation.

- (b) Along the top edge of the shaft mark off as many distances P as will fit within the desired thread length. Mark off a distance of $\frac{1}{2}P$ along the bottom edge.

Note: This is a right-hand thread. When the designated thread is a left-hand thread, the P distances would be marked off along the lower edge and the $\frac{1}{2}P$ distance along the top edge.

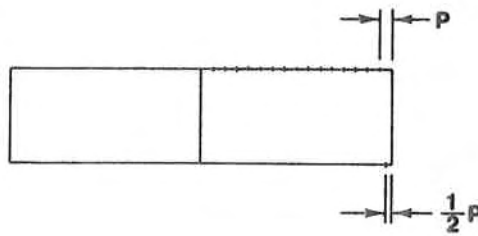


Figure 12-6(b)

- (c) Connect the first P distance with the $\frac{1}{2}P$ distance. Then draw lines, parallel to this line, through each of the P distances as shown.

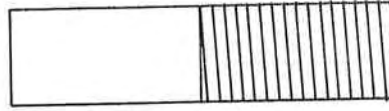


Figure 12-6(c)

- (d) Draw short 60° -lines as shown.

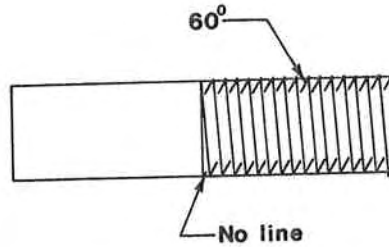


Figure 12-6(d)

- (e) Draw short 60° -lines so that they intersect the lines drawn in step (d) as shown.

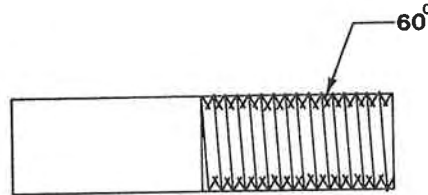


Figure 12-6(e)

- (f) Connect the intersections of the 60° -lines as shown. These lines are not parallel to the lines drawn in step (c).

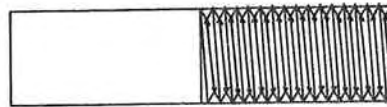


Figure 12-6(f)

- (g) Darken the lines as shown and add the appropriate thread call out.

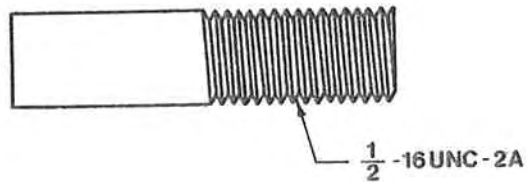


Figure 12-6(g)

12-5 THREADS IN A SECTIONAL VIEW

Figure 12-7 shows the three different thread representations as they appear in a sectional view. Note that the simplified representation includes hidden lines. Hidden lines are drawn in sectional views when a simplified representation is used and in all end views of threaded holes regardless of the representation.

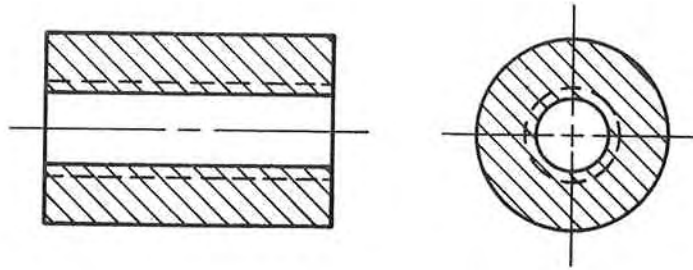


Figure 12-7(a) Simplified representation.

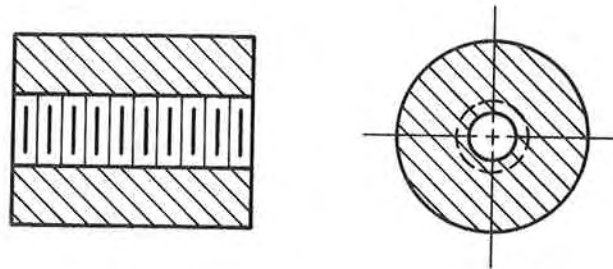


Figure 12-7(b) Schematic representation.

*Root and Crest Lines
may be Omitted*

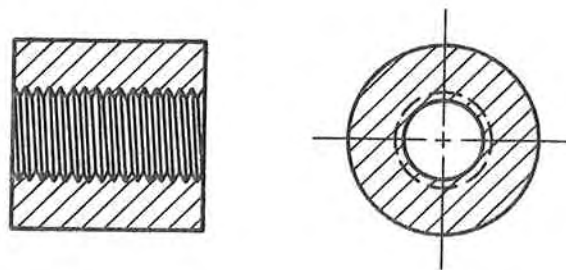


Figure 12-7(c) Detailed representation.

12-6 THREADS

There are several different kinds of threads: square, acme, knuckles, sharp V, and others. Figure 12-8 shows profiles of these threads.

A double thread has two threads cut on the same shaft. When it is rotated, it advances or recedes twice as fast as a single thread (one revolution of a double thread will transverse twice the distance traveled by one revolution of a single thread). Double threads may be cut in any thread—square, UNC, UNF, and so on. Figure 12-9 includes a double thread drawn by using simplified representation. Note how the thread note is written and that the picture portion of the drawing is the same as for single threads.

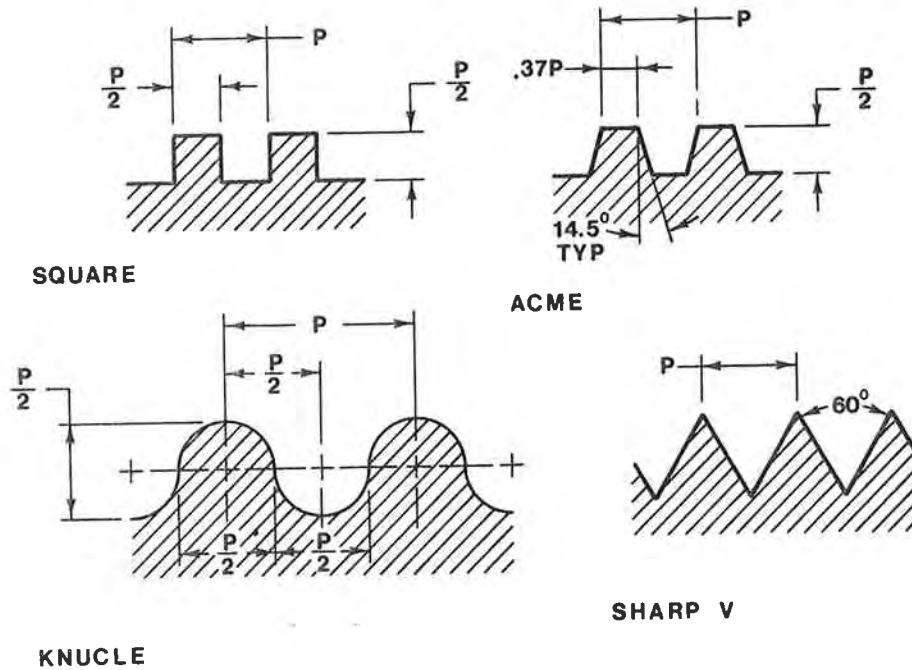


Figure 12-8 Various thread profiles.

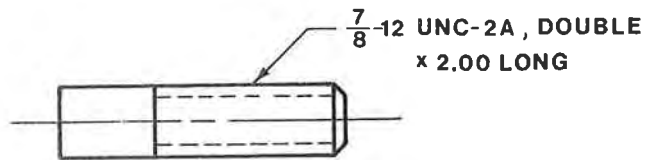


Figure 12-9 A double thread call out and simplified representation.

Most threads are right-hand threads—that is, they advance when they are turned clockwise. There are also left-hand threads. The oxygen lines in most hospitals are made with left-hand threads as a safety precaution to prevent an accidental mix-up with other gas lines. The schematic and detailed representations are drawn the same for left- or right-hand threads. Only the notation is amended to include an “LH”

for left-hand threads. It is assumed that a thread is a right-hand thread if LH does not appear. Figure 12-10 illustrates a call out note for a left-hand thread.

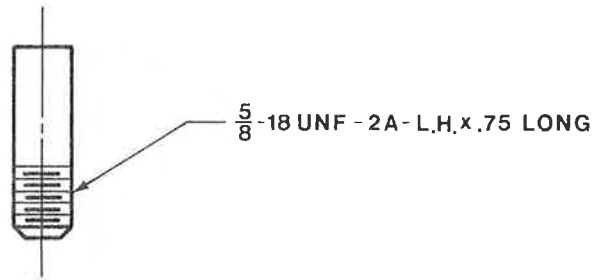


Figure 12-10 A left hand thread call out and schematic representation.

The detailed representation of a left-hand thread is different from the detailed representation of a right-hand thread. To draw a left-hand thread, use the same procedure but change the initial $P/2$ offset shown in step 2 of Figure 12-6 from the top edge to the bottom edge of the thread.

12-7 TYPES OF BOLTS AND SCREWS

Figure 12-11 illustrates several of the many different mechanical fasteners that are commercially available. The exact size and shape specifications are available from the manufacturers.

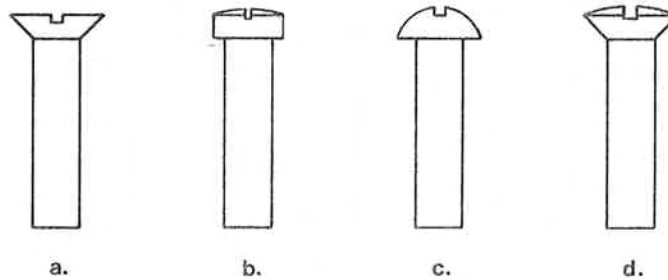


Figure 12-11 Different types of mechanical fasteners. (a) Flat-head, (b) Fillester Head, (c) Round Head, (d) Oval Head.

12-8 THREADED HOLES

When you draw a threaded hole representation, it is important to know how such a hole is created. First, a hole, called a *pilot hole*, is drilled. This hole is then tapped (threads are cut into the surface of the pilot hole). Holes are not usually tapped all the way to the bottom of the pilot hole because this would cause severe damage to the tapping

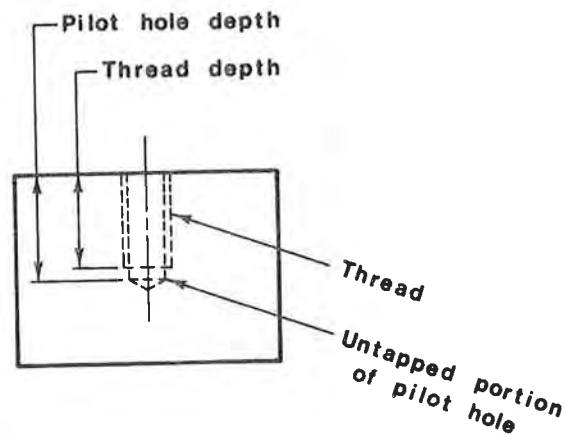


Figure 12-12 A tapped hole.

bit (although special tapping bits are available that will tap to the bottom of a pilot hole).

When you draw a threaded hole, always show the untapped portion of the pilot hole as illustrated in Figure 12-12. The pilot hole usually extends the equivalent of two thread lengths beyond the tapped portion of the hole. For example, if we wish to draw a threaded hole in which the thread depth is to be 3 and the thread type is to be 1-8UNC-2, we would first calculate the depth of one thread by using Equation (12-1):

$$\begin{aligned}
 P &= \frac{1}{\text{Number of threads per inch}} \\
 &= \frac{1}{8} \\
 P &= 0.125 \\
 2P &= 0.250
 \end{aligned}$$

See Figure 12-13 for an example of this.

We would then calculate the depth of the pilot hole by adding the total length of the thread to the equivalent of two thread lengths.

$$\begin{aligned}
 \text{total thread length} + 2P &= \text{pilot drill depth} \\
 3.000 + 0.250 &= \text{pilot drill depth}
 \end{aligned}
 \tag{12-2}$$

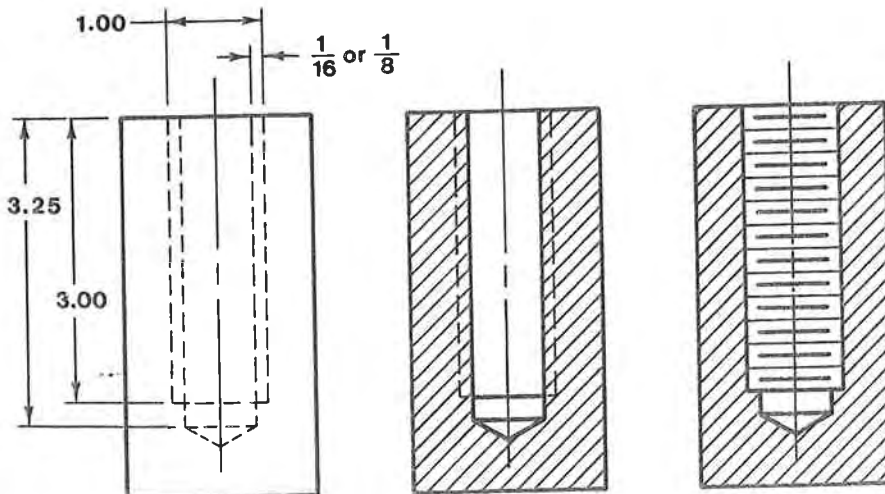


Figure 12-13 An orthographic view, a sectional view using the simplified representation, and a sectional view using the schematic representation of a 1-8UNC-2 x 3 thread.

If we wished to draw a threaded hole with a 3/8-16UNC-2 thread cut to a depth of 1.38, the calculations would be as follows:

From Equation (12-1)

$$P = \frac{1}{16}$$

$$P = 0.0625$$

$$2P = 0.125$$

From Equation (12-2)

$$1.38 + .125 = \text{pilot drill depth}$$

$$1.505 = \text{pilot drill depth}$$

Figure 12-14 illustrates a threaded hole with a screw assembled into it. Note how the bottom of the screw is distinguished from the threads by the 45°-chamfers and also note that the threads extend beyond the bottom of the screw. Threads usually extend at least two thread lengths beyond the bottom of a screw to prevent the screw from bottoming and jamming in the hole.

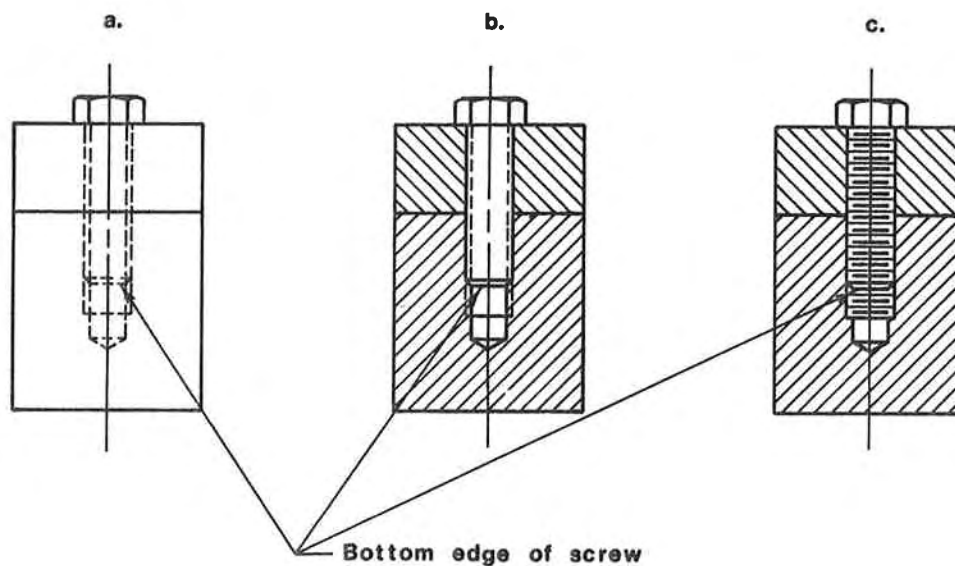


Figure 12-14 A threaded hole with a screw assembled into it. (a) orthographic view, (b) simplified representation, (c) schematic representation.

To draw a threaded hole with a fastener assembled in it, calculate the thread depth from Equation (12-3) and the pilot hole depth from Equation 12-2.

$$\text{threaded hole depth} = \text{fastener depth} + 2P \quad (12-3)$$

For example, to draw a threaded hole for a $\frac{3}{4}$ -10UNC-1 \times 2.50 machine screw, first calculate the threaded length by using Equation (12-1).

$$P = \frac{1''}{10}$$

$$P = 0.10$$

$$2P = 0.20$$

Calculate the threaded hole depth by using Equation (12-3).

$$\text{threaded hole depth} = 2.50 + 0.20 = 2.70$$

Finally, calculate the pilot hole depth by using Equation (12-2).

$$\text{pilot hole depth} = 2.70 + 0.20 = 2.90$$

A table of pilot hole diameters for various thread diameters is included in the Appendix.

12.9 DRAWING BOLT AND SCREW HEADS

Figure 12-15 illustrates how to draw a hex head bolt. The procedure used is as follows:

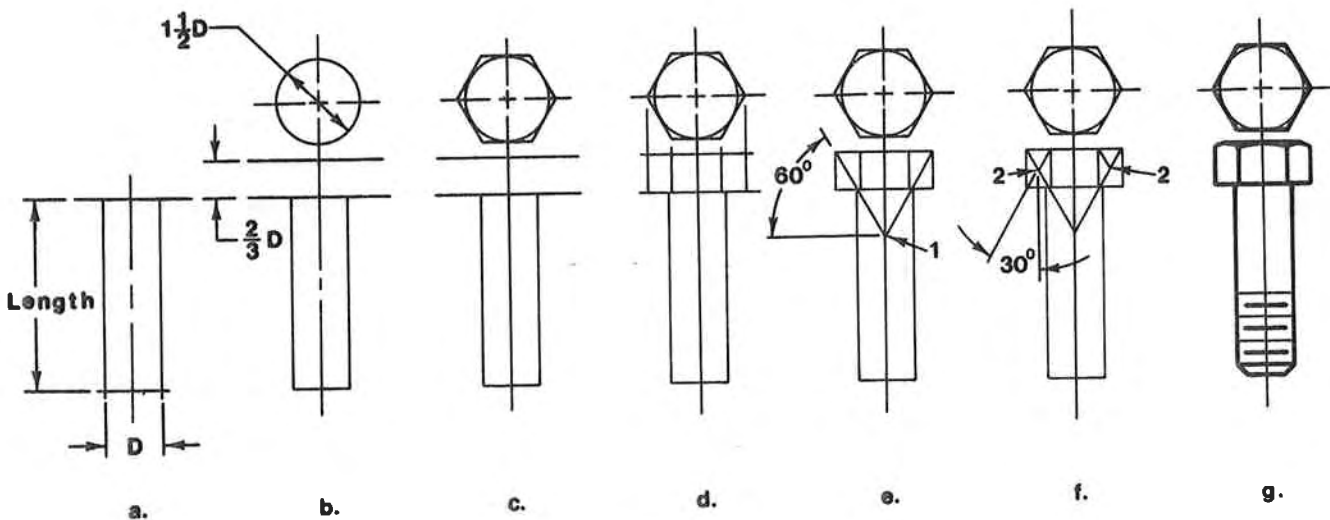


Figure 12-15 How to draw a hex head bolt.

- (a) Define the diameter and length of the bolt.
- (b) Draw a circle of $1\frac{1}{2}D$ diameter as shown. Draw a line parallel to the top of the bolt shank as a distance $\frac{2}{3}D$ as shown. *Note:* The term $1\frac{1}{2}D$ means one and one half times the diameter. Similarly, the $\frac{2}{3}D$. If, for example, the diameter of the bolt were $\frac{1}{2}$, $1\frac{1}{2}D$ would equal

$$1\frac{1}{2}D = \frac{3}{2} \left(\frac{1}{2} \right) = \frac{3}{4}$$

$2/3D$ would equal

$$\frac{2}{3}D = \frac{2}{3} \left(\frac{1}{2} \right) = \frac{2}{6} = \frac{1}{3}$$

- (c) Circumscribe a hexagon around the $1\frac{1}{2}D$ circle.
- (d) Project the hexagon's corners as shown.
- (e) Draw a line 60° to the horizontal through the intersection of the outside corner projection line and $2/3D$ line created in step (b) such that it crosses the center line of the bolt. Do the same for the other corner intersection. Label the intersection of the two 60° -lines point 1.
- (f) Draw a 60° -line through each of the intersections of the inside projection lines and the $2/3D$ line created in step (b). Label the intersections of these 60° -lines with those created in step (e) points 2.
- (g) Using point 1 and both points 2 as compass points, draw arcs as shown. Darken in the appropriate lines and add the desired thread notation.

Figure 12-16 illustrates how to draw a square head bolt. The procedure used is as follows:

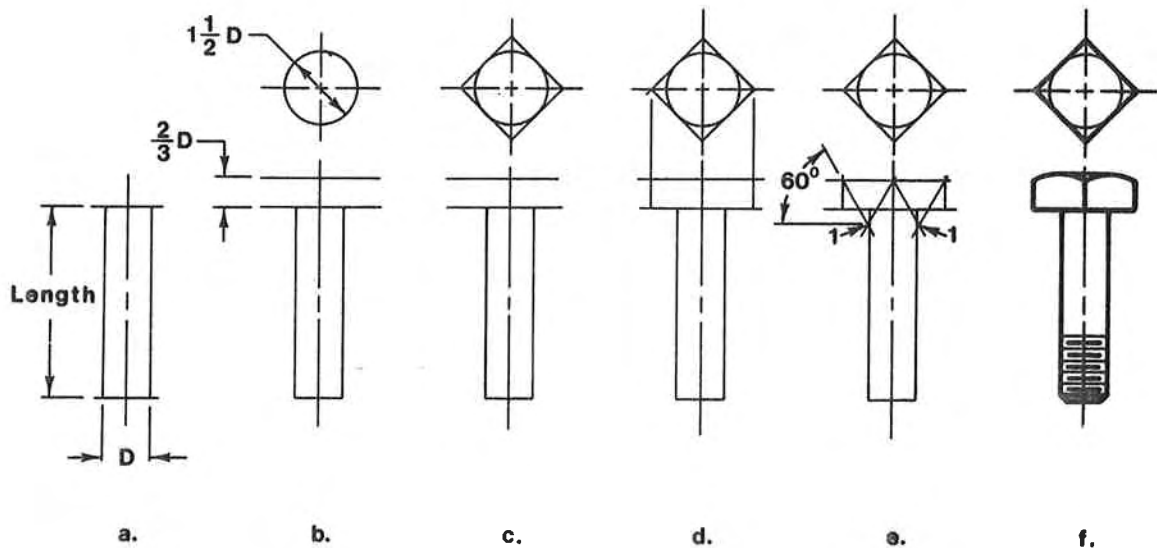


Figure 12-16 How to draw a square head bolt.

- (a) Define the diameter and length of the bolt.
- (b) Draw a circle of $1\frac{1}{2}D$ diameter as shown. Draw a line parallel to the top of the bolt shank at a distance $2/3D$ as shown.
- (c) Circumscribe a square around the $1\frac{1}{2}D$ circle.
- (d) Project the square's corners as shown.
- (e) Draw 60° -lines through the intersection of the projection lines drawn in step (d) with the $2/3D$ line drawn in step (b). Label the two intersections of the 60° -lines points 1.
- (f) Using the points 1 as compass centers, draw in the arcs as shown. Darken in the appropriate lines and add the desired thread notation.

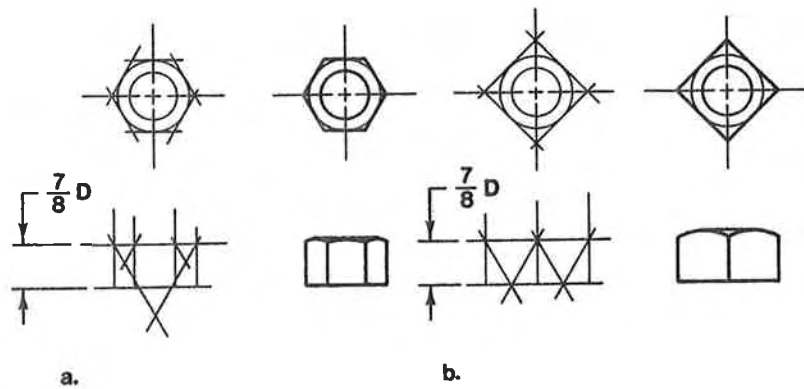


Figure 12-17 How to draw hex and square nuts.

Nuts are drawn by using the same procedures as for bolt heads except that they are $7/8D$ high instead of $2/3D$ high. Figure 12-17 illustrates a hex and square nut.

12-10 RIVETS

Rivets are metal fasteners that are commonly used to hold sheet metal parts together. Although they are inexpensive and light weight, they are not as strong as screws or bolts. Rivets are not reusable and once they are placed in an assembly, they can only be removed by drilling.

Figure 12-18 illustrates two of the many representations used to call out rivets on a drawing. The detailed representation in the top view consists of circles with diameters equal to the diameter of the rivet's head. The side view is as shown. In the top view the schematic representation consists of short, perpendicularly crossed lines that locate the center of the rivet. The side view looks like a center line of a hole, except that it always ends with a short line.

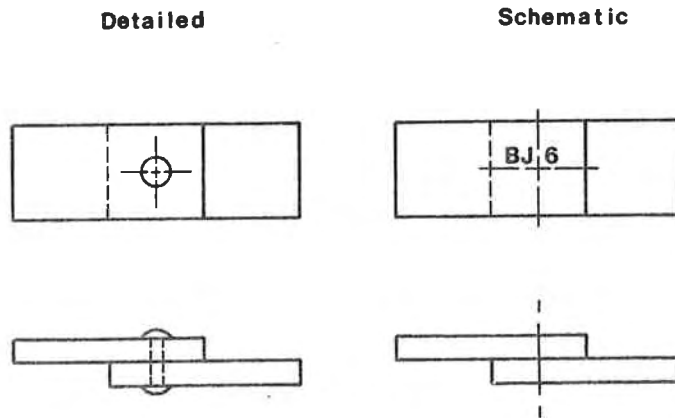


Figure 12-18 Rivet representations.

The meaning of the call outs for schematic representations is illustrated in Figure 12-19. The actual identification letter designations (BJ, CX, HY, and so on) vary from company to company, although most aircraft companies use the National Aircraft Standards (NAS).

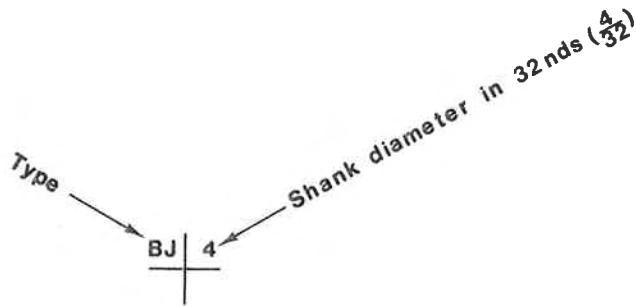


Figure 12-19 The meaning of schematic representation rivet callouts.

A long row of rivets, provided that the rivets are all exactly the same kind, may be called out by calling out only the first and last rivet in the row. Figure 12-20 illustrates this kind of rivet call out.

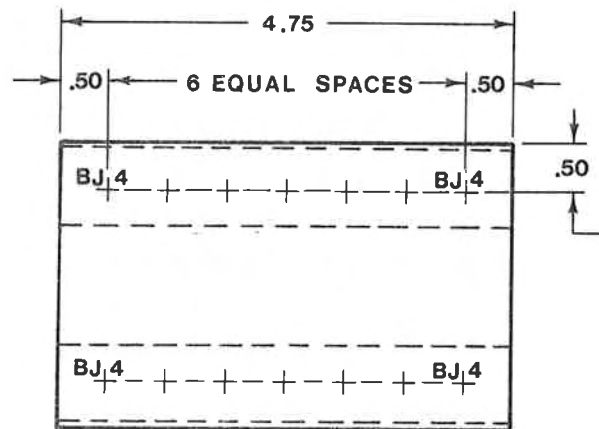


Figure 12-20 How to call out rows of rivets.

12-11 WELDS

Welds are usually called out on a drawing by notes such as shown in Figure 12-21. There are many different welds. Interested students are referred to the American Welding Society, 2501 N.W. 7th St., Miami, Florida 33125.

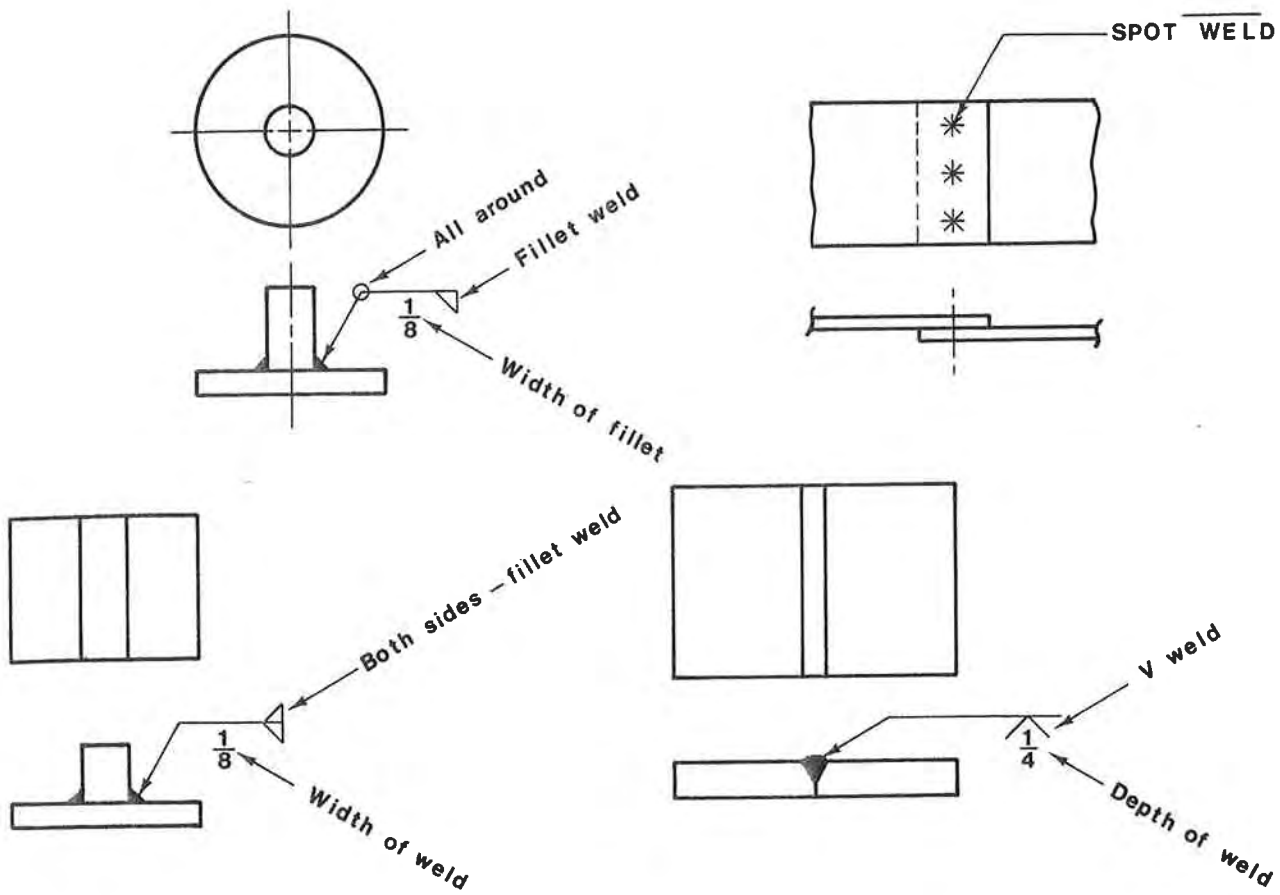
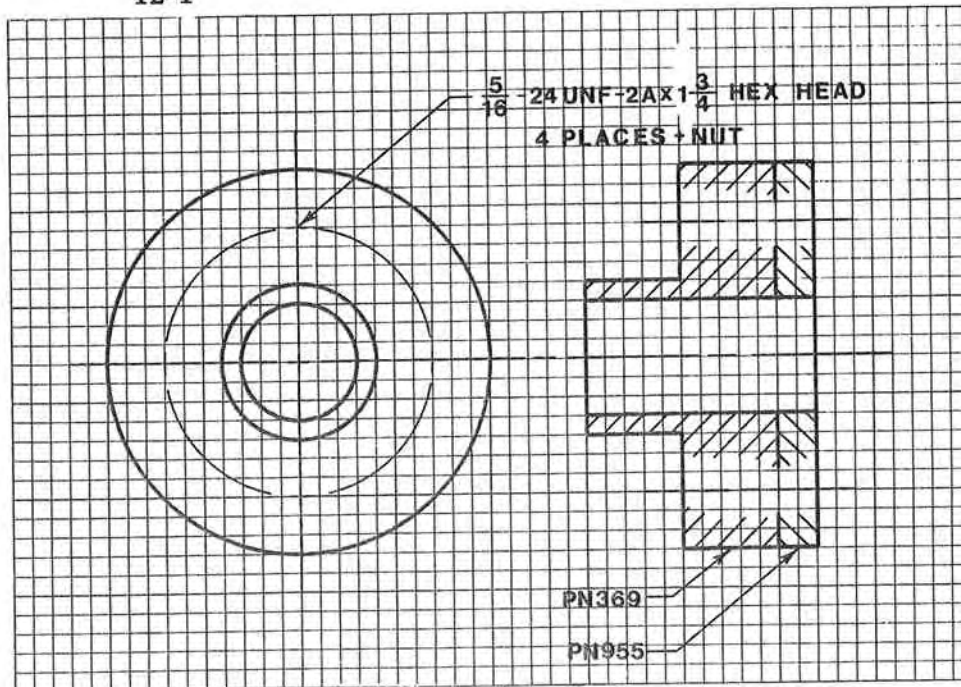


Figure 12-21 Weld call outs per standards set by the American Welding Society.

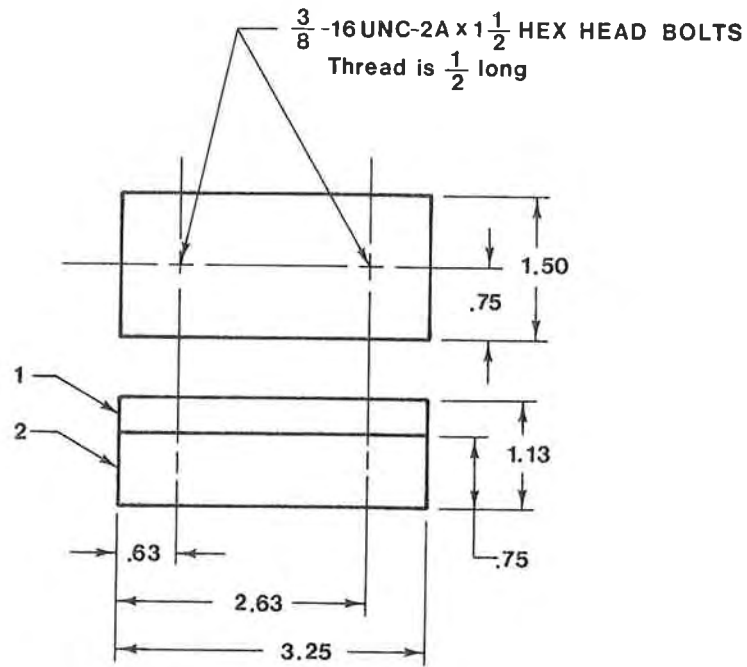
PROBLEMS

Redraw the following and add the appropriate fasteners. Use the representation specified by your instructor. Each square on the grid pattern is 0.20 per side.

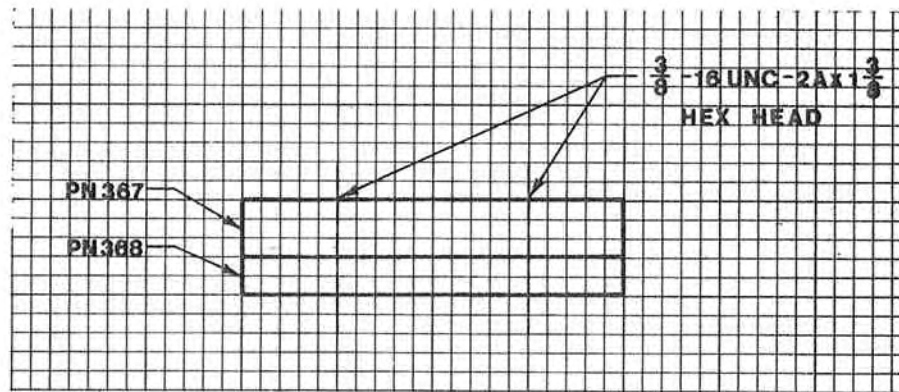
12-1



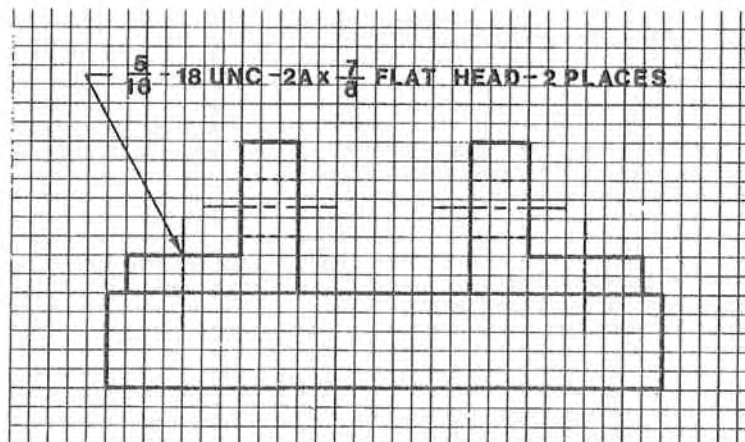
12-2



12-3

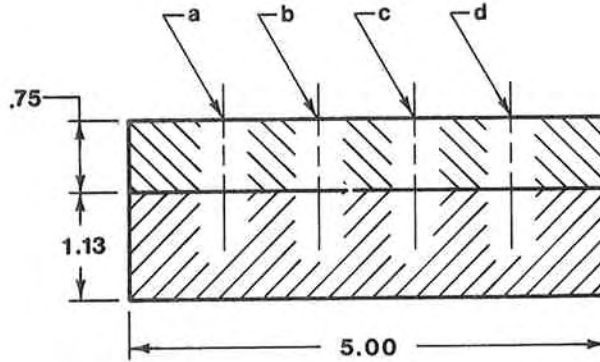


12-4

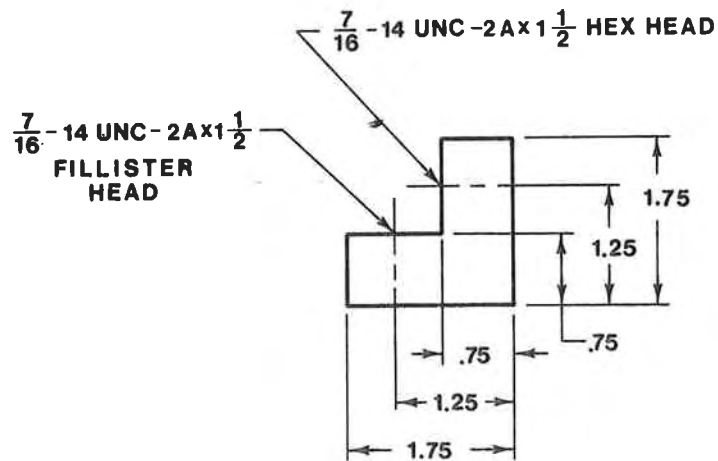


12-5 Redraw the following sectional view and add the following fasteners:

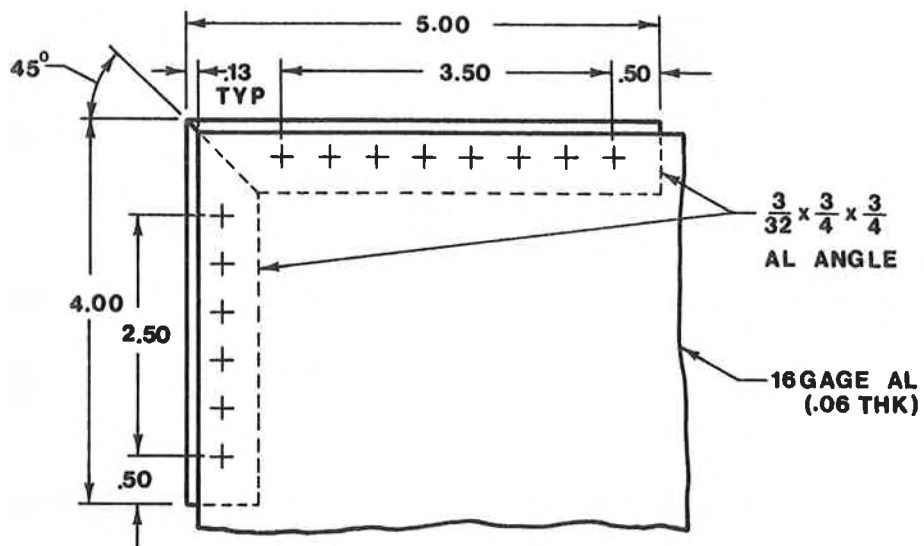
- (a) 5/16-18UNC-2A \times 1.25 hex head bolt
- (b) 7/16-14UNC-2A \times 1.38 square head bolt
- (c) #10 (.190)-32UNF-3A \times 1.50 hex head bolt
- (d) 9/16-18UNF-3A \times 1.00 square head bolt



12-6 The shop complains that the following fastener call outs are incorrect because the heads interfere, that is, bump into one another. Prepare a layout to verify if this is true. If it is true, how would you alleviate the interference?



12-7 Redraw the following figure and add the appropriate rivet call outs. Make the end rivets of each row (first and last rivet) BJ6s and all other rivets BJ4s.



METRICS 13

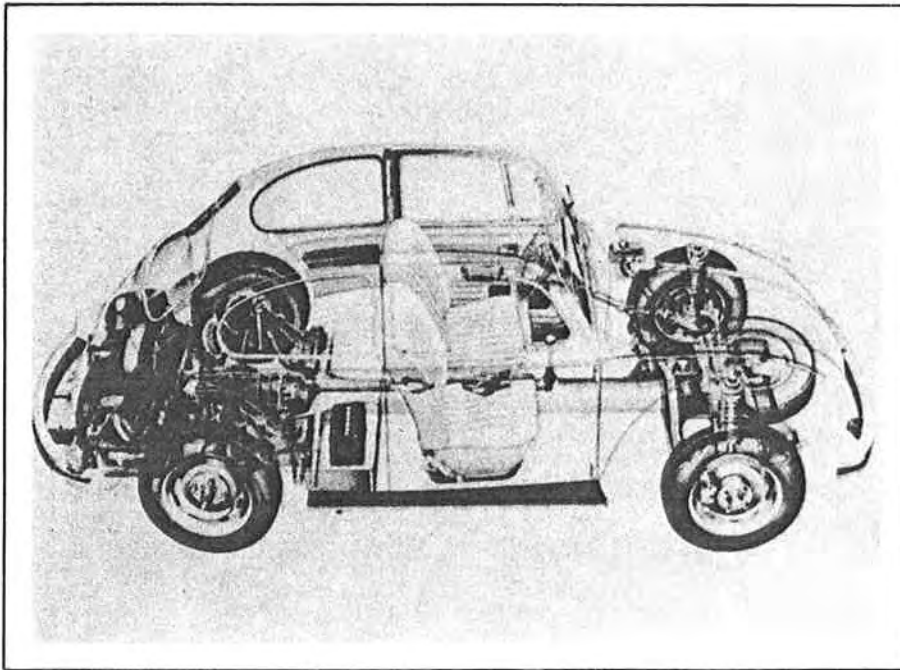


Figure 13-0 Photograph courtesy of Volkswagenwerk, Wolfsburg, Germany

13-1 INTRODUCTION

Many large corporations, both in the United States and in other countries, are multinational corporations. They operate plants, buy goods, and sell products in many countries. Olivetti-Underwood, for example, is an Italian company headquartered in Ivrea, Italy, but it owns and operates manufacturing plants in Spain, the United Kingdom, the United States, Argentina, Brazil, Colombia, and Mexico, and it sells its products worldwide.

Because so many companies operate internationally, engineers and draftsmen must be prepared to exchange technical information internationally. This may be difficult, not only because of the language differences, but also because of the different systems used to measure and present technical information. In the United States we use the English system of measuring (feet and inches) and third angle projections for presenting orthographic views. Most other countries use the metric system of measuring (meters and millimeters) and first angle projections for presenting orthographic views.

Because the metric system is easier to use than the English system, all major nonmetric countries have started to change their engineering measuring systems to the metric system, but the change has not yet been completed. In the United States the change has been slow, primarily because of the enormous costs involved in replacing existing nonmetric tools and machinery. Until the metric system becomes universal, it is important that draftsmen know how to work comfortably in *both* systems. This chapter will explain the metric system and first angle projection and then it will compare them with the English system and third angle projection.

13-2 THE METRIC SYSTEM

In the metric system measurements of length are based on a fixed unit of distance called a *meter*. A meter is slightly longer than a yard. A meter is divided into smaller units called *centimeters* and *millimeters*. There are 100 centimeters or 1000 millimeters to a meter. Most mechanical measurements in the metric system are made by using millimeters just as most mechanical measurements in the English system are made by using inches.

The symbol for a millimeter is mm (5 mm, 26 mm, and so on). Figure 13-1 shows a millimeter scale along with a few sample measurements.

To convert a given millimeter value to meters, divide the given value by 1000, which is the same as shifting the decimal point three

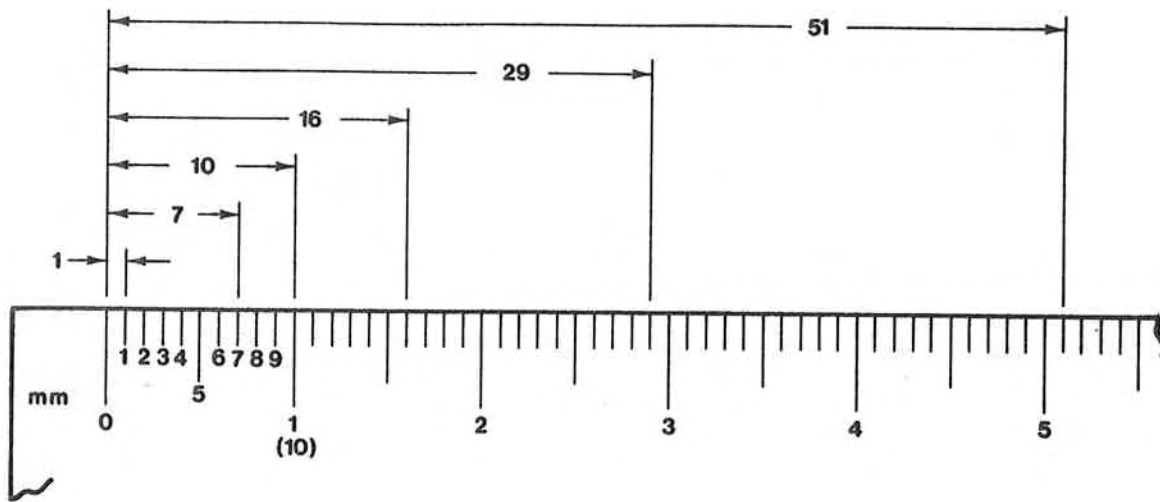


Figure 13-1 A millimeter scale with some sample measurements.

places to the left. For example,

423 mm = how many meters?

$$\frac{423}{1000} = .423 \text{ m}$$

To convert a given meter value to millimeters, multiply the given value by 1000, which is the same as shifting the decimal point three places to the right. For example,

5.1 m = how many millimeters?

$$(5.1)(1000) = 5100 \text{ mm}$$

All intermetric distance conversions are accomplished in a similar manner. Remember that there are 10 millimeters to 1 centimeter, 100 centimeters to 1 meter, and 1000 millimeters to 1 meter.

13-3 CONVERSION BETWEEN MEASURING SYSTEMS

To convert millimeters to inches or inches to millimeters, use the following equality:

$$25.4 \text{ mm} = 1 \text{ inch}$$

If you are given a value in millimeters and wish to convert it to an inch value, divide the millimeter value by 25.4. For example,

354 mm = how many inches?

$$\frac{354}{25.4} = 13.94 \text{ inches}$$

* * *

10 mm = how many inches?

$$\frac{10}{25.4} = 0.394 \text{ inch}$$

If you are given a value in inches and wish to convert it to a millimeter value, multiply the inch value by 25.4. For example,

3.20 inches = how many millimeters?

$$(3.20)(25.4) = 81.28 \text{ mm}$$

* * *

0.68 inch = how many millimeters?

$$(0.68)(25.4) = 17.27 \text{ mm}$$

If you are given a fractional inch value and wish to change it to a millimeter value, you must first change the fractional value to its decimal equivalent in inches and then multiply the decimal value by 25.4. For example,

$6\frac{7}{8}$ inches = how many millimeters?

$$6\frac{7}{8} \text{ inches} = 6.88 \text{ inches}$$

$$(6.88)(25.4) = 174.75 \text{ mm}$$

* * *

$\frac{9}{16}$ inch = how many millimeters?

$$\frac{9}{16} \text{ inch} = .56 \text{ inches}$$

$$(.56)(25.4) = 14.22 \text{ mm}$$

13-4 CONVERSION TABLES

This section contains two conversion tables: one for converting inches to millimeters (Table 13-1), and one for converting millimeters to inches (Table 13-2). Conversion tables enable you to convert given values directly without having to go through extensive calculations. The tables, however, are limited and any values not included in them must be converted mathematically.

To use the inches to millimeters table, break the given value into its whole number, tenths, hundredths, and thousandths values and

Whole Numbers		Tenths		Hundreds		Thousands	
in	mm	in	mm	in	mm	in	mm
1	25.4	.1	2.54	.01	.254	.001	.0254
2	50.8	.2	5.08	.02	.508	.002	.0508
3	76.2	.3	7.62	.03	.762	.003	.0762
4	101.6	.4	10.16	.04	1.016	.004	.1016
5	127.0	.5	12.70	.05	1.270	.005	.1270
6	152.4	.6	15.24	.06	1.524	.006	.1524
7	177.8	.7	17.78	.07	1.778	.007	.1778
8	203.2	.8	20.32	.08	2.032	.008	.2032
9	228.6	.9	22.86	.09	2.286	.009	.2286
10	254.0	1.0	25.40	.10	2.540	.010	.2540
11	279.4						
12	304.8						
13	330.2						
14	355.6						
15	381.0						
16	406.4						
17	431.8						
18	457.2						
19	482.6						
20	508.0						
21	533.4						
22	558.8						
23	584.2						
24	609.6						

Table 13-1 Inches to millimeters.

mm	in	mm	in	mm	in	mm	in
1	.039	26	1.024	51	2.008	76	2.992
2	.079	27	1.063	52	2.047	77	3.032
3	.118	28	1.102	53	2.087	78	3.071
4	.158	29	1.141	54	2.126	79	3.110
5	.197	30	1.181	55	2.165	80	3.150
6	.236	31	1.221	56	2.205	81	3.189
7	.276	32	1.260	57	2.244	82	3.228
8	.315	33	1.300	58	2.284	83	3.268
9	.354	34	1.339	59	2.323	84	3.307
10	.394	35	1.378	60	2.362	85	3.347
11	.433	36	1.417	61	2.402	86	3.386
12	.472	37	1.457	62	2.441	87	3.425
13	.512	38	1.496	63	2.480	88	3.464
14	.551	39	1.535	64	2.520	89	3.504
15	.591	40	1.575	65	2.559	90	3.543
16	.630	41	1.614	66	2.598	91	3.583
17	.669	42	1.653	67	2.638	92	3.622
18	.709	43	1.693	68	2.677	93	3.661
19	.748	44	1.732	69	2.717	94	3.701
20	.787	45	1.772	70	2.756	95	3.740
21	.827	46	1.811	71	2.795	96	3.780
22	.866	47	1.850	72	2.835	97	3.818
23	.906	48	1.890	73	2.874	98	3.858
24	.945	49	1.929	74	2.913	99	3.898
25	.984	50	1.969	75	2.953	100	3.937

mm	in	mm	in
100	3.937	600	23.622
200	7.874	700	27.559
300	11.811	800	31.496
400	15.748	900	35.433
500	19.685	1000	39.370

Table 13-2 Millimeters to inches.

convert each separately. Then add the individual values together to form a final equivalence value. For example,

Given 3.472 inches

How many millimeters is this equal to?

Whole number value	3.000 = 76.2000	Values from Table 13-1
Tenths value	0.400 = 10.1600	
Hundredths value	0.070 = 1.7780	
Thousandths value	0.002 = <u>0.0508</u>	
	88.1888	

Therefore,

3.472 inches = 88.1888 mm, or approximately 88 mm

Table 13-1 is only good for decimal values. Fractional values must be converted to decimal equivalents before they may be converted into millimeters. For example,

Given $\frac{3}{8}$ inch

How many millimeters is this equal to?

$$\frac{3}{8} \text{ inch} = 0.375$$

Whole number value	0.000 = 0.0000	Values from Table 13-1
Tenths value	0.300 = 7.6200	
Hundredths value	0.070 = 1.7780	
Thousandths value	0.005 = <u>0.1270</u>	
	9.525	

Therefore,

$$\frac{3}{8} \text{ inch} = 9.525 \text{ mm}$$

To use the millimeters to inches table (Table 13-2), simply look up the value in the table. Fractions of a millimeter are not included. If a fractional millimeter value is required, use the relationship 1 inch = 25.4 mm and calculate the value as shown in Section 13-3. For values greater than 100 mm, look up the hundredths value in the hundredths value table and look up the tenths and units values in the main part of the table; then add the results to form a final equivalent value. For example,

537 mm = how many inches?

500 mm	= 19.685	Values from Table 13-2
37 mm	= <u>1.457</u>	
	21.142	

537 mm = 21.142 inches

13-5 FIRST ANGLE PROJECTIONS

Not only do many foreign countries use a different measuring standard than is used in the United States, they also use a different projection system for presenting orthographic views. The United States uses what is called *third angle projection*, but many other countries use *first angle projection*. Figure 13-2 illustrates the differences in the two systems by showing the same object drawn in each. By comparing the two drawings shown in Figure 13-2, we see that the front views in each system are exactly the same. The top views also appear to be the same although they are located differently relative to the front view. If you are familiar with third angle projections, you will know that the top view of a first angle projection appears to be located where the bottom view should be. This apparent reversal of locations comes about because of the way the views are taken. In third angle projection the viewer looks *at* the object. In first angle projection the viewer looks *through* the object.

To clarify this concept, study the right side view of the third angle projection and the left end view of the first angle projection. In the third angle projection the right side view is a view taken from the right

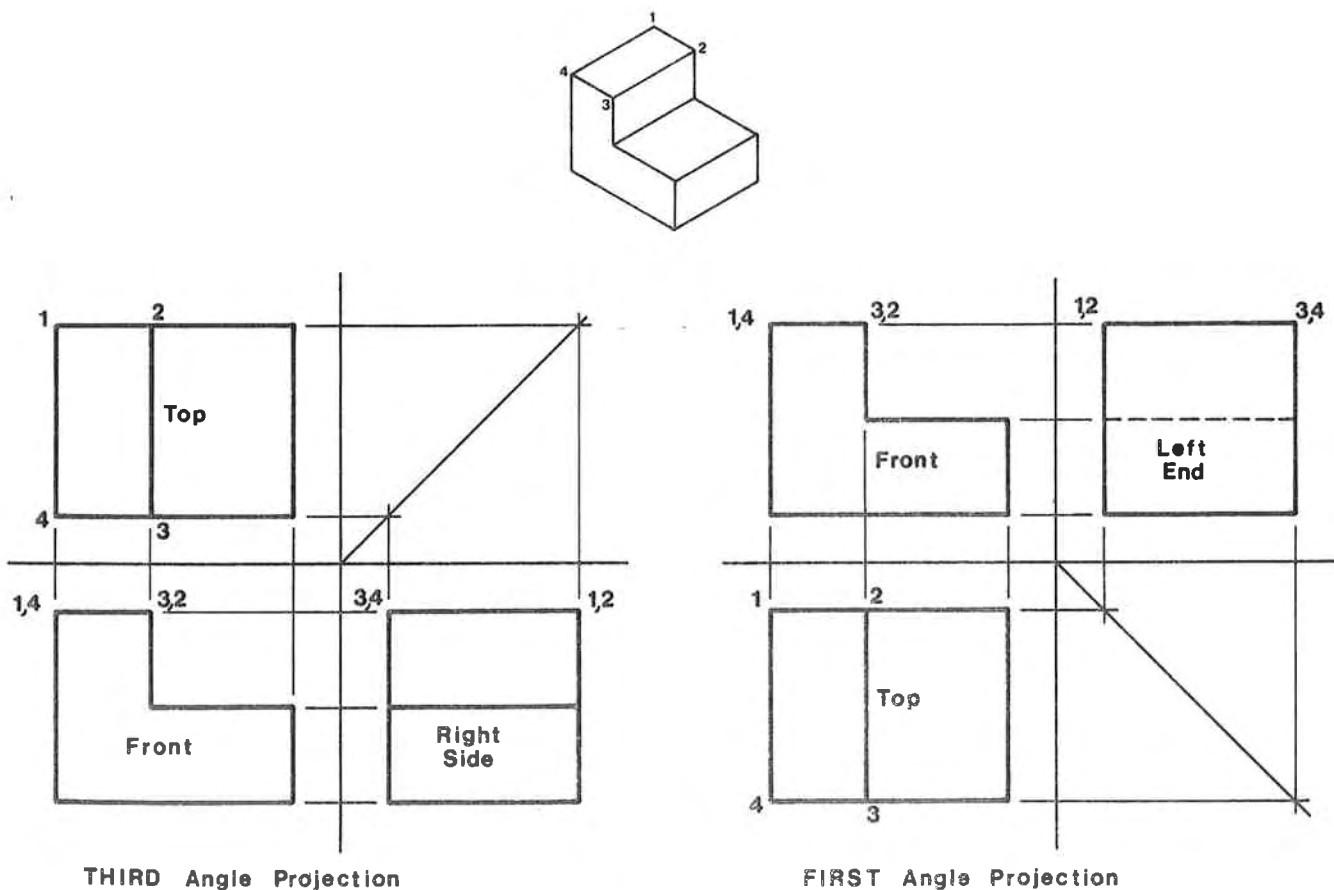


Figure 13-2 A comparison between first and third angle projections of the same object.

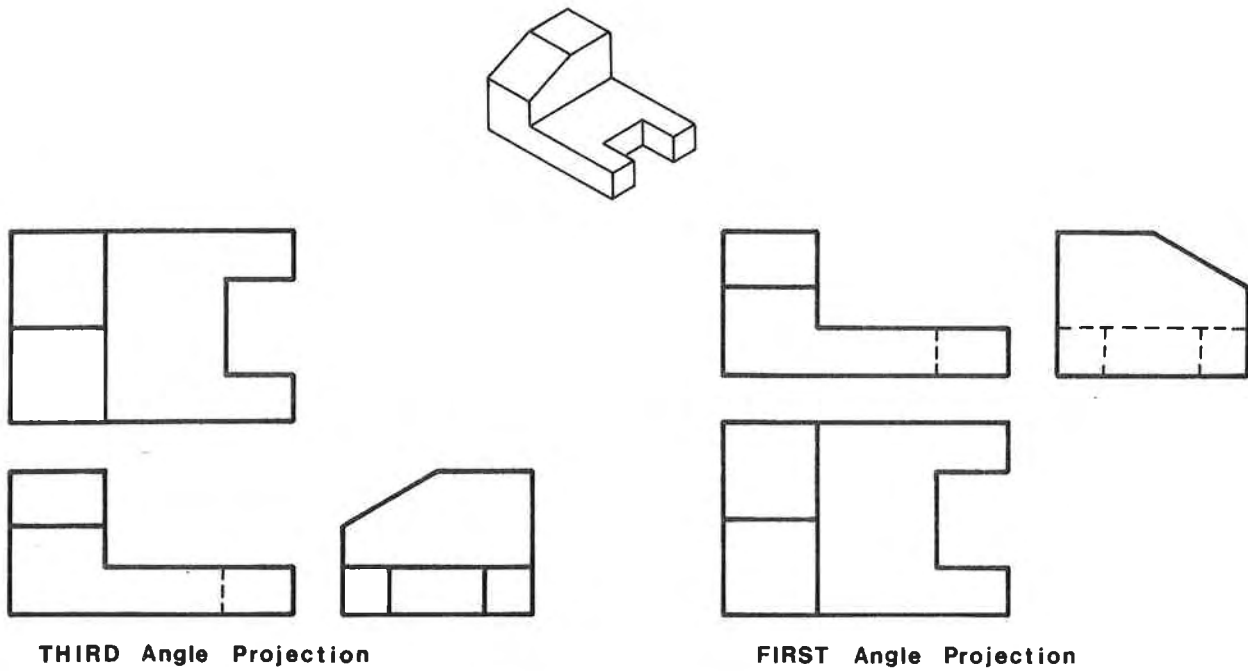
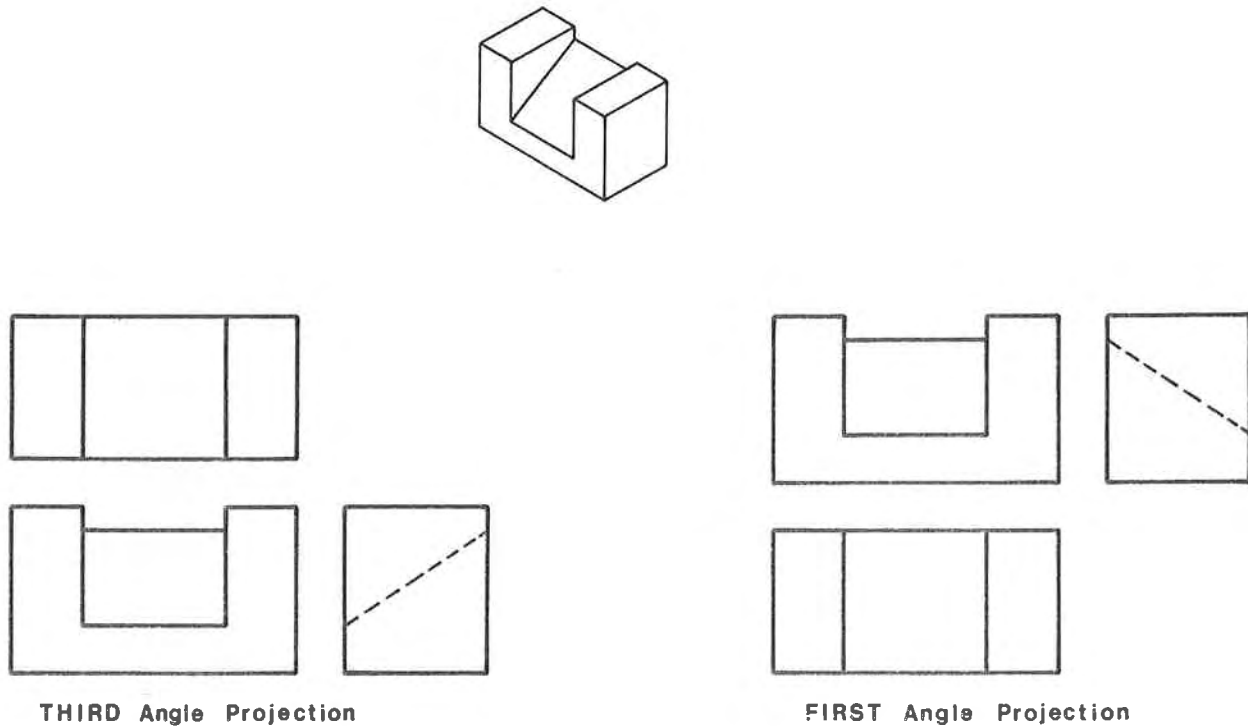


Figure 13-3 A comparison between first and third angle projections of the same object.

side of the object, looking into the object, and drawn on the same side of the object as the viewer. In first angle projection the left end view is a view taken from the left side of the object, looking through the object, and drawn on the side of the object opposite the viewer. Figures 13-3 and 13-4 are two more examples that compare first and third angle projections of the same objects. Study them. *Look into* and *look through* the objects.

Figure 13-4 A comparison between first and third angle projections of the same object.



From a drawing technique standpoint, the two systems are equally demanding. Visible lines must be heavy and black. Visible lines must be heavier than dimension lines and hidden lines. Lettering must be neat and uniform. The projection theory presented in Chapter 4 is also applicable, although the 45° -miter line is located differently (see Figure 13-2).

PROBLEMS

13-1 Convert the following millimeter values into inches:

- a) 20 mm
- b) 4 mm
- c) 327 mm
- d) 526 mm
- e) 103 mm
- f) 57 mm
- g) 5384 mm
- h) 910 mm
- i) 38 mm
- j) 237 mm

13-2 Convert the following inch values into millimeters:

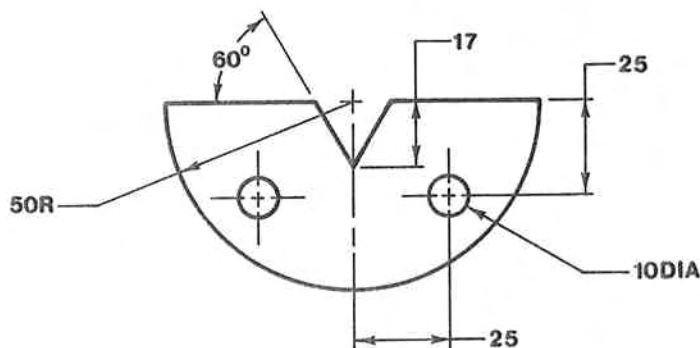
- a) 2.378"
- b) 0.750"
- c) 12.875"
- d) 0.020"
- e) 1.006"
- f) 4.125"
- g) 3.500"
- h) 120.000"
- i) 8.820"
- j) 1.324"

13-3 Convert the following inch values into millimeters:

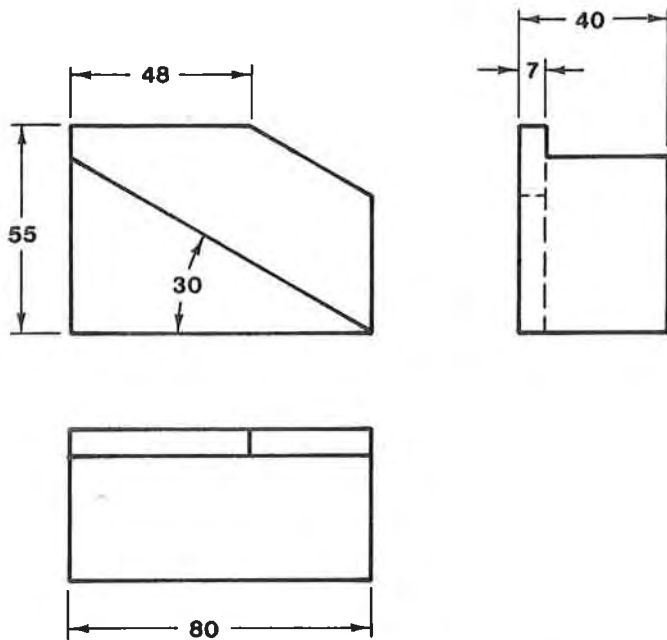
- a) $1/2$ "
- b) $2-1/4$ "
- c) $3-7/8$ "
- d) $12-5/16$ "
- e) $5-13/32$ "

Your company has purchased the rights to produce some parts which up to now have been produced only in Europe. As part of the agreement, the European producer has supplied manufacturing drawings of the parts involved. Convert these drawings, done in millimeters and first angle projection, into drawings that may be read by American craftsmen (decimal inches and third angle projections).

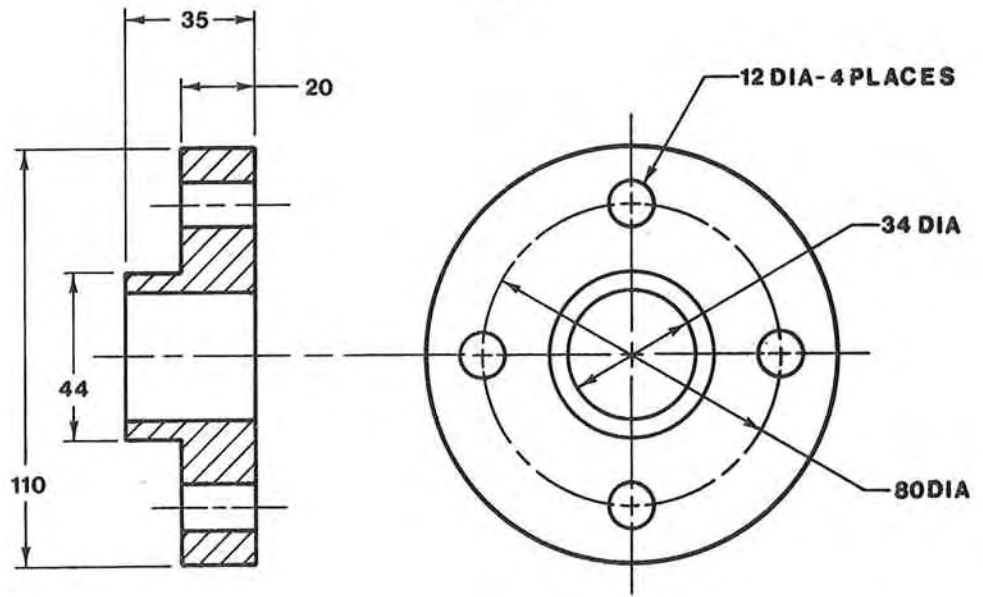
13-4



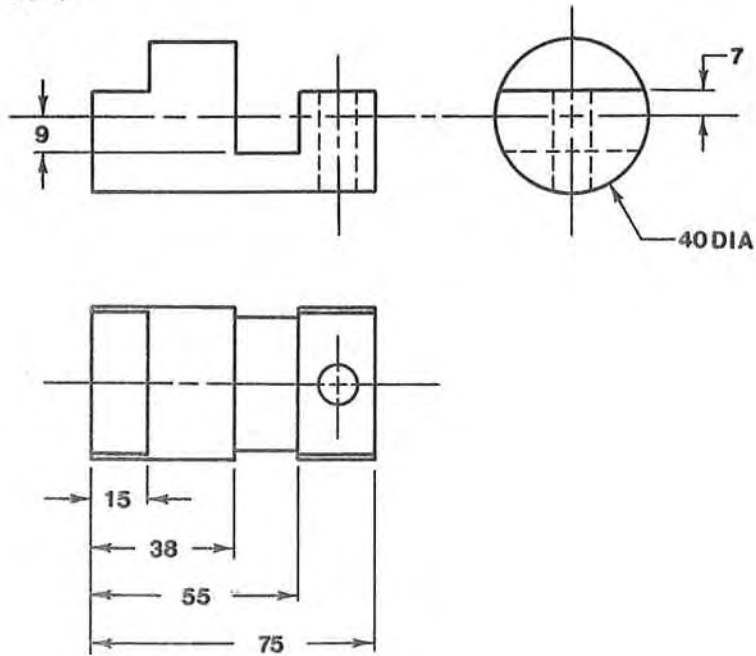
13-5



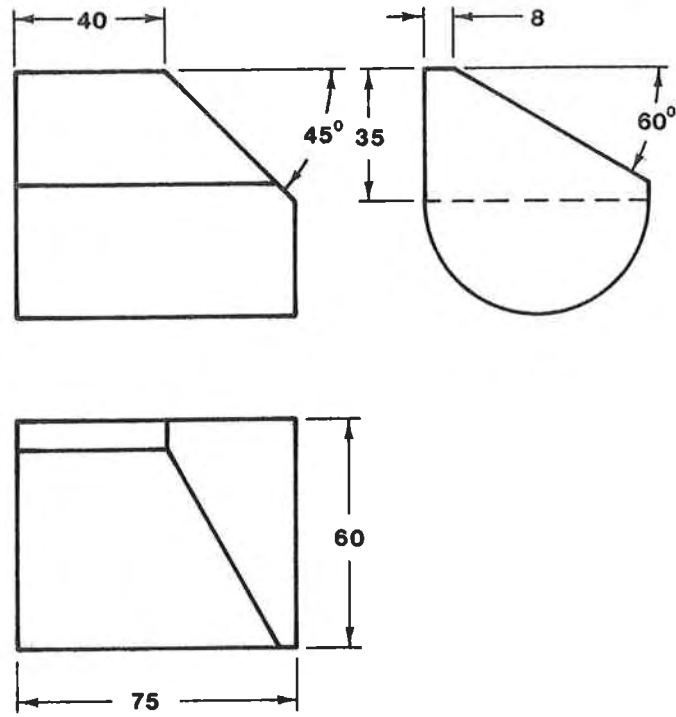
13-6



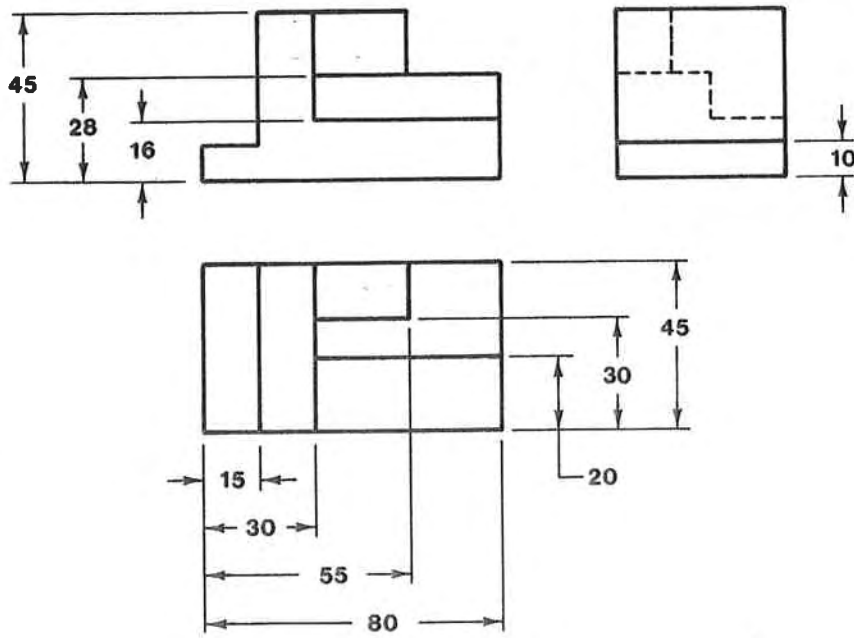
13-7



13-8

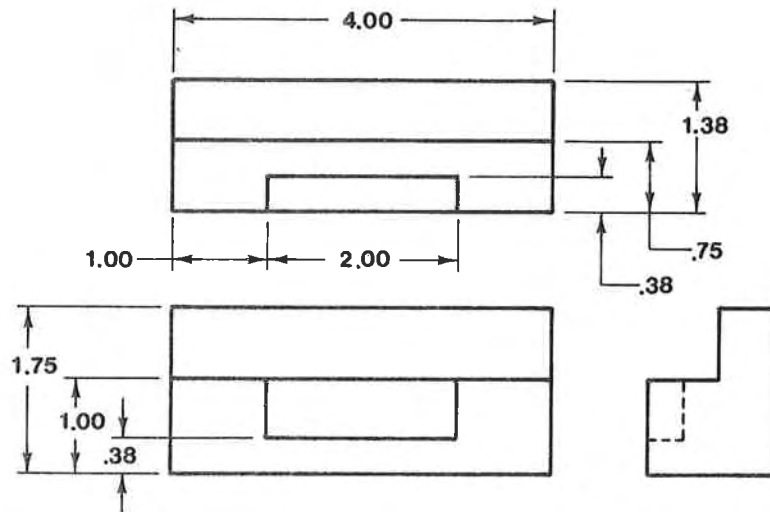


13-9

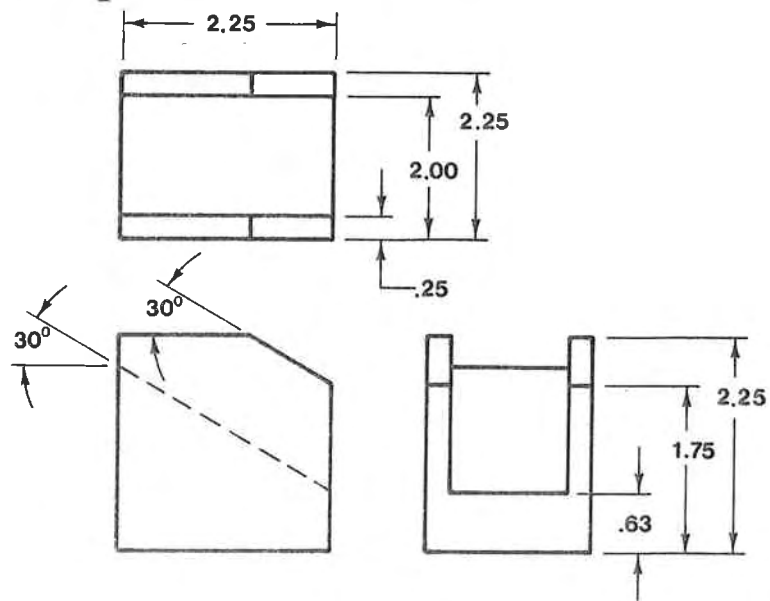


Your company has decided to manufacture the following parts in a European plant. In order to do this, the manufacturing drawings must be converted into the European system of millimeters and first angle projections. Convert the following drawings so that they may be read by European craftsmen:

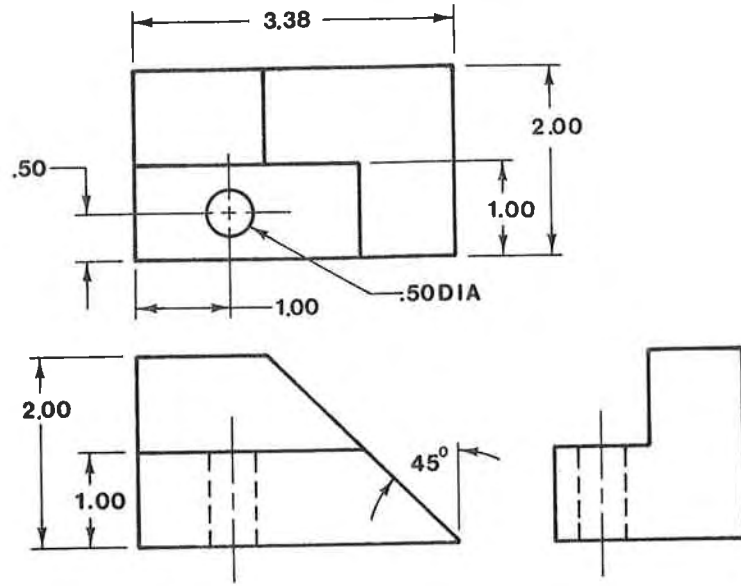
13-10



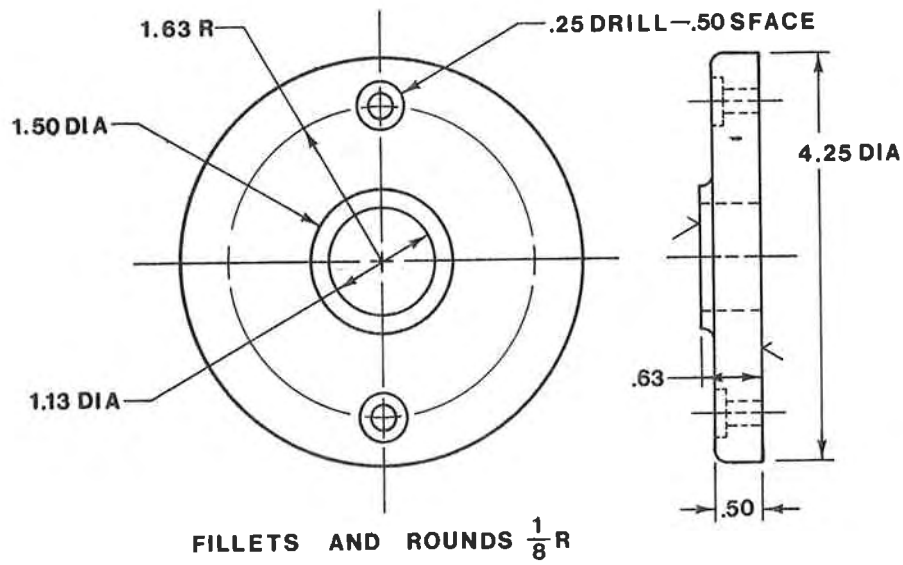
13-11



13-12



13-13



PRODUCTION DRAWINGS 14

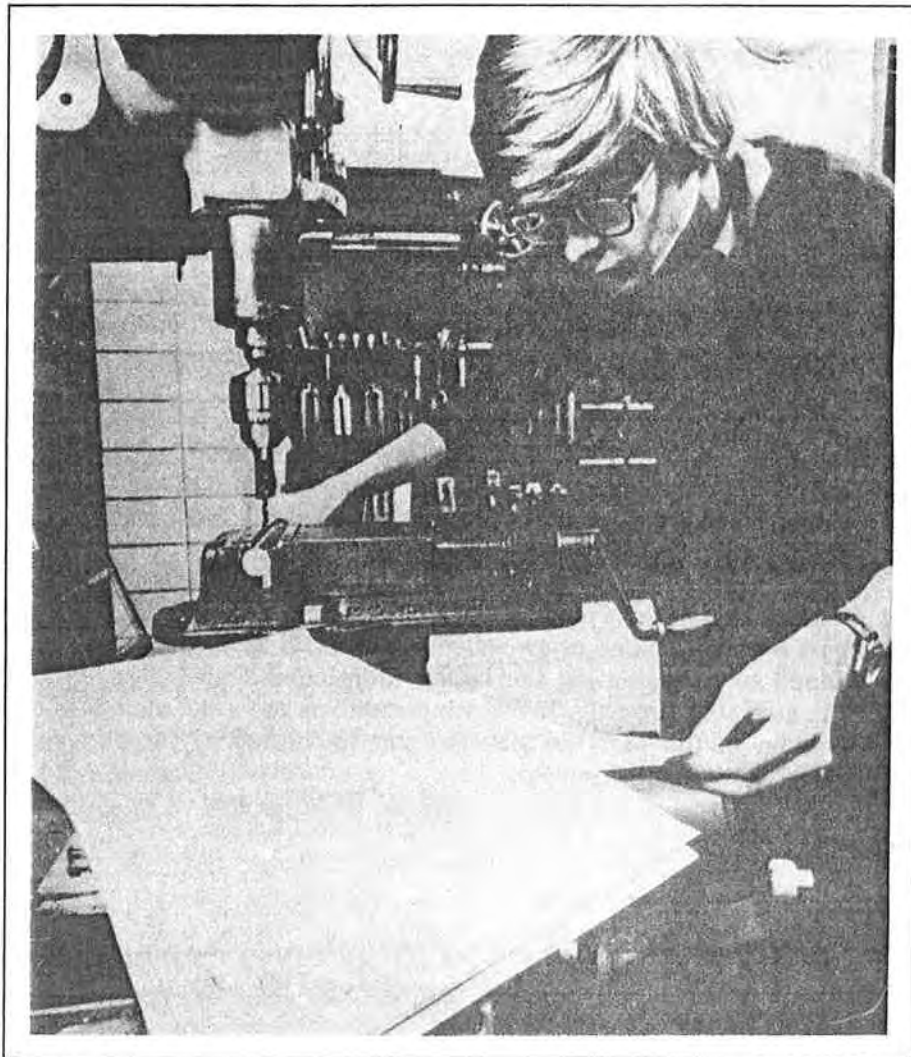


Figure 14-0 Illustration courtesy of Teledyne Post, Des Plaines, Illinois 60016.

14-1 INTRODUCTION

Production drawings are used to aid a craftsman in the manufacturing of an object. They are generally either detail drawings or assembly drawings. A detail drawing usually presents only one object. An assembly drawing presents several objects together.

It is sometimes difficult to realize that the picture portion of a drawing is only one part of the total finished drawing. The title block, revision block, and drawing notes are just as important as the picture portion, and often they are just as time-consuming to prepare. This chapter will briefly describe title blocks, revision blocks, and so on, and will explain more specifically the makeup of detail and assembly drawings.

This chapter will also present the concept of using fewer than three orthographic views to describe an object. It will explain drawing scales, drawing details, and several common drawing call outs.

14-2 ASSEMBLY DRAWINGS

Assembly drawings show several objects joined together. An assembly drawing must include all information needed by the craftsman to correctly assemble the parts. They do not usually include specific object dimensions, but they do include those dimensions which are necessary for assembly.

Figure 14-1 illustrates an assembly drawing. Each object is identified by part number, but it is not dimensioned. Hidden lines have been omitted to make the drawing easier to read. This is not always possible, especially for assemblies that contain internal parts.

If any specific operation is to be performed by the assembler, it must be noted on the assembly drawing. For example, if several parts are to be joined together by a bolt, the bolt hole should, if possible, be drilled during the parts assembly to insure that all the parts align properly.

Assembly drawings sometimes reassign new part numbers to the various component pieces that make up the assembly. Assembly numbers are usually one or two digit numbers (1, 2, 3, 14, 22, etc.) and are added to save printing the larger, more complicated part numbers on the assembly drawing. If assembly numbers are used, include them in a column in the parts list next to and to the left of the part numbers. Label the column Assy No.

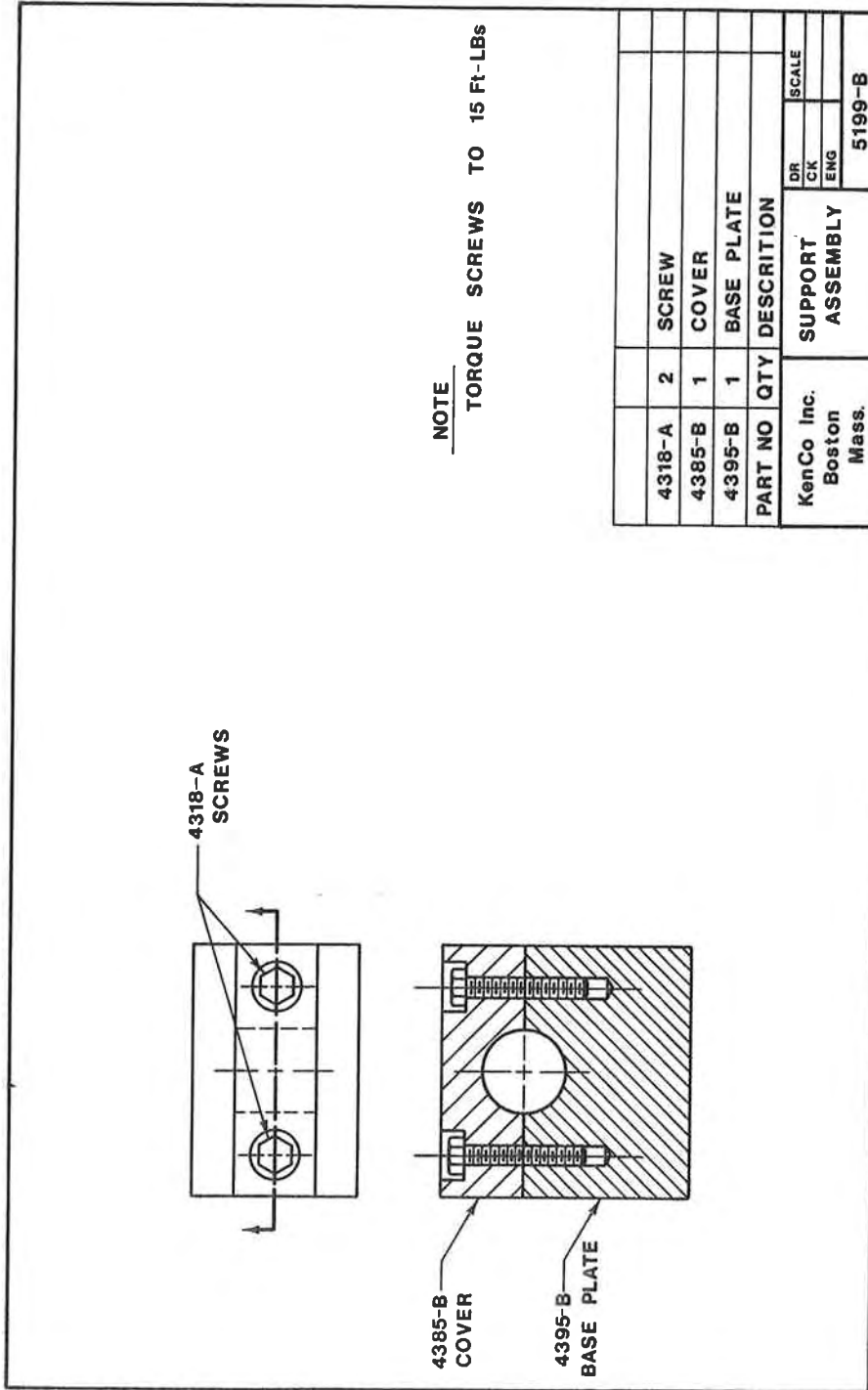


Figure 14-1 An example of an assembly drawing.

14-3 DETAIL DRAWINGS

Detail drawings are used by craftsmen to produce a finished object. They are a set of instructions that should include all information necessary for the complete and accurate manufacture of the object. They should include, among other things, a complete size and shape definition of the object; the material from which the object is to be made; all necessary information on treatment of the materials; surface finish requirements; references to applicable company, customer, or government specifications; any necessary inspection information; and, if necessary, instructions for handling the finished object. Figure 14-2 illustrates a detail drawing.

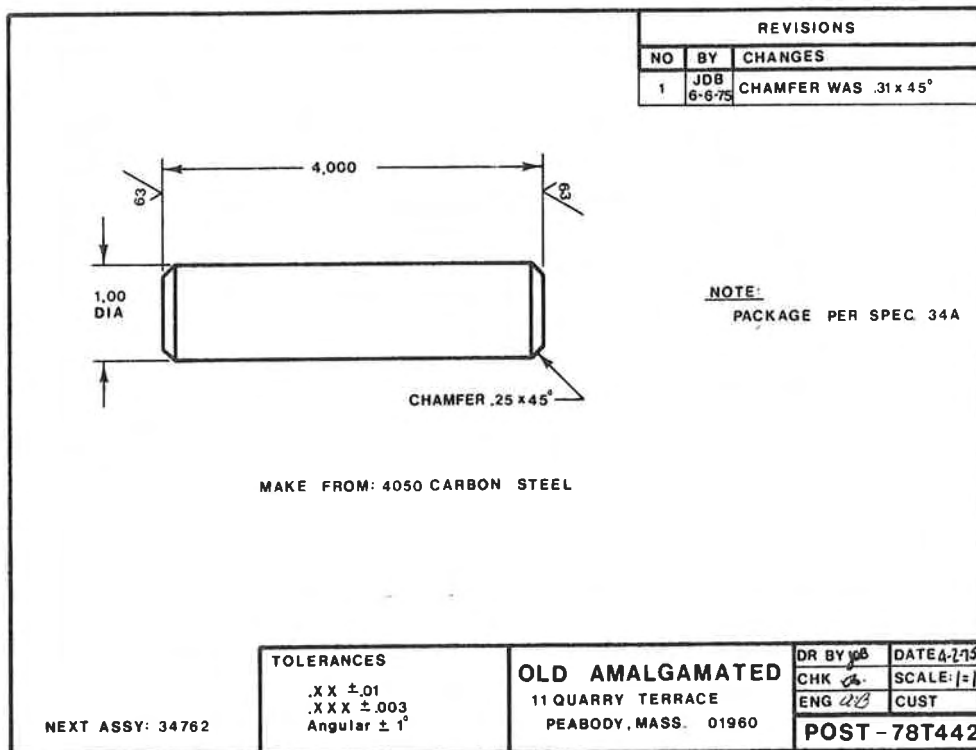


Figure 14-2 An example of a detail drawing.

14-4 TITLE BLOCKS

The title block of a drawing contains the title of the object, the part number, the company name and address, and signatures of the engineers and draftsmen who prepared the drawing. It may also include customer order numbers, tolerance specifications, signature blocks (for various approval signatures), and the drawing scale. Figure 14-3 illustrates a title block.

Title blocks are usually located in the lower right-hand corner of the drawing.

TOLERANCES ON MACHINE DIMENSIONS UNLESS OTHERWISE SPECIFIED		ATWOOD & MORRILL CO. SALEM, MASS.	DRAWN -	SCALE -
FRACTIONAL DIMENSIONS	± 1/32		APP'V'D -	B/M -
ANGULAR DIMENSIONS	+ 1/2'		DATE -	PATT -
SURFACE FINISHES	125√			
ALL CORNERS 1/32 R OR CHAM UNLESS OTHERWISE SPECIFIED				

Figure 14-3 A company title block courtesy of the Atwood and Morrill Co., Salem, Mass.

14-5 PARTS LIST

A parts list is a listing of the names and numbers of parts called out on the drawing. It may also include material information, stock size, manufacturing quantity, finishing specifications, weight calculations, and so on. Figure 14-4 illustrates a parts list.

PART NO	QTY	DESCRIPTION	STOCK SIZE	MATL
5025-02	3	CLIP	.06 x 1.5 x 6.0	7075-T6
5025-01	1	BRACKET	2 x 6 x 20	STL

Figure 14-4 An example of a parts list.

14-6 REVISION BLOCKS

A revision block is a listing of all changes that have been made in the drawing. It should include a description of the change, the date the change was made, where the change is located on the drawing, the draftsman's initials, and any necessary approval signatures.

Revision blocks are usually located in the upper right-hand corner of the drawing. Figure 14-5 illustrates a revision block.

REVISIONS		
NO	BY	CHANGE
1	JOB 8-3-75	MATL WAS C.R. STEEL

Figure 14-5 An example of a revision block.

14-7 DRAWING ZONES

Large drawings are divided into zones similar to those used on a map. Letters are used to define the horizontal zones and numbers are used to define the vertical zones. Figure 14-6 illustrates a zoned drawing.

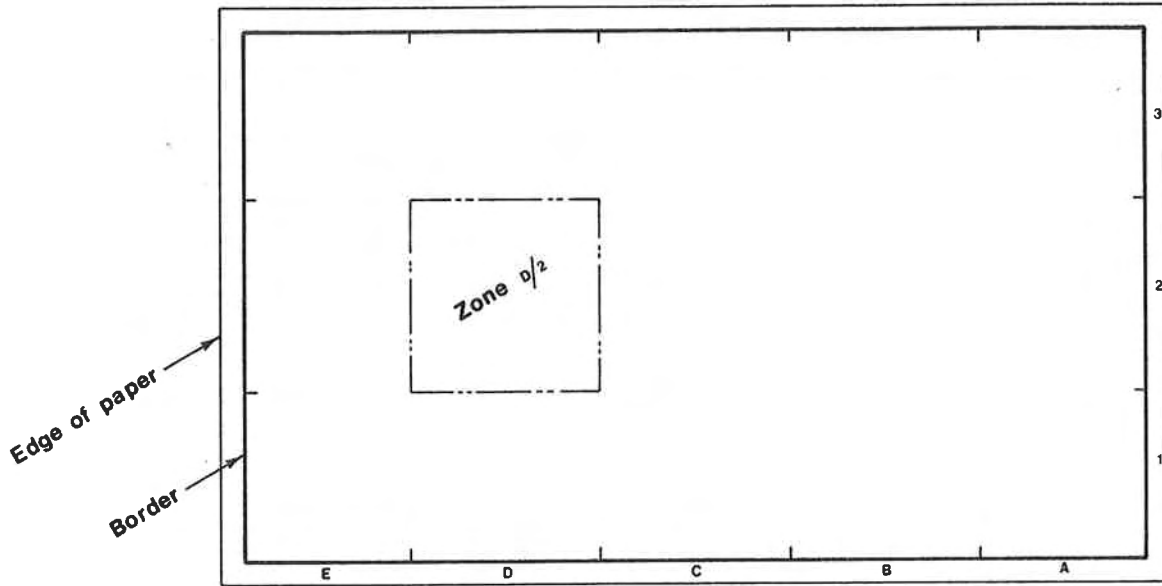


Figure 14-6 An example of a zoned drawing.

Zone numbers are usually written in boxes with the letter over the number as follows:

$\boxed{C/4}$, $\boxed{D/2}$, $\boxed{A/13}$, etc.

14-8 DRAWING NOTES

Drawing notes are written instructions that are included as part of a drawing. They are written because they cannot be drawn (for example, heat treating or finishing instructions). Figure 14-1 includes a note that defines the torquing requirements of the assembly.

14-9 ONE-, TWO-, AND PARTIAL VIEW DRAWINGS

Up to this point we have shown three views of every object. Three views are not always necessary for complete definition of an object and in some cases two views are sufficient. Occasionally, just one view is enough. Figure 14-7 is an example of a two-view drawing. Figure 14-8 is an example of a one-view drawing. In both figures the objects are completely defined and require no other orthographic views.

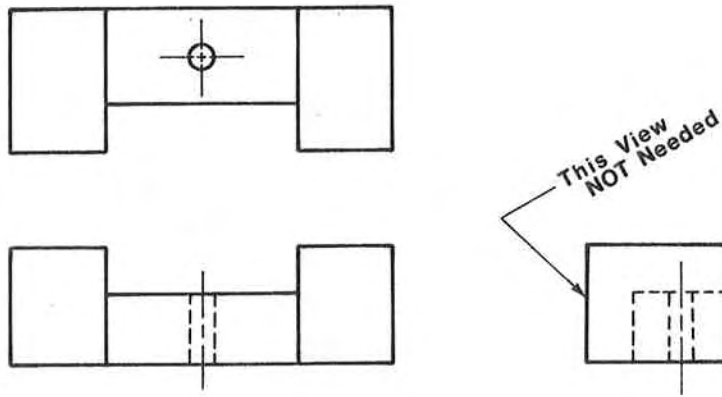


Figure 14-7 An example of a two-view drawing. In this case, the side view adds nothing to the drawing and so can be eliminated.

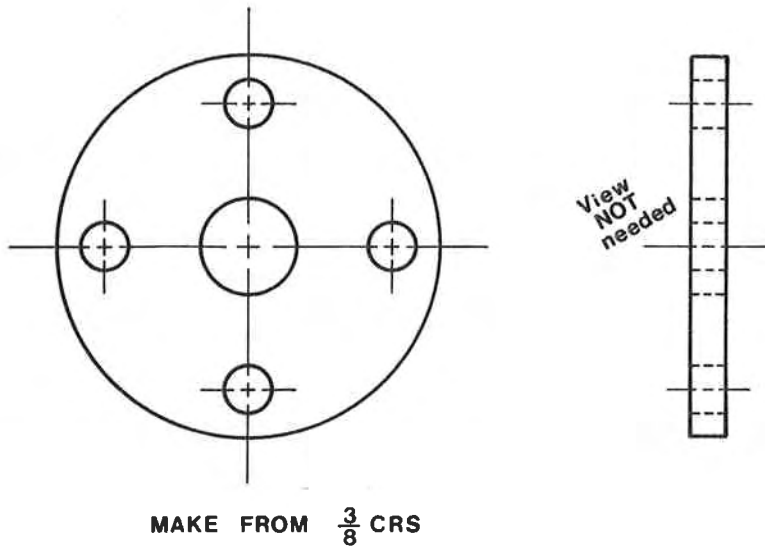


Figure 14-8 An example where one view is sufficient to define the object.

Unfortunately, there is no rule to follow in determining the number of views needed. Each object must be judged separately according to its individual drawing requirements.

For some objects, one orthographic view and part of another are sufficient for complete definition. A view that includes only part of an orthographic view is called a *partial view*. When and where to use partial views is up to the discretion of the draftsman, as long as the final drawing completely defines the object. Figure 14-9 is an example of a drawing that includes partial views.

To show where a partial view has been broken off (the rest of the view has been omitted), use a break line. Two kinds of break lines are used—one for general use and one when break lines are very long. Figure 14-10 illustrates the two break lines. Figure 14-11 presents an

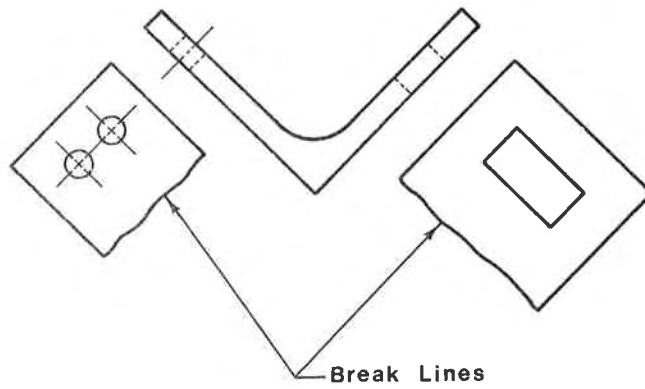


Figure 14-9 An example of a drawing which includes partial views.

BREAK LINES

for Shorter Breaks



for Long Breaks



Figure 14-10 How to draw breaklines. The wavy line used for shorter breaks is drawn freehand whereas the line for longer breaks is drawn as shown.

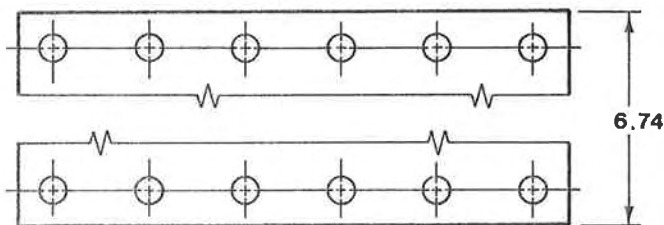


Figure 14-11 An example which includes a long break line.

example of how the long break line is used and Figure 14-9 illustrates the general break line. General break lines are drawn freehand as shown in Figure 14-10.

14-10 A DRAWING DETAIL

A drawing detail is a special kind of partial drawing. It is used to enlarge a specific part of a drawing that is too small or too complicated to be completely understood if only shown in its existing size. Figure 14-12 is an example of a drawing that includes a drawing detail.

When you draw a drawing detail, always clearly state the scale used and always label both the detail and the original source of the detail. As with one-view, two-view, and other partial drawings, there is no rule on when a drawing detail should be used. It is up to the draftsman to judge his (or her) drawing and to determine whether or not a drawing detail will help clarify any particular area.

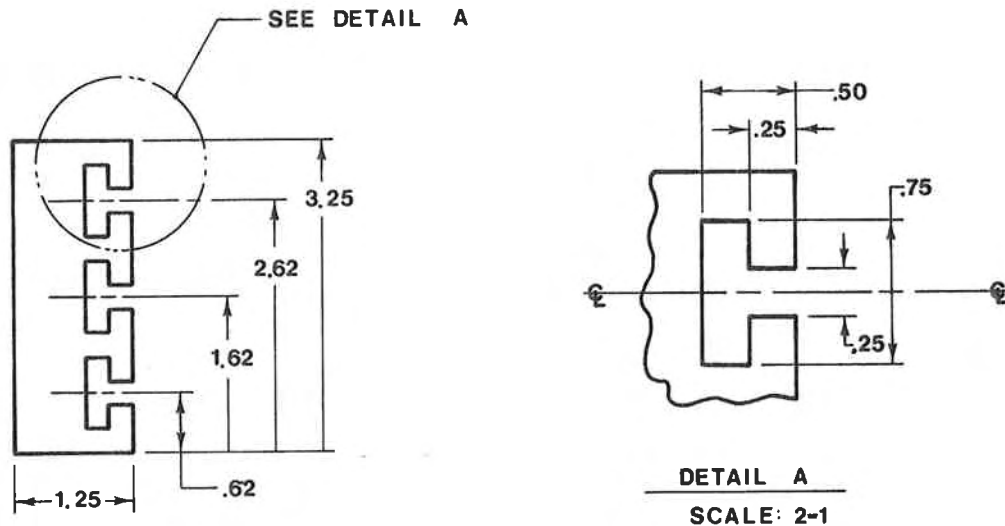


Figure 14-12 An example of a drawing detail.

14-11 DRAWING SCALES

Drawing scales are used because some objects are too big to fit on a sheet of drawing paper and others are so small that they could not be seen on a drawing. House drawings, for example, are drawn at a reduced scale. Electronic microcircuits are drawn at an increased scale.

Figure 14-13 shows one full-sized and two scaled drawings of the same square. Note that the scale used is clearly defined.

The scale note $\frac{1}{2} = 1$ means that every $\frac{1}{2}$ inch on the drawing is actually 1 inch on the object. In other words, the drawing is one-half the size of the true object size. Similarly, the scale note $2 = 1$ means

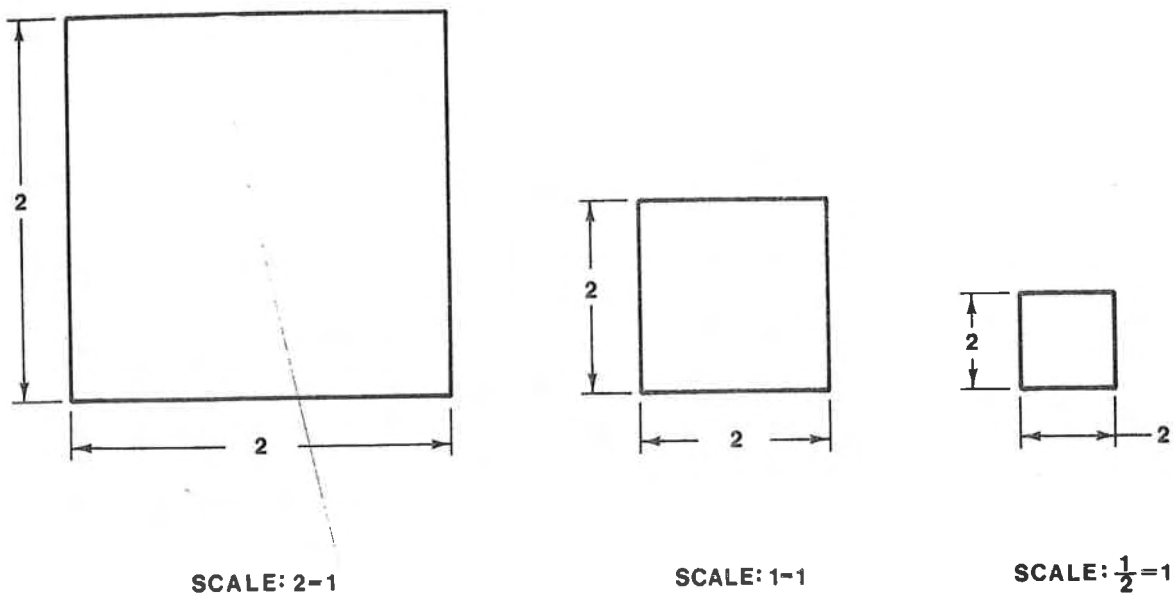


Figure 14-13 An example of drawing scales. The same square has been drawn using three different scales.

that 2 inch equals 1 inch; thus, the drawing is twice as large as the actual object. The note $1 = 1$ means that the drawing is the exact same size as the object.

When you dimension scaled drawings, never change the stated dimensions. Only change the size of the picture portion of the drawing. Look again at Figure 14-13. Note that the object has the same dimensions in each scale despite the change in the drawn size of the object.

14-12 DRILLING, REAMING, COUNTERBORING, AND COUNTERSINKING

Drilling, reaming, counterboring, and countersinking are very common machining operations that are called for on a drawing by a drawing note. Each operation is defined in this section and is illustrated in Figure 14-14.

DRILLING: a machine operation that produces holes. The bottom of drilled holes are drawn to a 30° -tapered point as shown in Figure 14-14(a).

REAMING: a machine operation that smooths out the surface of a drilled hole. From a drawing standpoint, reamings are drawn the same way that drilled holes are drawn. The call out notes, however, are different as shown in Figure 14-14(b).

COUNTERBORING: a machine operation in which part of a drilled hole is redrilled to a larger diameter [see Figure 14-14(c)].

COUNTERSINKING: a machine operation in which a drilled hole is redrilled to produce the tapered shape as shown in Figure 14-14(d). Countersinks are usually made at 82° , but they may be drawn at 90° (45° on each side) as shown in Figure 14-14(d).

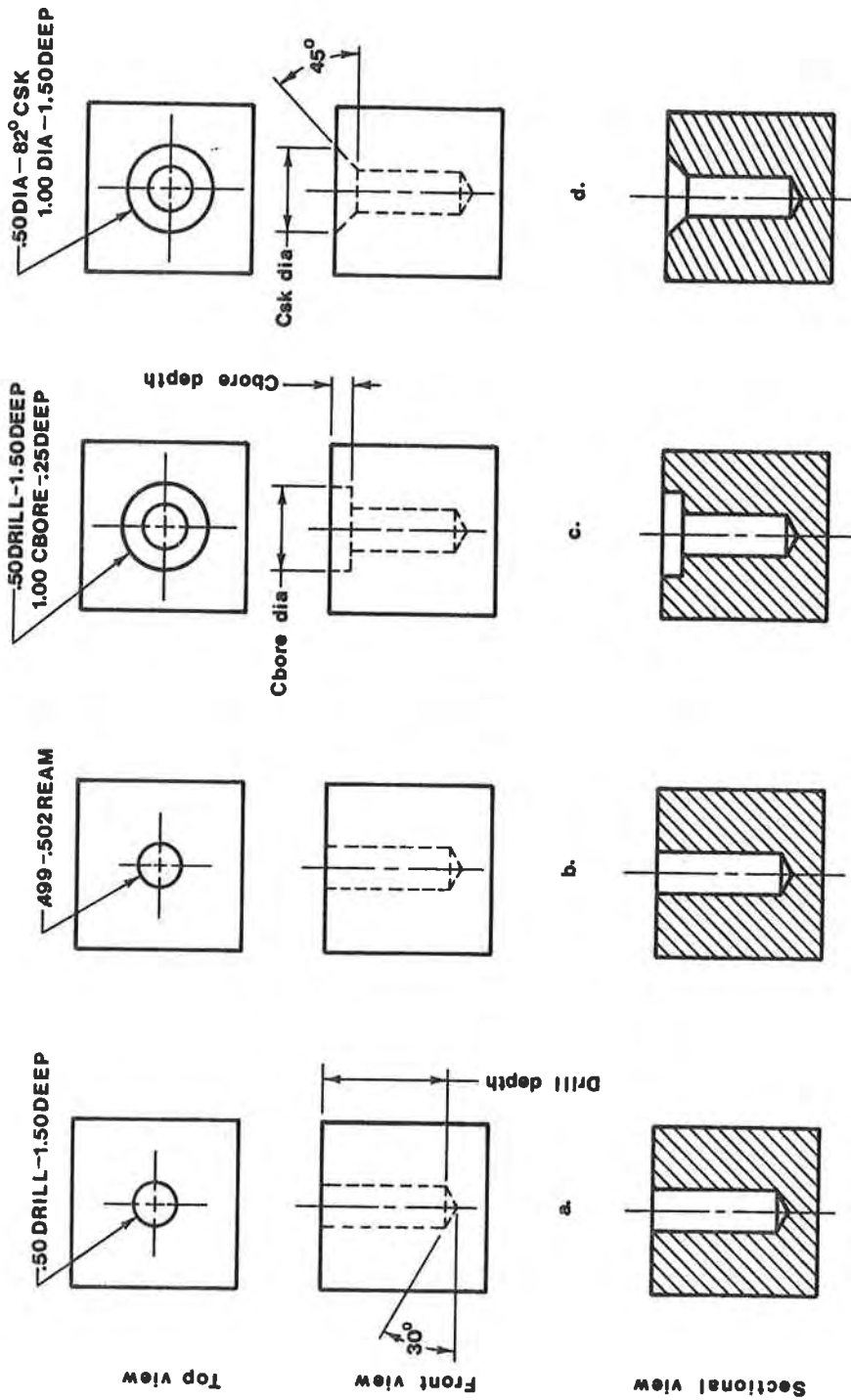
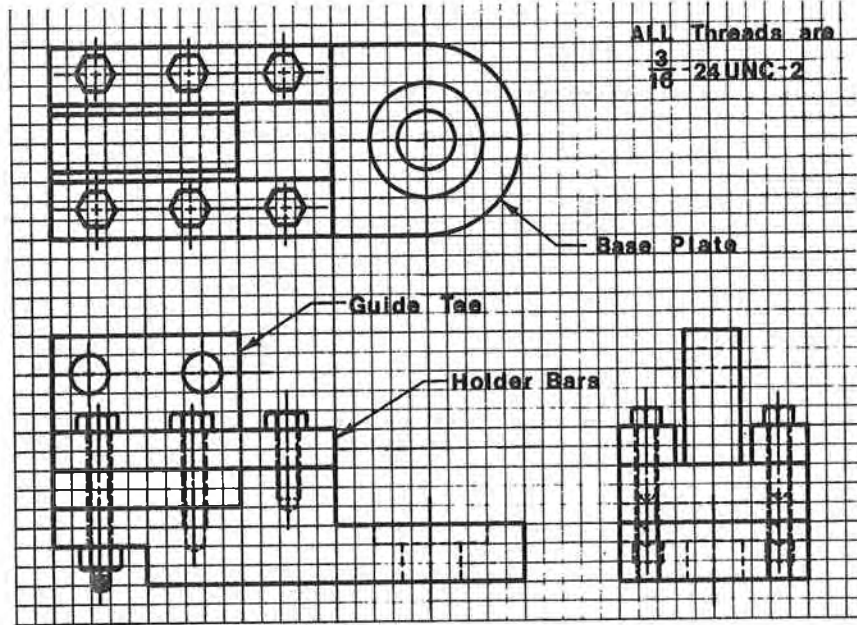


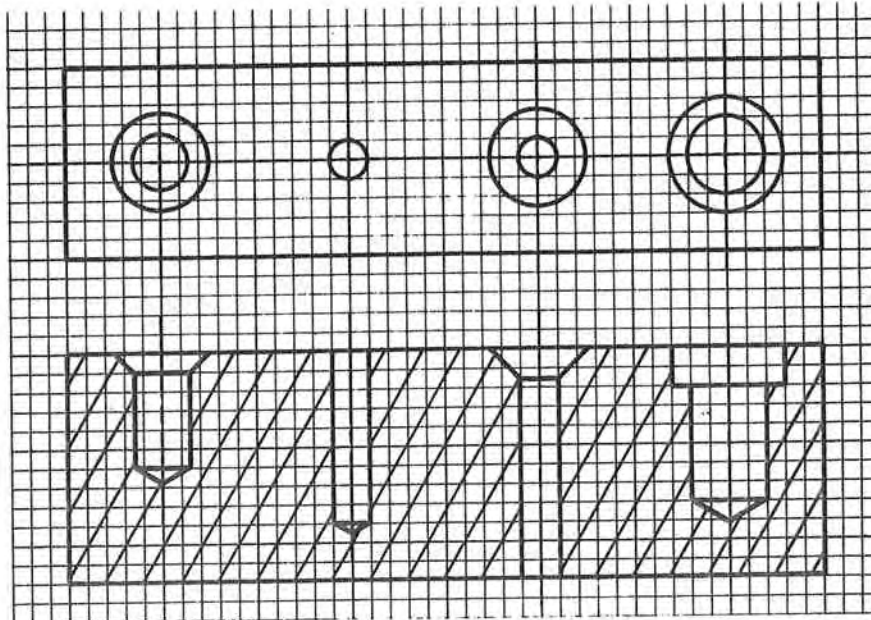
Figure 14-14 A top, front, and sectional view of (a) a drilled hole, (b) a reamed hole, (c) a counterbored hole, and (d) a counter-sunk hole along with appropriate drawing callouts.

PROBLEMS

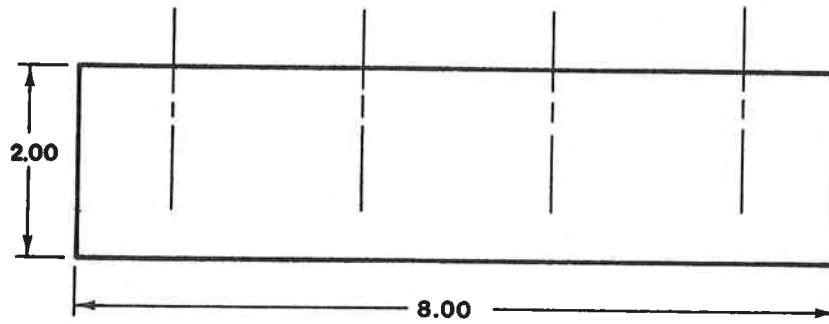
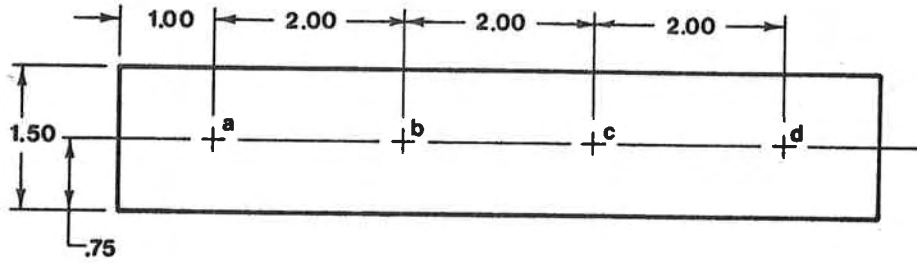
- 14-1 Redraw the following assembly. Make any changes that you feel will help clarify the drawing. Also draw detailed drawings of each of the component pieces of the assembly (including the screws). Each square on the grid is 0.20 per side.



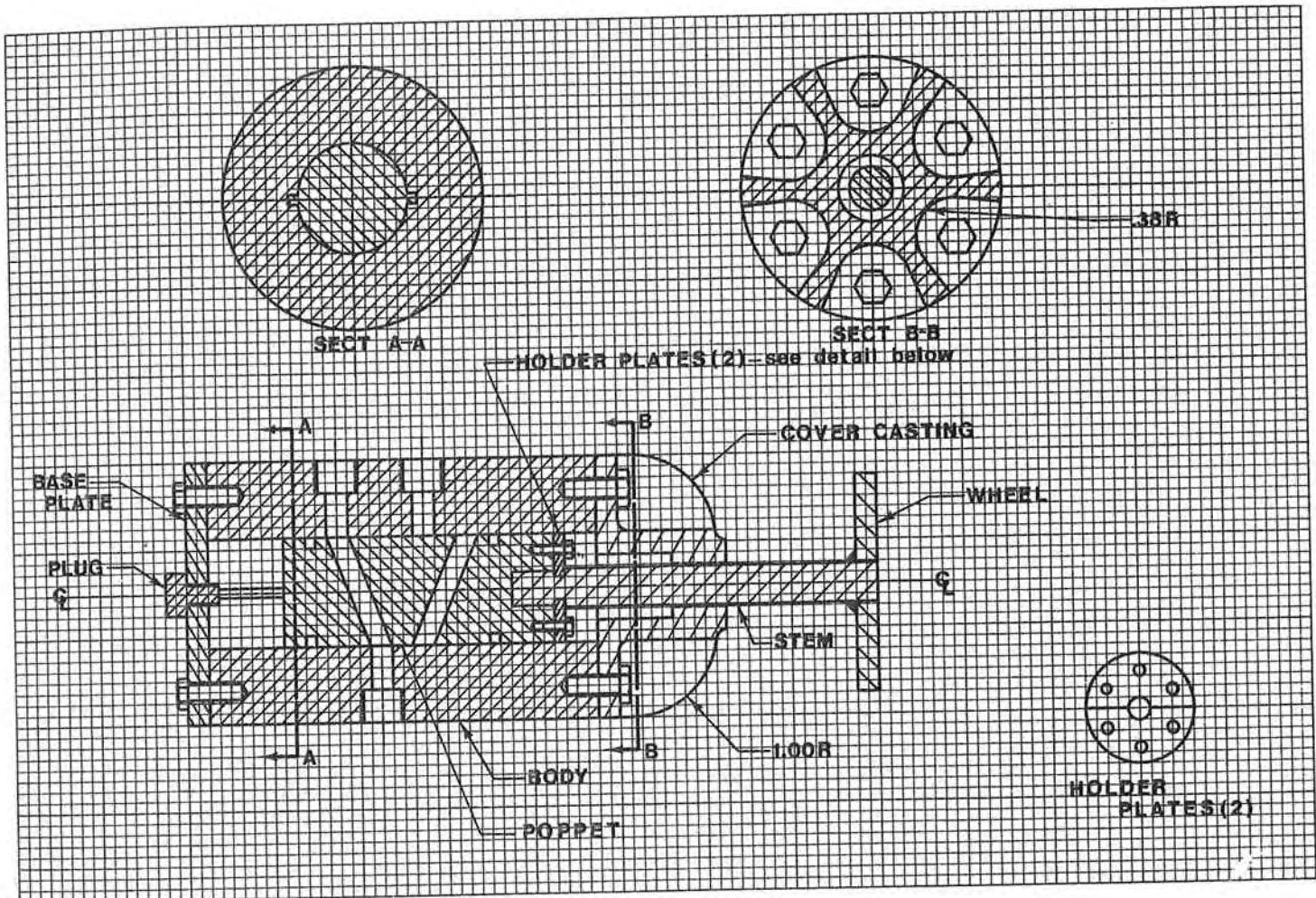
- 14-2 Redraw the following object and add the appropriate notes.



- 14-3 Redraw the following object and add the following:
- a) 0.44 DRILL-0.88 DEEP
 - b) 0.31 DIA-0.56 C BORE
0.19 DEEP
 - c) 0.63 DIA-82° CSK
1.38 DIA
 - d) 0.499-0.501 REAM



- 14-4 Given the following assembly drawing, prepare detail drawings of each of the component parts. Specify thread sizes for each of the screws. Assume that there are six screws between the base plate and body and six screws between the cover casting and body. Each square on the grid pattern is $1/8$ per side.

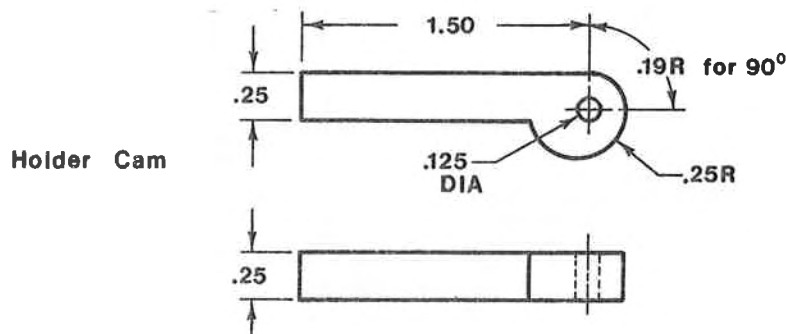
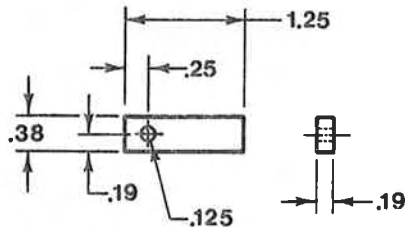


DESIGN PROBLEMS

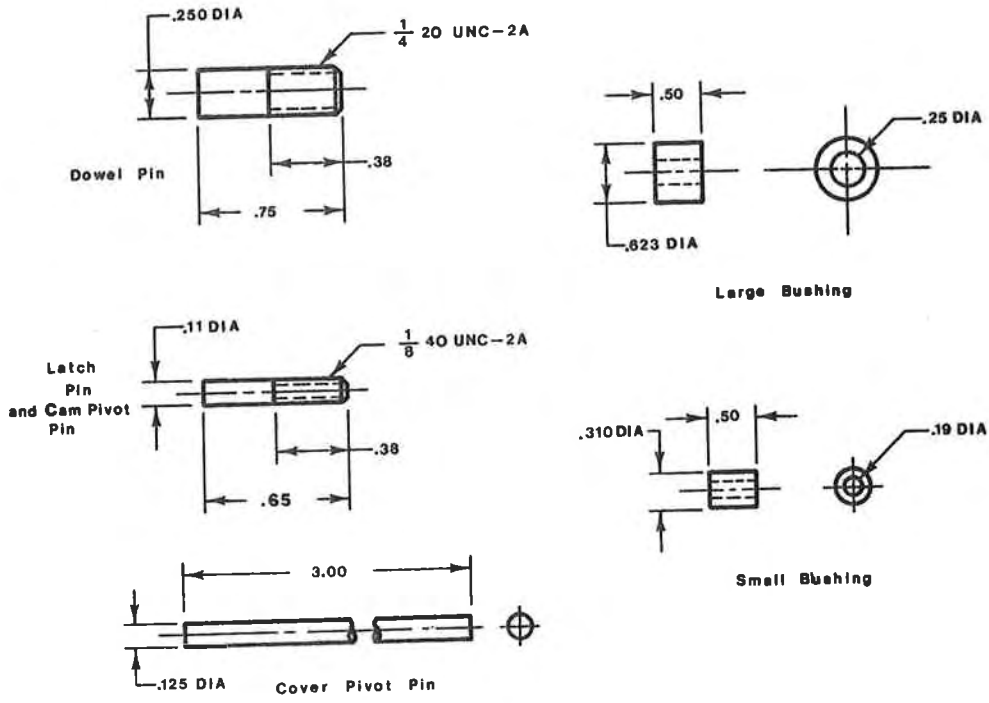
For each of the following designs, prepare an assembly drawing and detail drawings of each of the components parts, and a parts list.

- 14-5 Design a four-shelf bookcase.
- 14-6 Design a drawing table.
- 14-7 Design a case for carrying all your drafting equipment (do not include drafting machines).
- 14-8 Prepare a detail drawing of any standard tool (hammer, wrench, etc.).

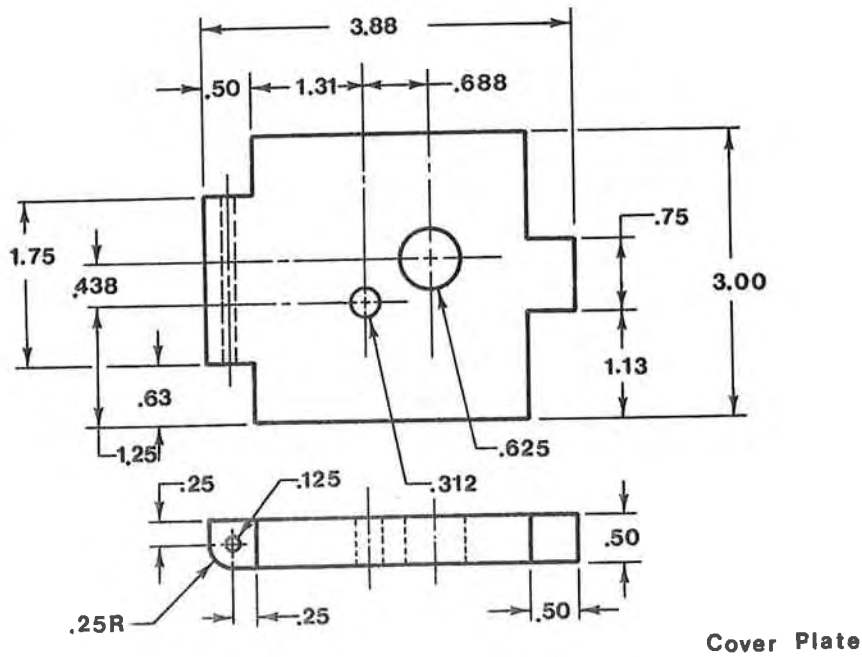
- 14-9 Prepare an assembly drawing and detail drawings of each of the component parts of a ball-point pen or leadholder.
- 14-10 Design a wine rack. Allow for bottles of at least three different sizes.
- 14-11 Design a portable, removable food tray for use while eating in a car. Specify the make of car for which you are designing the tray.
- 14-12 Given the following exploded drawing of a holding fixture and details of each of the fixture's component parts, draw a complete assembly drawing of the fixture. Use whatever views (orthographic, sectional, etc.) are necessary for complete definition of how all the pieces are to be assembled. Add a note to the assembly drawing to have the latch pin, dowel pins, cam pivot pin, and cover pivot pin pinned after assembly. Also add a parts list to the assembly drawing which includes a complete listing of parts required for the assembly.



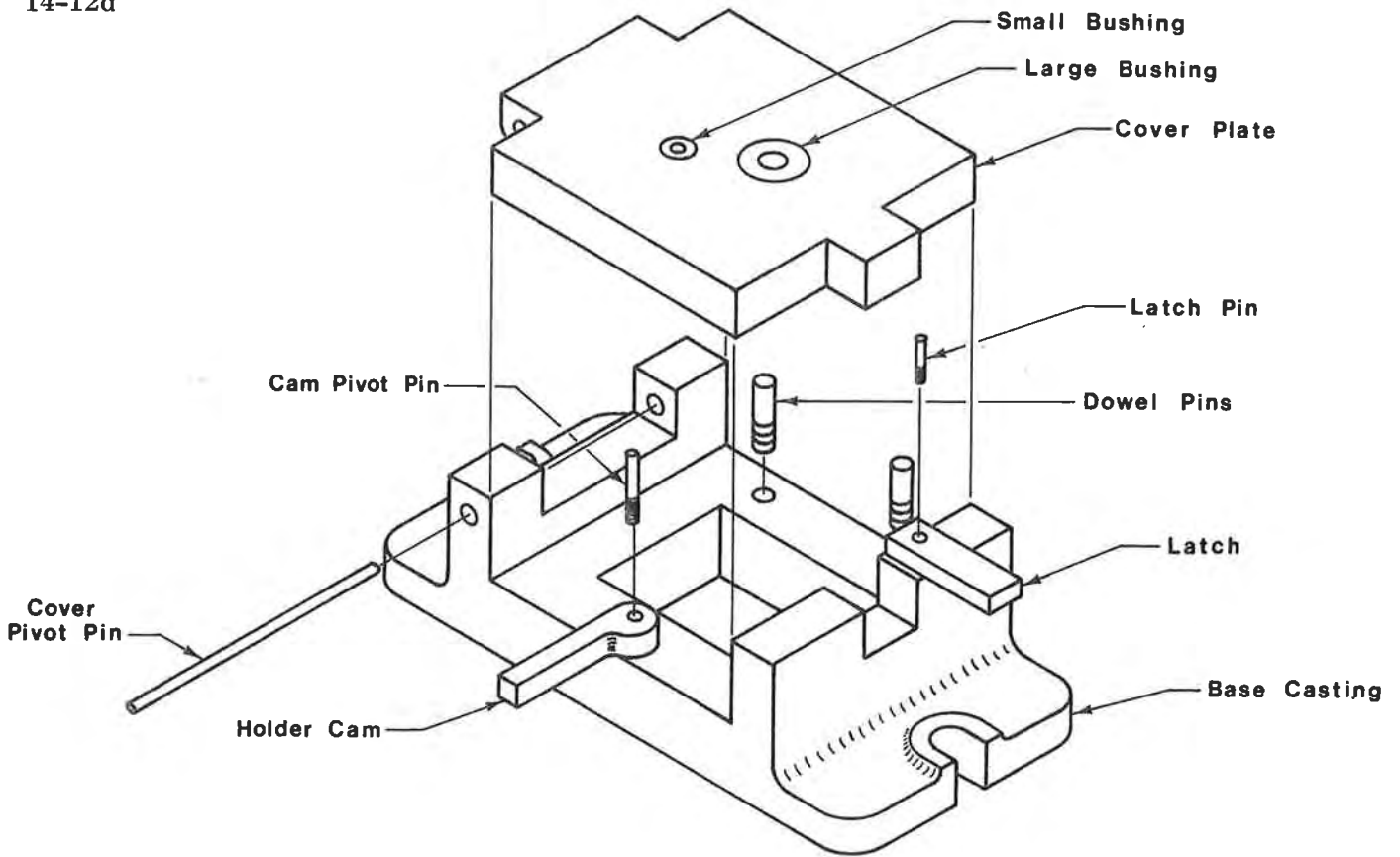
14-12b



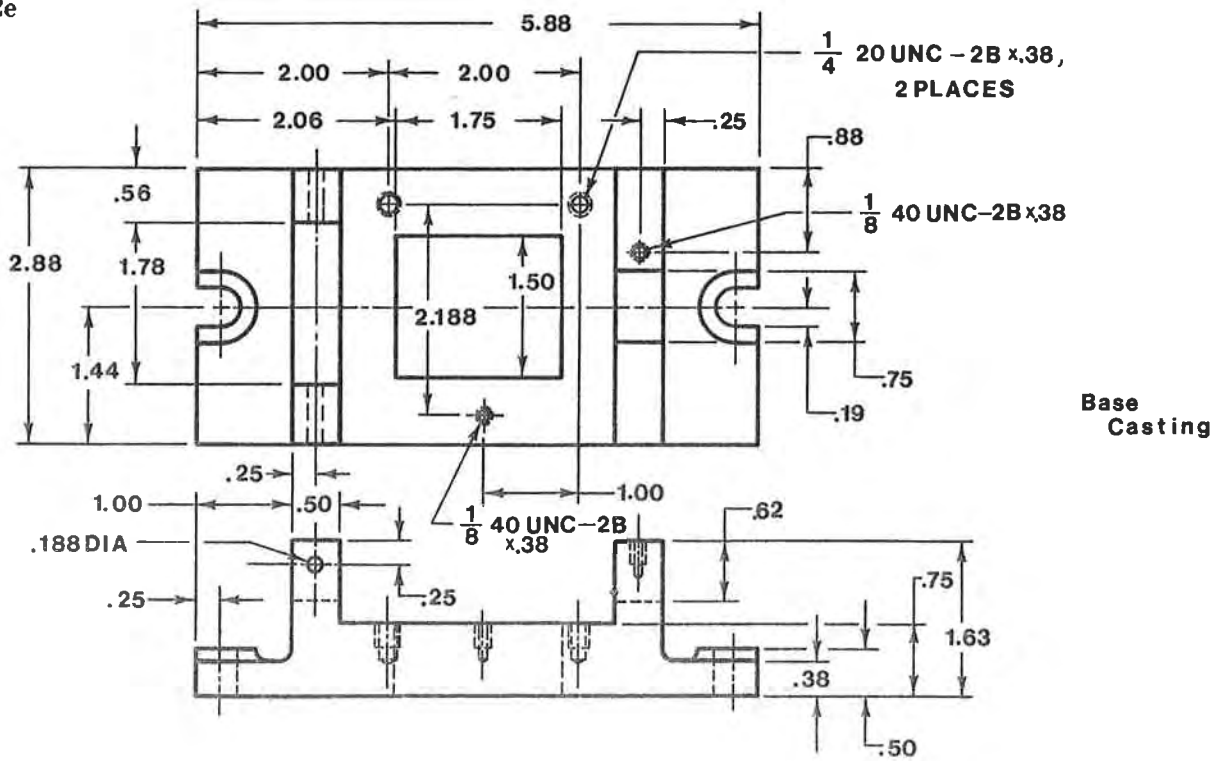
14-12c



14-12d



14-12e



ISOMETRIC DRAWINGS 15



Figure 15-0 Photograph courtesy of Buick Division, General Motors Corp.

15-1 INTRODUCTION

Isometric drawings are technical pictures that can be drawn by using instruments. They are not esthetically perfect pictures because their axes do not taper as they approach infinity. Figure 15-1 shows a comparison between an isometric drawing of a rectangular box and a pictorial drawing (such as an artist would draw) of the same object, and it demonstrates the distortion inherent in isometric drawings. Note how the back corner of the isometric appears much larger than the back of the pictorial drawing. Despite this slight distortion, isometric drawings are a valuable way to convey technical information.

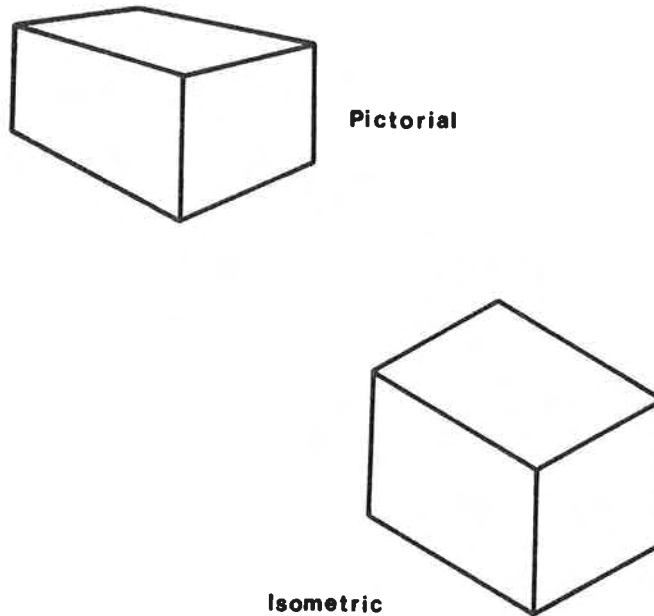


Figure 15-1 A comparison between an isometric drawing and a pictorial drawing. Note the visual distortion of the top rear corner of the isometric drawing.

The basic reference system for isometric drawings is shown in Figure 15-2. The three lines are 120° apart and may be thought of as a vertical line and two lines 30° to the horizontal, which means that they may be drawn by using a 30-60-90 triangle supported by a T-square. All isometric drawings are based on this axis system.

Normally, an isometric drawing is positioned so that the front, top, and right side views appear as shown in Figure 15-3. This may be

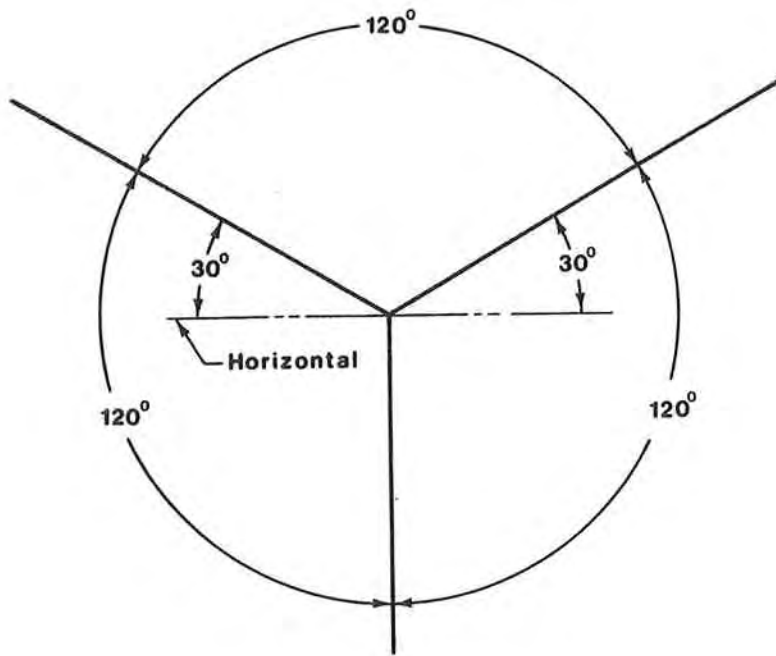


Figure 15-2 The basic reference system for isometric drawings.

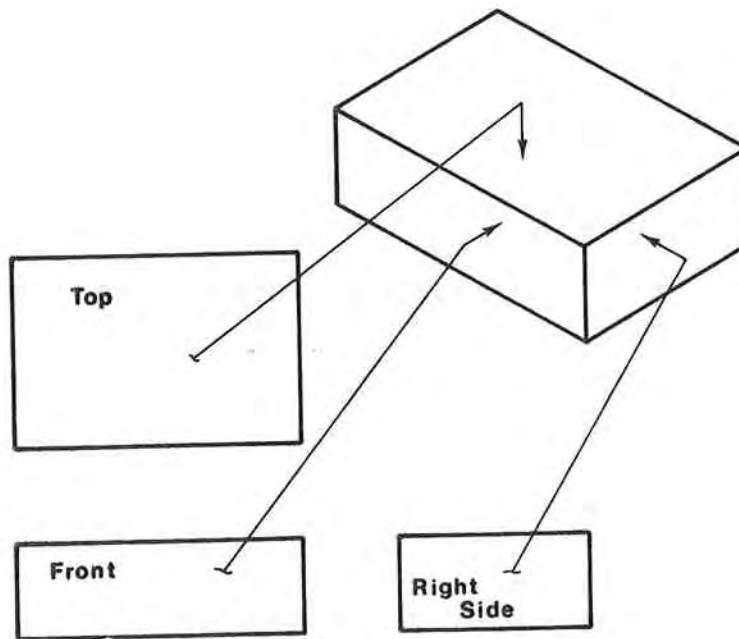


Figure 15-3 Definition of the relationship between the front, top, and side views as drawn orthographically and isometrically.

varied according to the position that the draftsman feels best shows the object.

Dimensional values are transferable from orthographic views only to the axis, or lines parallel to the axis, of isometric drawings. Angles and inclined dimensional values are not directly transferable and require special supplementary layouts which will be explained in this chapter.

Isometric drawings do not normally include hidden lines, although hidden lines may be drawn if special emphasis of a hidden surface is required.

15-2 NORMAL SURFACES

Figure 15-4 is a sample problem that requires you to create an isometric drawing from given orthographic views. Since all surfaces in the problem are normal (90° to each other), all dimensional values may be transferred directly from the orthographic views to the isometric axis, or lines parallel to the isometric axis. The basic height, width, and length of the object are $1\frac{1}{2}$, 2, and 3, respectively, in both the isometric

GIVEN: Front, top and side views.
PROBLEM: Draw an isometric drawing.

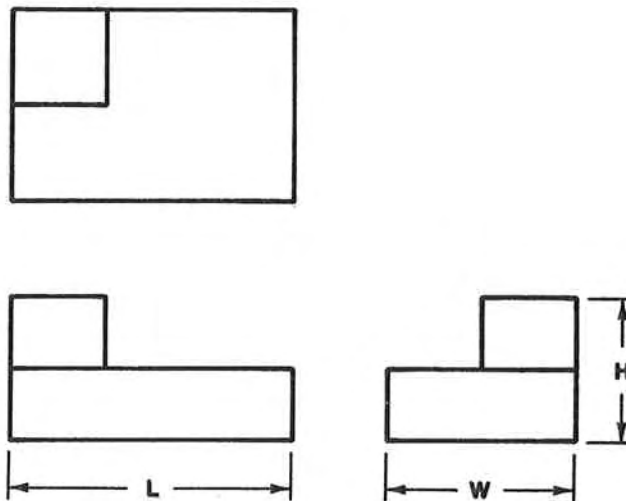


Figure 15-4

and orthographic drawings. Figure 15-5 is the solution to Figure 15-4 and was derived by the following procedure:

SOLUTION:

1. Make, to the best of your ability, a freehand sketch of the solution. See Section 5-6 for instructions on how to make sketches. Remember that since it is easier to make corrections and changes on a sketch than on a drawing, you should make your sketch as complete and accurate as possible.

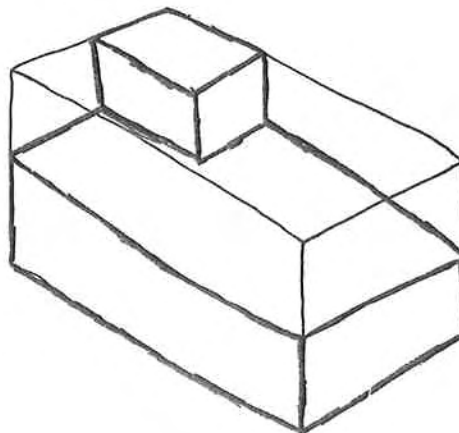


Figure 15-5(a)

- Using very light lines, lay out a rectangular box whose height, width, and length correspond to the height, width, and length given in the orthographic views.

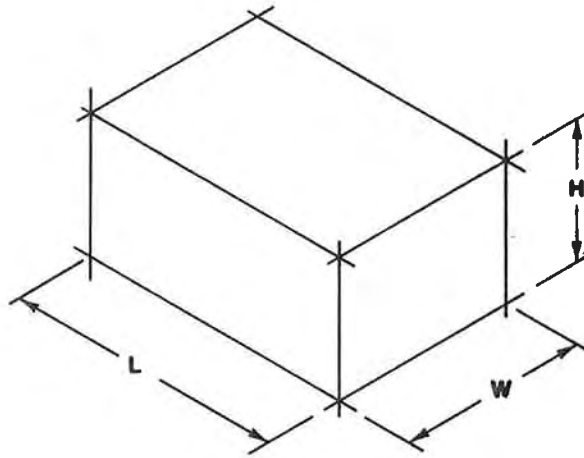


Figure 15-5(b)

- Using very light lines, lay out the specific shape of the object. Transfer dimensional values directly from the orthographic views to the axis, or lines parallel to the axis, of the isometric drawing.

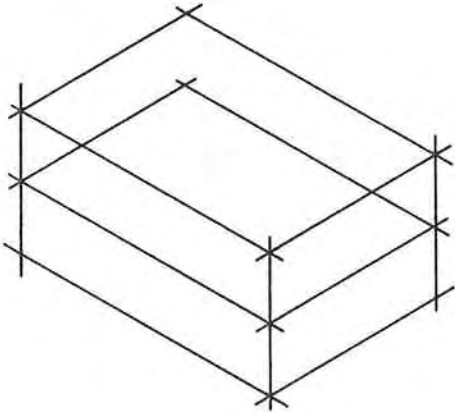


Figure 15-5(c)

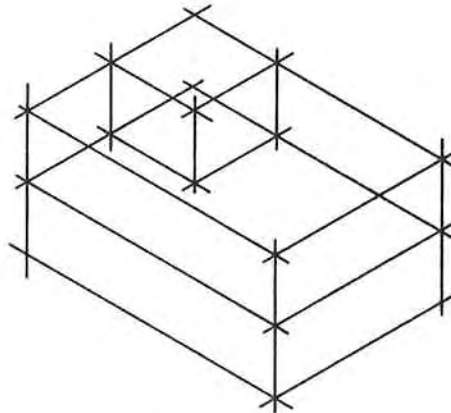


Figure 15-5(d)

- Erase all excess lines and smudges; carefully check your work; and then darken in all final lines to their proper color and pattern.

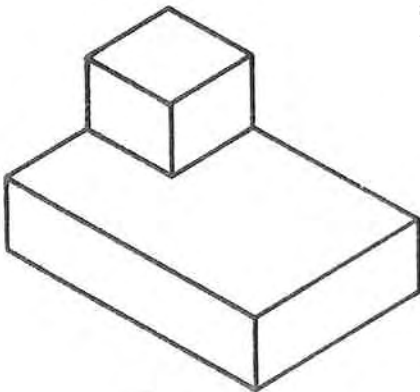


Figure 15-5(e)

Figure 15-6 is another example of an isometric drawing created from given orthographic views and including only normal surfaces.

GIVEN: Front, top, and side views.
PROBLEM: Draw an isometric drawing.

SOLUTION:

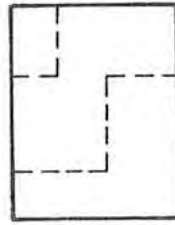
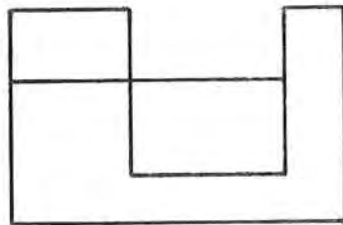
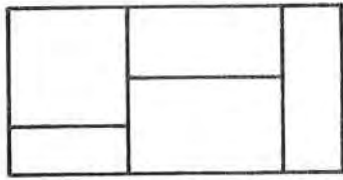


Figure 15-6(a)

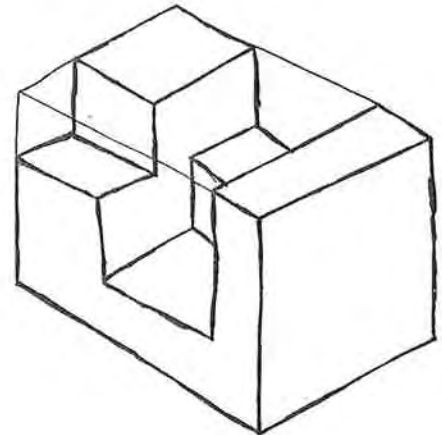


Figure 15-6(b)

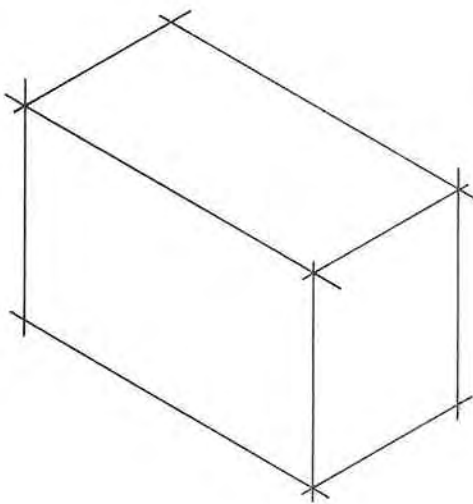


Figure 15-6(c)

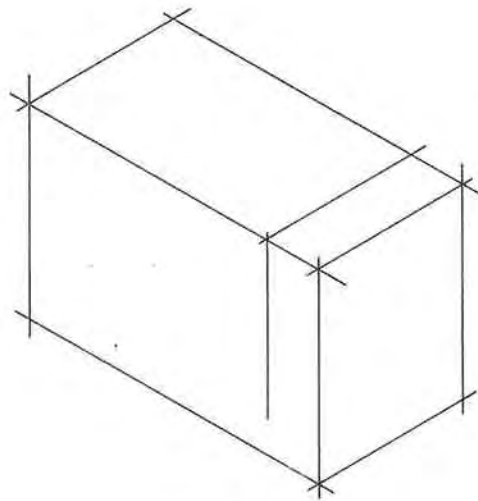


Figure 15-6(d)

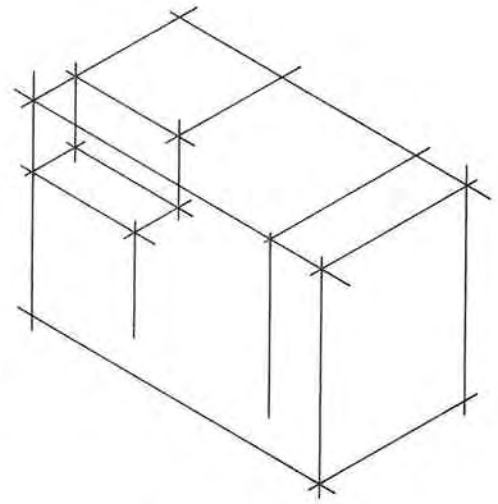


Figure 15-6(e)

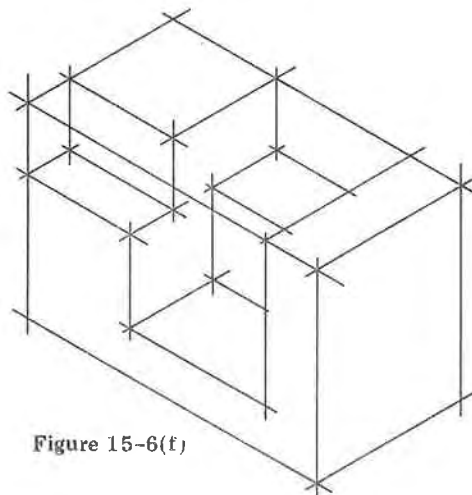


Figure 15-6(f)

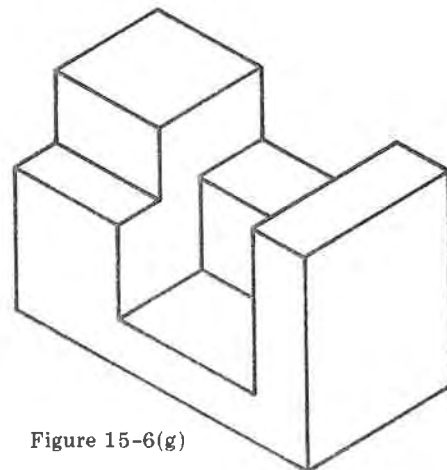


Figure 15-6(g)

15-3 SLANTED AND OBLIQUE SURFACES

Figure 15-7 is a sample problem that involves the creation of an isometric drawing from given orthographic views that contain a slanted surface. The slanted surface is dimensioned by using an angular dimension that presents a problem because angular dimensions cannot be directly transferred from orthographic views to isometric drawings.

GIVEN: Front, top, and side views.
PROBLEM: Draw an isometric drawing.

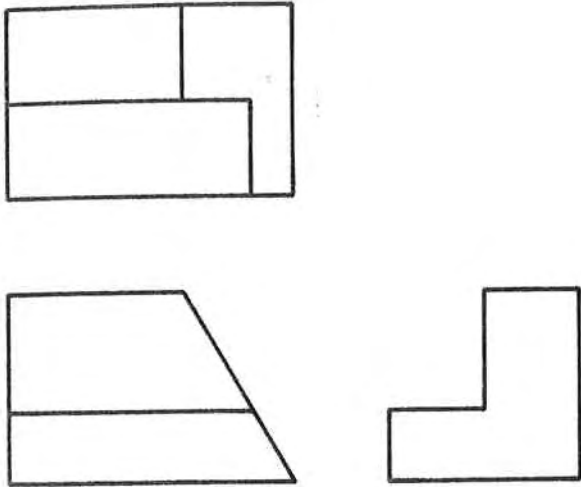


Figure 15-7

To transfer an angular dimensional view from an orthographic view to an isometric drawing, convert the angular dimensional value to its component linear value and transfer the component values directly to the axis of the isometric drawing. Figure 15-8 illustrates this procedure by showing two angular dimensions that have been converted

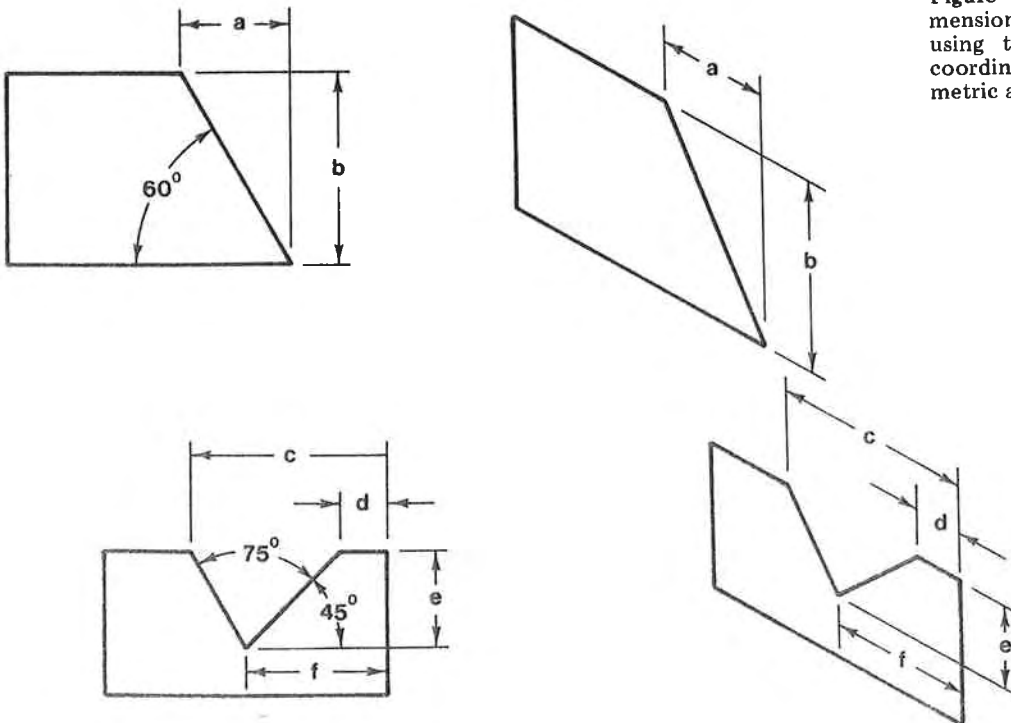


Figure 15-8 Two examples of angular dimensions which have been redimensioned using their linear coordinates. The linear coordinates have been transferred to an isometric axis.

to their respective component linear values and then showing how these values are transferred to the isometric axis. Normally, a draftsman simply measures his full-sized orthographic views and then transfers the information, but if this information is not available, he (or she) makes a supplementary layout from which the necessary values may be measured. Supplementary layouts may be made on any extra available paper and should be saved for reference during the checking of the drawing.

Figure 15-9 is the solution to Figure 15-7 and was derived by the following procedure:

SOLUTION:

1. Make, to the best of your ability, a freehand sketch of the solution.

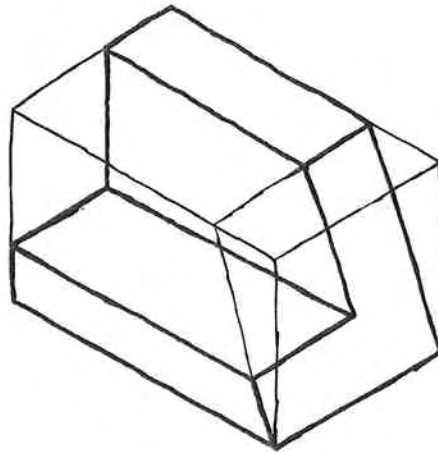


Figure 15-9(a)

2. Using very light lines, lay out a rectangular box whose height, width, and length correspond to the height, width, and length given in the orthographic views.

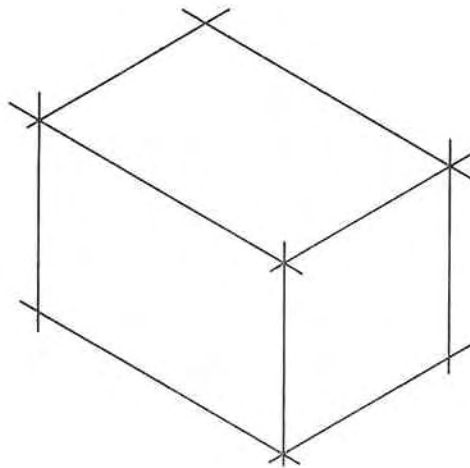


Figure 15-9(b)

3. Using very light lines, lay out the specific details of the object. Where necessary, make supplementary layouts that furnish the linear component values which you can transfer to the isometric axis. In this case, the 30° component layout is shown in Figure 15-8.

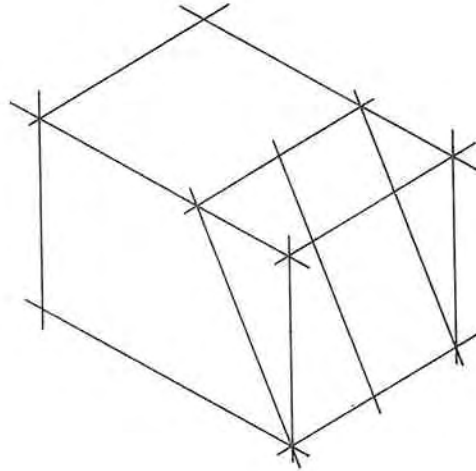


Figure 15-9(c)

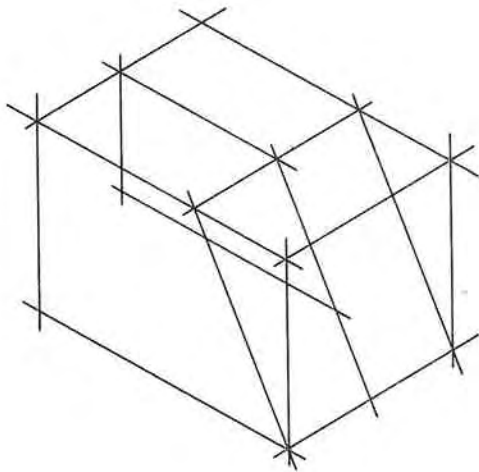


Figure 15-9(d)

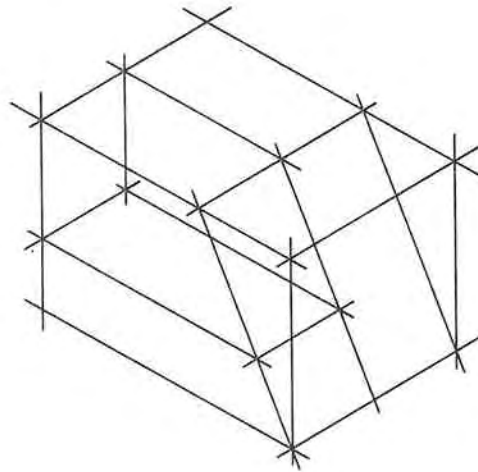


Figure 15-9(e)

4. Erase all excess lines and smudges; check your work; and then draw in all lines to their proper color and pattern.

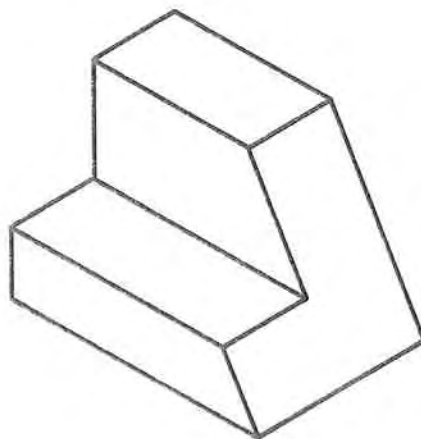


Figure 15-9(f)

Figure 15-10 is a sample problem that requires you to make an isometric drawing from given orthographic views that include an oblique surface. The solution was derived by using basically the same procedure that was used for slanted surfaces. As with angular dimensional values, the dimensional values that define an oblique surface must be converted to their respective linear component values before they may be transferred to the isometric axis. If necessary, supplementary layouts should be made. Figure 15-11 is the solution to Figure 15-10.

GIVEN: Front, top, and side views.
PROBLEM: Draw an isometric drawing.

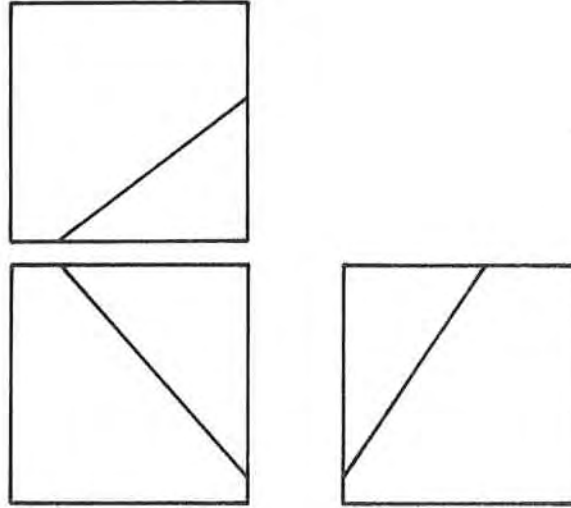


Figure 15-10

SOLUTION:

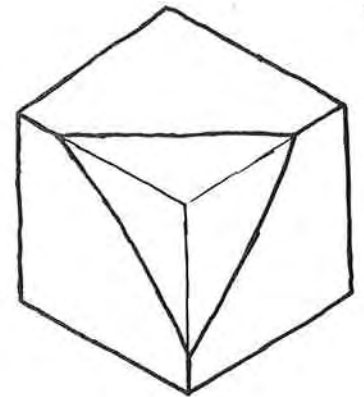


Figure 15-11(a)

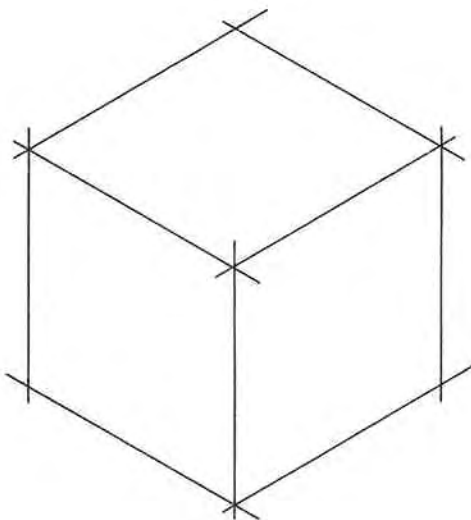


Figure 15-11(b)

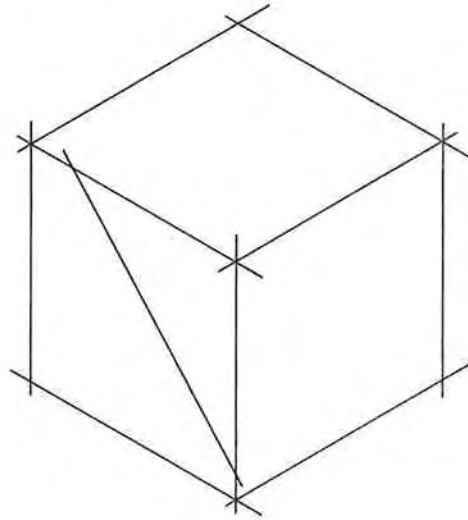


Figure 15-11(c)

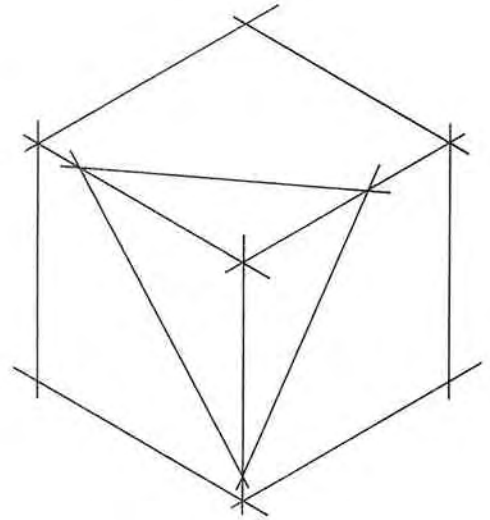


Figure 15-11(d)

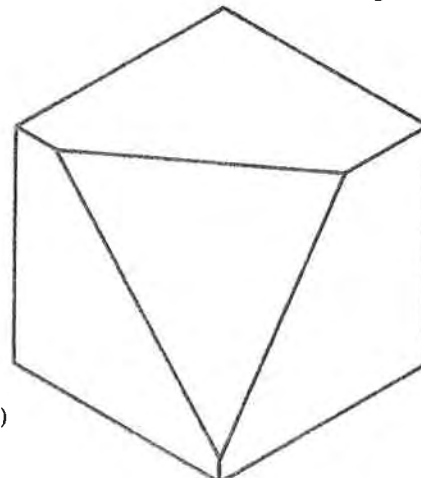


Figure 15-11(e)

15-4 HOLES IN ISOMETRIC DRAWINGS

There are two basic methods for drawing holes for isometric drawings. One method is to use instruments and draw the holes by using the four-center ellipse method. The other method is to use an isometric hole template as a guide. The template is much easier and faster to use, but templates are available only in standard hole sizes. Very large or odd-sized holes may only be drawn by using the four-center ellipse method.

The four-center ellipse method is presented in Figure 15-14(a). When you use this method, be careful that the four centers are located accurately. If the centers are not located properly, the four individual arcs will not meet to form a smooth, continuous ellipse. A good practice that will help you draw a smooth continuous ellipse is to lightly construct the ellipse and then check it for accuracy before drawing in the final heavy arcs.

An isometric hole template may be conveniently used as a guide for drawing the hole size for which it is cut. Figure 15-12(a) illustrates an isometric hole template. To align the template for drawing, first draw in the hole center lines, and then align the guidelines printed on the template adjacent to the desired hole with the center lines on the drawing. If you are still unsure of how to position the template, draw in the center lines and the major and minor axes of the ellipse as shown in Figure 15-12(b). Then align the template with the four intersections formed by the center lines as they cross the major and minor axes (labeled points 1, 2, 3, and 4 in Figure 15-12) and draw in the ellipse.

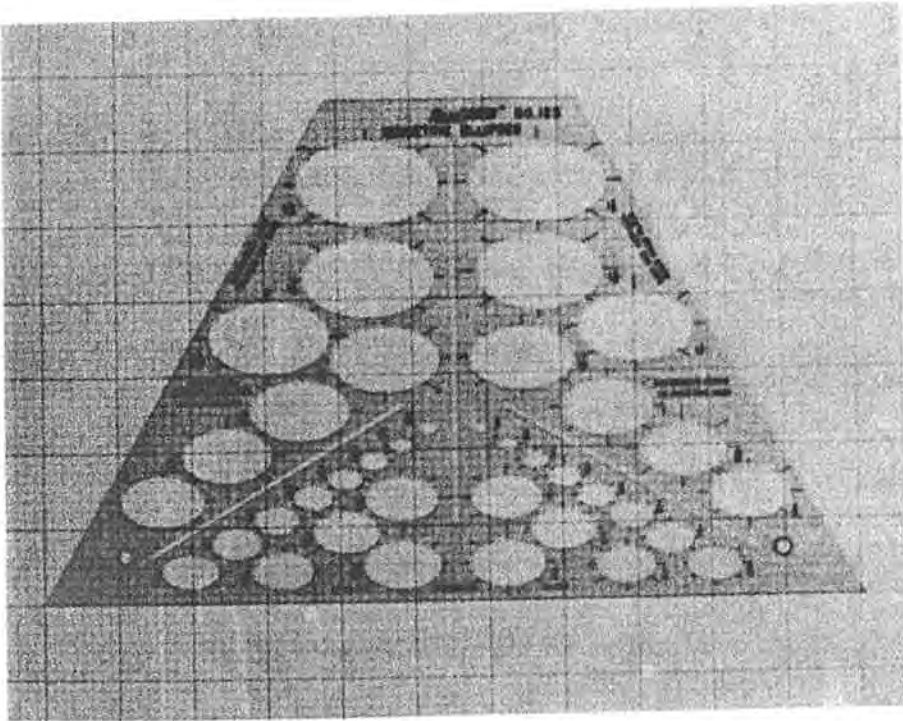


Figure 15-12(a) Isometric hole template

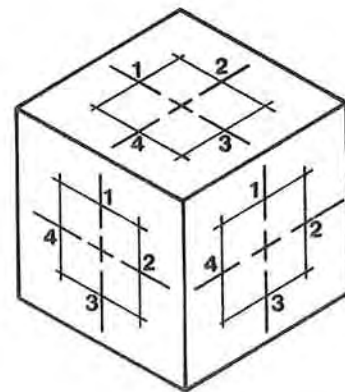


Figure 15-12(b)

GIVEN: Front and side views.
PROBLEM: Draw an isometric drawing.

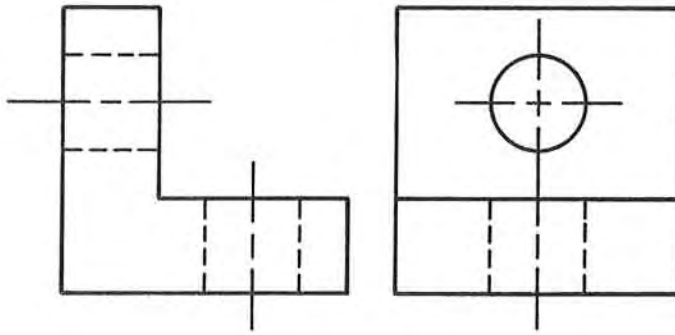
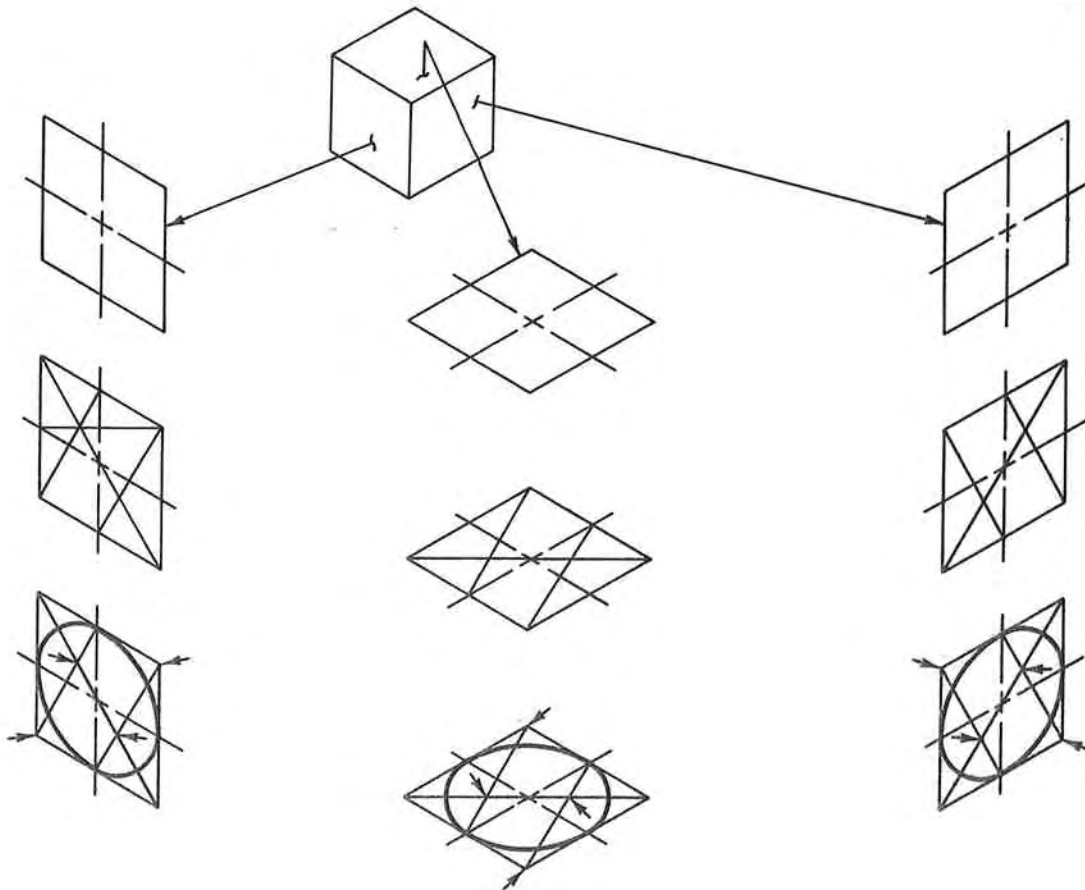


Figure 15-13

Figure 15-13 is a problem that requires you to draw a hole in an isometric drawing. Figure 15-14 is the solution using the four-center ellipse method, and Figure 15-15 is the solution using an isometric hole template.

Figure 15-14(a) Four center method for drawing isometric ellipses. Note: this method is ONLY good for isometric drawings; use the approximate ellipse method described in Section 3-28 for all other ellipses.



← Indicates the location of compass center points

SOLUTION:

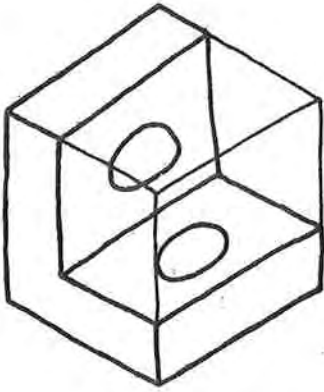


Figure 15-14(b)

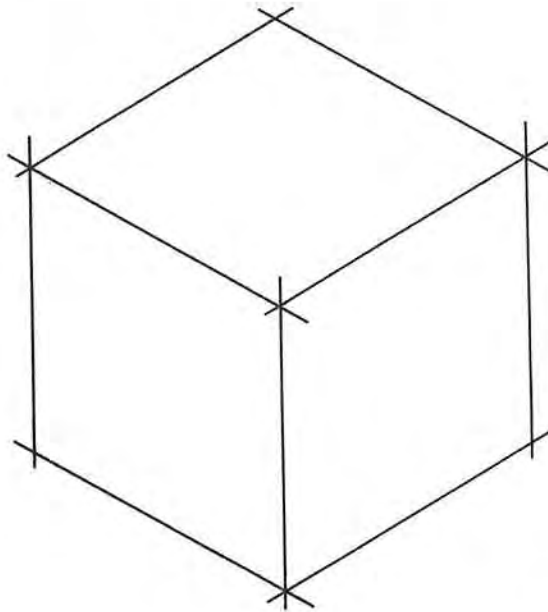


Figure 15-14(c)

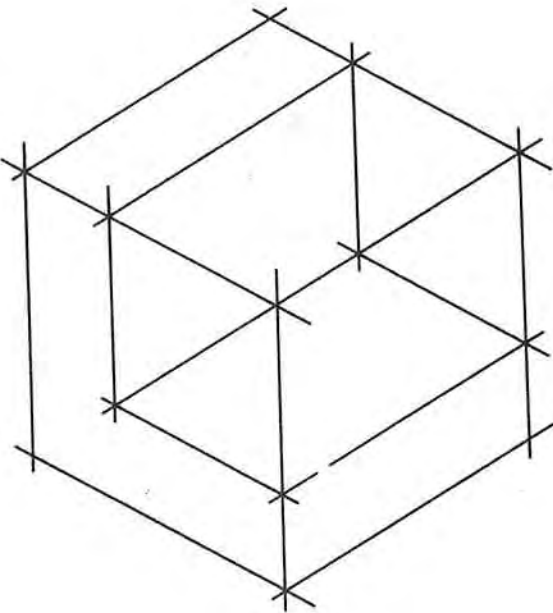


Figure 15-14(d)

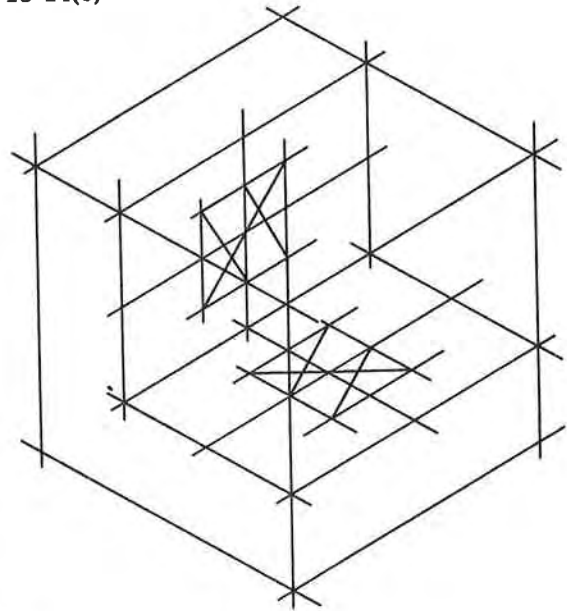


Figure 15-14(e)

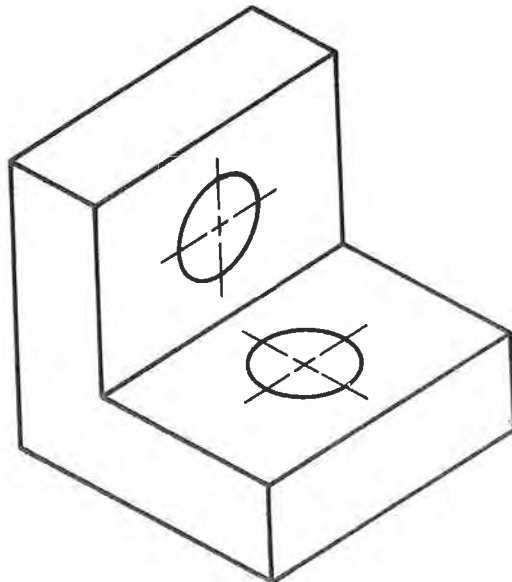


Figure 15-14(f)

SOLUTION:

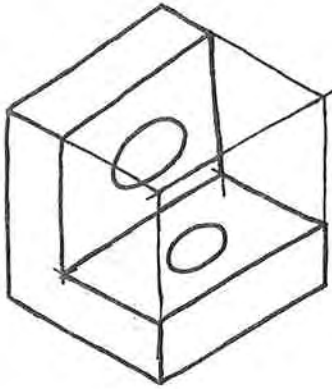


Figure 15-15(a)

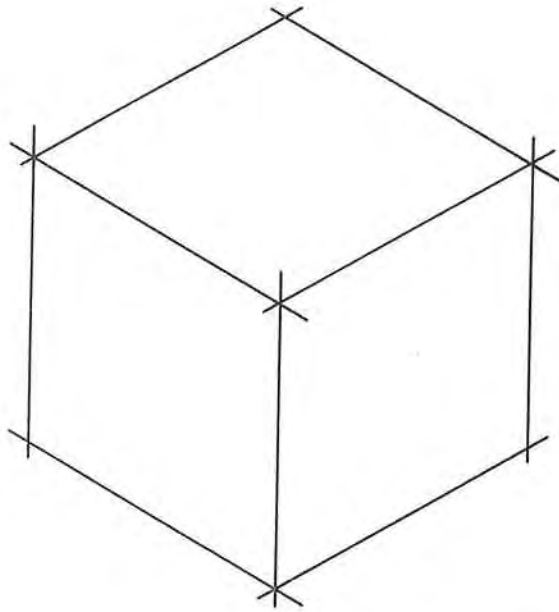


Figure 15-15(b)

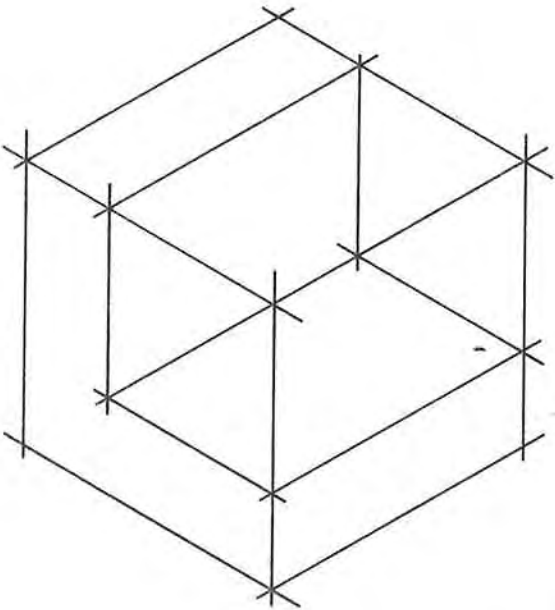


Figure 15-15(c)

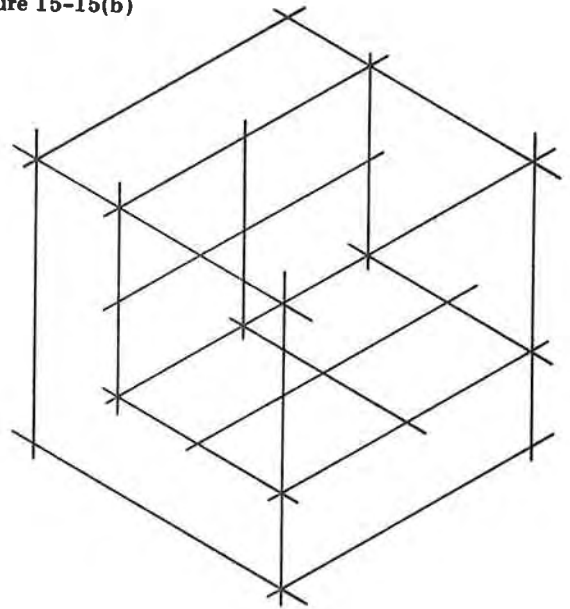


Figure 15-15(d)

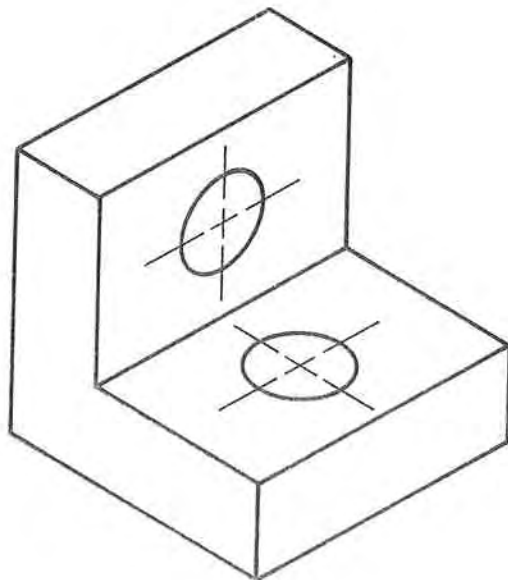


Figure 15-15(e)

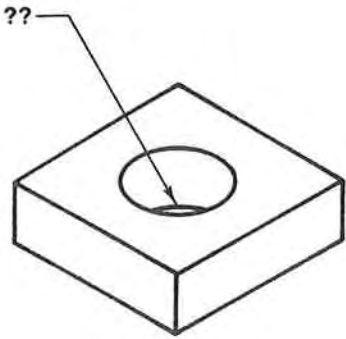


Figure 15-16 When does the bottom edge of a hole show in an isometric drawing?

In drawing a hole for an isometric drawing there arises the question of whether or not the bottom edge of the hole can be seen. If it can be seen, how much of it can be seen? Figure 15-16 illustrates the problem.

To determine exactly if and how much of the bottom edge of the hole should be drawn, locate the center point of the hole on the bottom surface and draw in the hole by using the same procedure you used for the hole on the top surface. If the hole drawn on the bottom surface appears within the hole on the top surface, it should appear on the finished drawing. If the hole drawn on the bottom surface does not appear within the hole on the top surface, it should not appear on the finished drawing. Figure 15-17 presents a sample problem that illustrates this procedure.

GIVEN: A front view.

PROBLEM: Draw an isometric drawing.

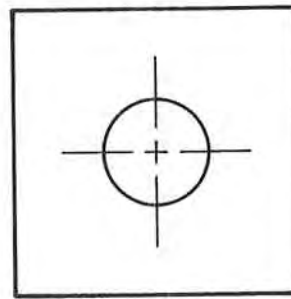


Figure 15-17(a)

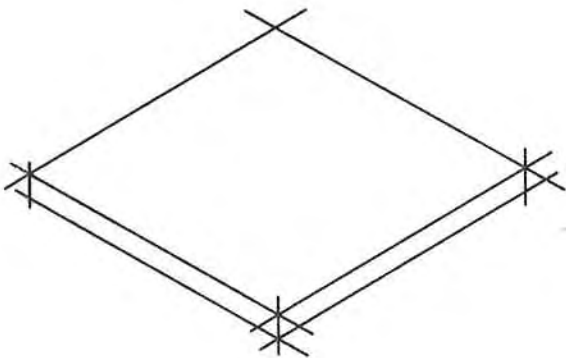


Figure 15-17(b)

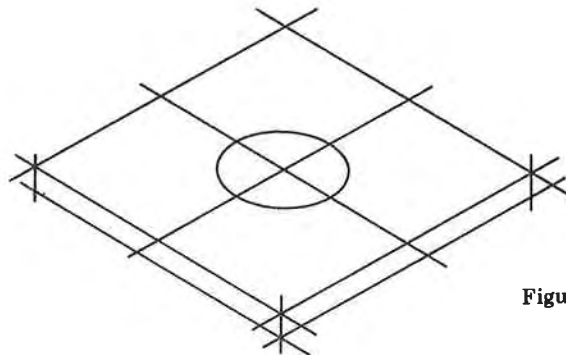


Figure 15-17(c)

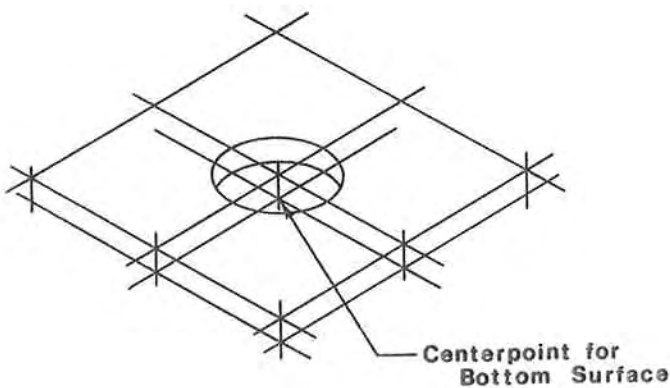


Figure 15-17(d)

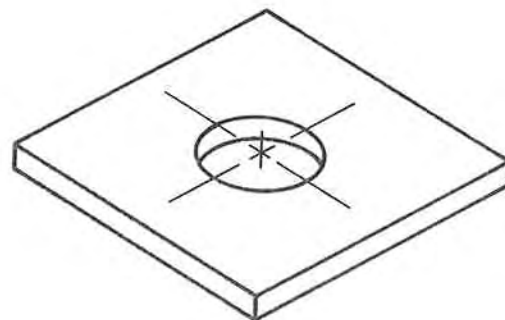


Figure 15-17(e)

15-5 ROUND AND IRREGULAR SURFACES

Figure 15-18 is a sample problem that requires you to create an isometric drawing from given orthographic views that contain a round surface. To make an isometric drawing of a round surface, use either an isometric template for a guide or the point method as described in this section. Figure 15-19 is a solution to Figure 15-18 that was derived by using an isometric ellipse template. Figure 15-20 is a solution that was

GIVEN: Front, top, and side views.
PROBLEM: Draw an isometric drawing.

SOLUTION:

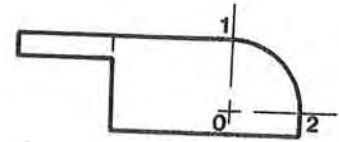


Figure 15-19(a)

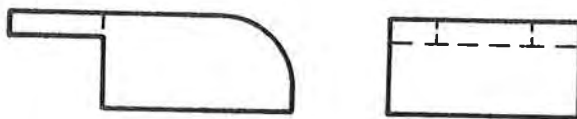
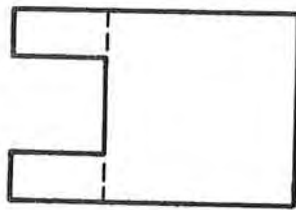


Figure 15-18

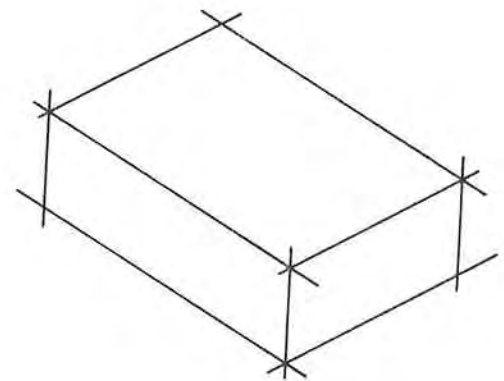


Figure 15-19(b)

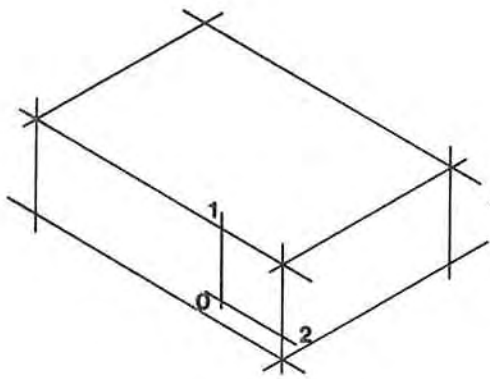


Figure 15-19(c)

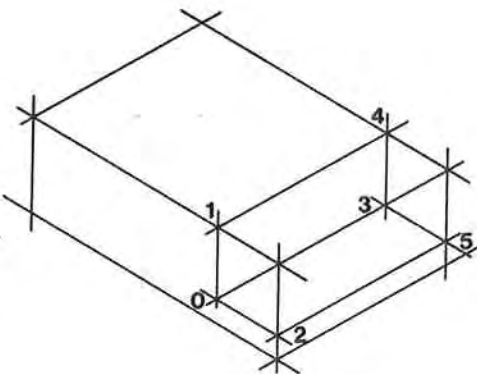


Figure 15-19(d)

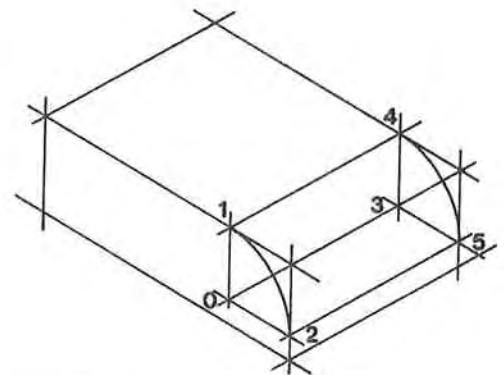


Figure 15-19(e)

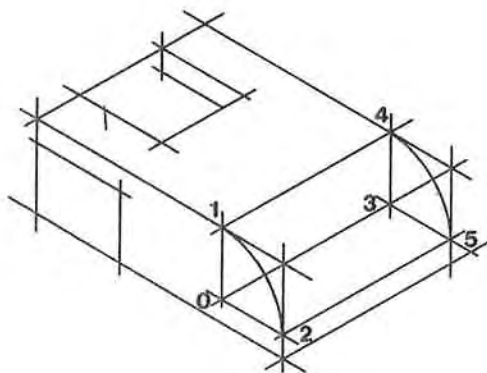


Figure 15-19(f)

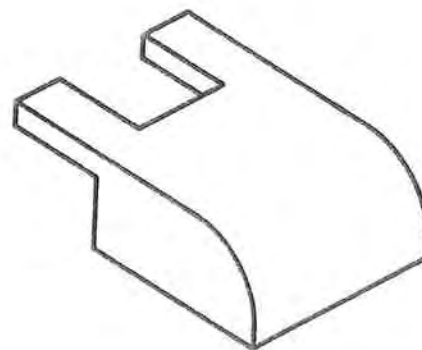


Figure 15-19(g)

SOLUTION:

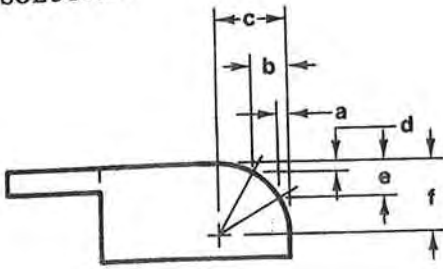


Figure 15-20(a)

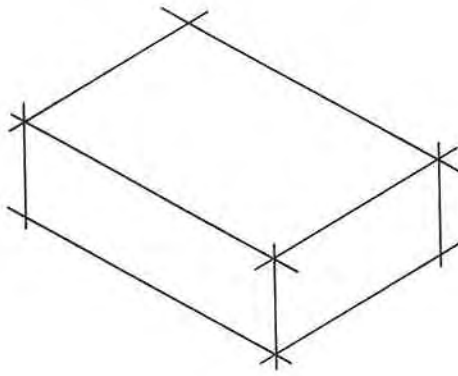


Figure 15-20(b)

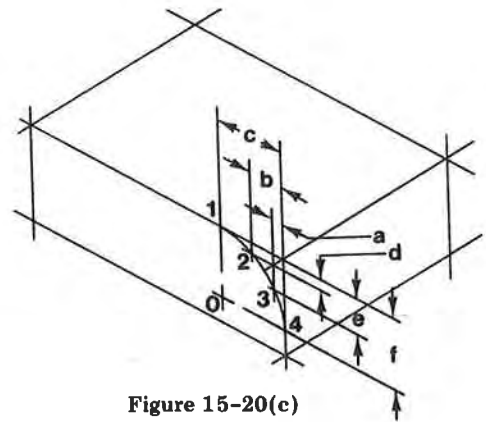


Figure 15-20(c)

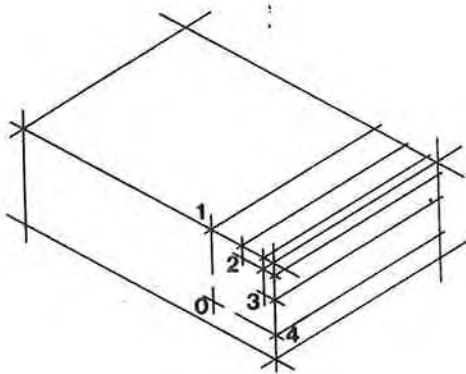


Figure 15-20(d)

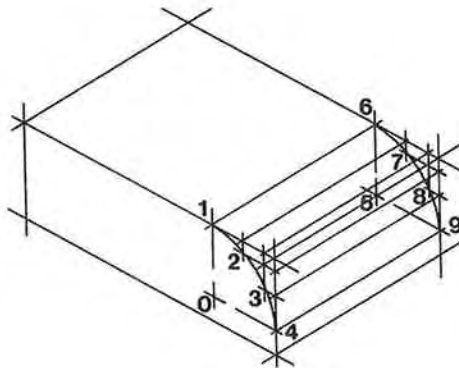


Figure 15-20(e)

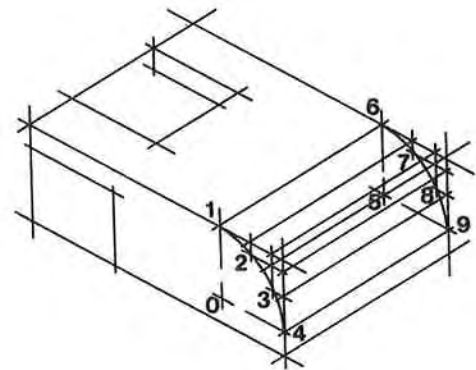


Figure 15-20(f)

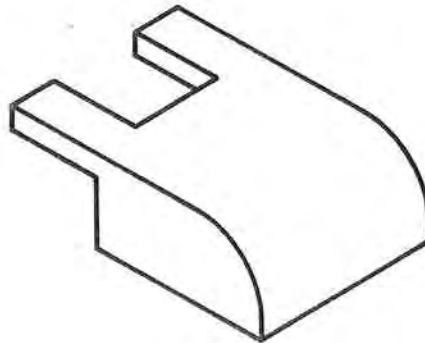


Figure 15-20(g)

derived by using the point method. The procedures are as follows. To draw a round surface by using an isometric ellipse template, do the following:

1. Define on one of the orthographic views (the one that shows the round surface as part of a circle) the center point of the

- round surface and the intersections of the center lines with the surfaces of the object. In this example the center point is marked 0, and the two intersections are marked points 1 and 2.
2. Draw a rectangular box and transfer the points 1, 2, and 0 to the front plane of the isometric drawing and label them 3, 4, and 5.
 3. Project the points in the front plane across the isometric drawing to the back plane.
 4. Align the proper hole in the isometric ellipse template with the center lines on the front isometric surface, and draw in the isometric arc. Repeat the same procedure for the back surface.
 5. Erase all excess lines and smudges; check your work; draw in the remaining lines of the object lightly at first and then darken them to their proper color and pattern.

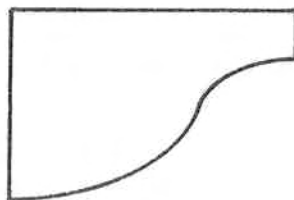
To draw a round surface by using the point method; do the following:

1. On one of the orthographic views (the one that shows the round surface as part of a circle) mark off a series of points along the rounded surface. The points need not be equidistant. The more points you take, the more accurate will be the final isometric ellipse. If necessary, make a full-sized supplementary layout.
2. Dimension each point horizontally and vertically as shown.
3. Transfer the dimensional values to the isometric axis as shown.
4. Using a French curve as a guide, draw in the isometric arc.
5. Transfer the points to the back of the surface, and, again using a French curve as a guide, draw in the isometric arc.
6. Erase all excess lines and smudges; check your work; draw in the remaining lines of the object lightly at first and then darken them to their final color and pattern.

Figure 15-21 is a sample problem that requires you to draw an isometric drawing from given orthographic views that contain an irregular surface. The point method described for drawing isometric drawings of round surfaces is directly applicable to the creation of isometric drawings of irregular surfaces provided that we use two of the orthographic views to locate the points. Two views are required because the surface may not be parallel to any of the principal planes. Figure 15-22 is the solution to Figure 15-21.

GIVEN: An object.

PROBLEM: Draw an isometric drawing of the object.



MATL $\frac{3}{4}$ C.R. STEEL

Figure 15-21

SOLUTION:

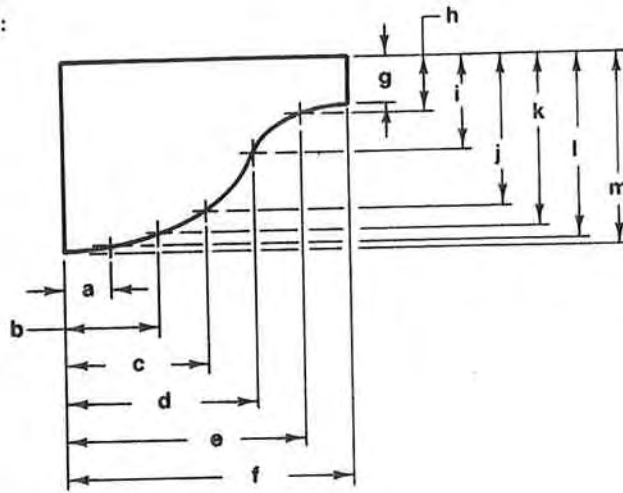


Figure 15-22(a)

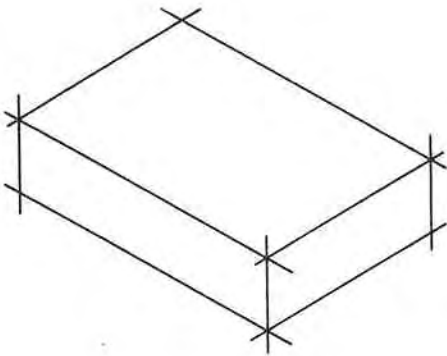


Figure 15-22(b)

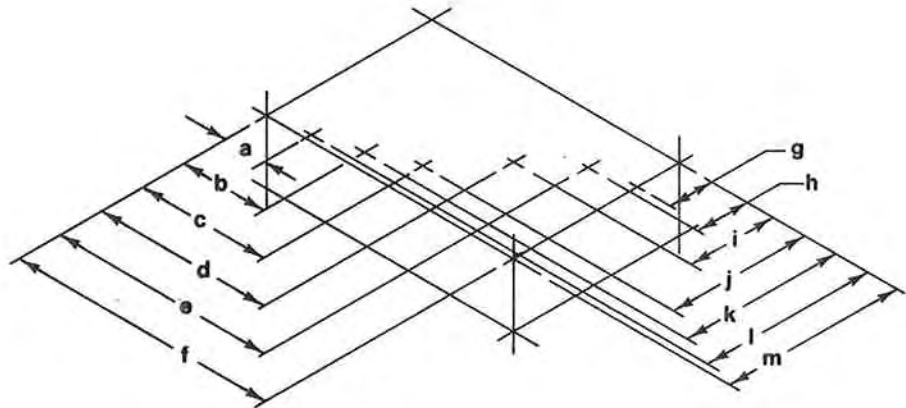


Figure 15-22(c)

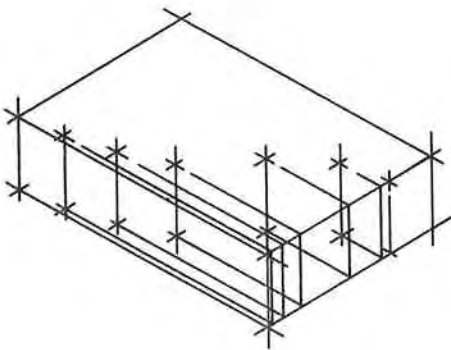


Figure 15-22(d)

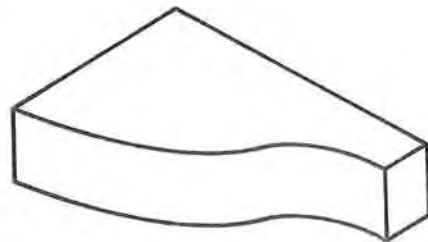


Figure 15-22(e)

15-6 ISOMETRIC DIMENSIONS

Isometric drawings may be dimensioned by using either the aligned system or the unidirectional system. All isometric drawings in this book are dimensioned by using the unidirectional system. Section 6-4 gives a further explanation of the differences between the two systems.

Regardless of the system used, the leader lines must be drawn in the same isometric plane as the surface they are defining. The guidelines for the dimensions in the aligned system are drawn parallel to the edge being defined while the guidelines for the unidirectional system are always horizontal. Figure 15-23 is another example of the unidirectional system. The numbers are drawn 1/8 to 3/16 in both systems.

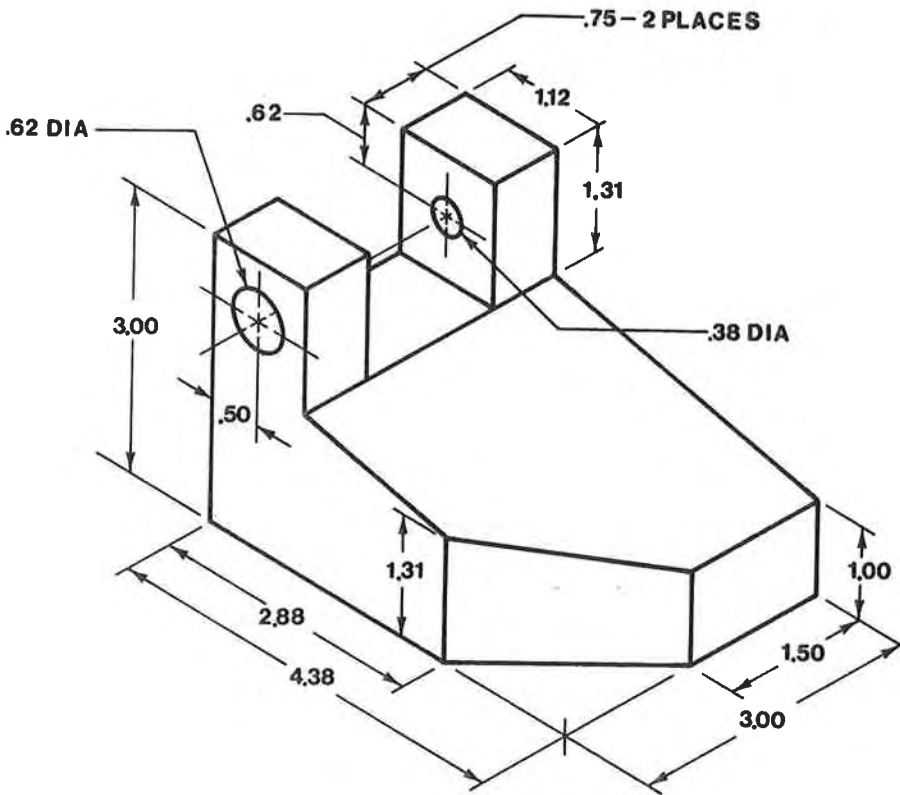


Figure 15-23 An example of an isometric drawing dimensioned using the unidirectional system.

15-7 ISOMETRIC SECTIONAL VIEWS

Isometric sectional views are used for the same reasons that orthographic sectional views are used—to clarify objects by exposing important internal surfaces that would otherwise be hidden from direct view. Figure 15-24 shows a full isometric sectional view and a half isometric sectional view. Note that, as with orthographic sectional views, hidden lines are omitted and the cross-hatching lines are drawn medium to

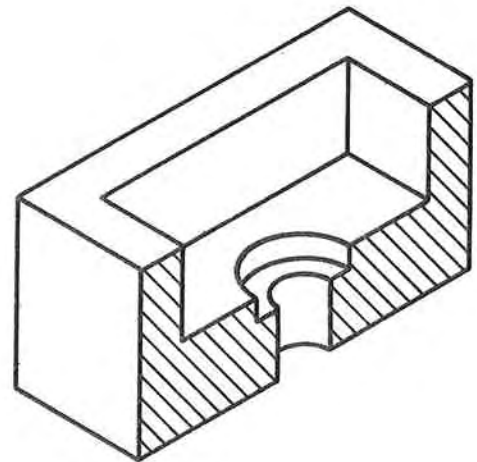


Figure 15-24 Isometric section cut.

light in color, $3/32$ apart at an inclined angle. Isometric sectional views do not require a defining cutting plane and are usually presented as individual pictures with no accompanying reference drawing. Dimensions are placed on an isometric sectional view in the same way they are for regular isometric drawings.

15-8 AXONOMETRIC DRAWINGS

Isometric drawings are actually just one of a broad category of drawings called *axonometric drawings*. An axonometric drawing is a pictorial drawing, drawn with instruments, that uses some initially defined axis system which remains parallel to infinity.

There are three kinds of axonometric drawings: isometric, dimetric, and trimetric. The classification of an axonometric drawing depends on its axis system. An isometric axis has three equal angles (120°), a dimetric axis has two equal angles, and a trimetric axis has no equal angles. Figure 15-25 shows examples of the three axonometric axes. The oblique drawing, which is covered in the next chapter, is a special form of trimetric drawing.

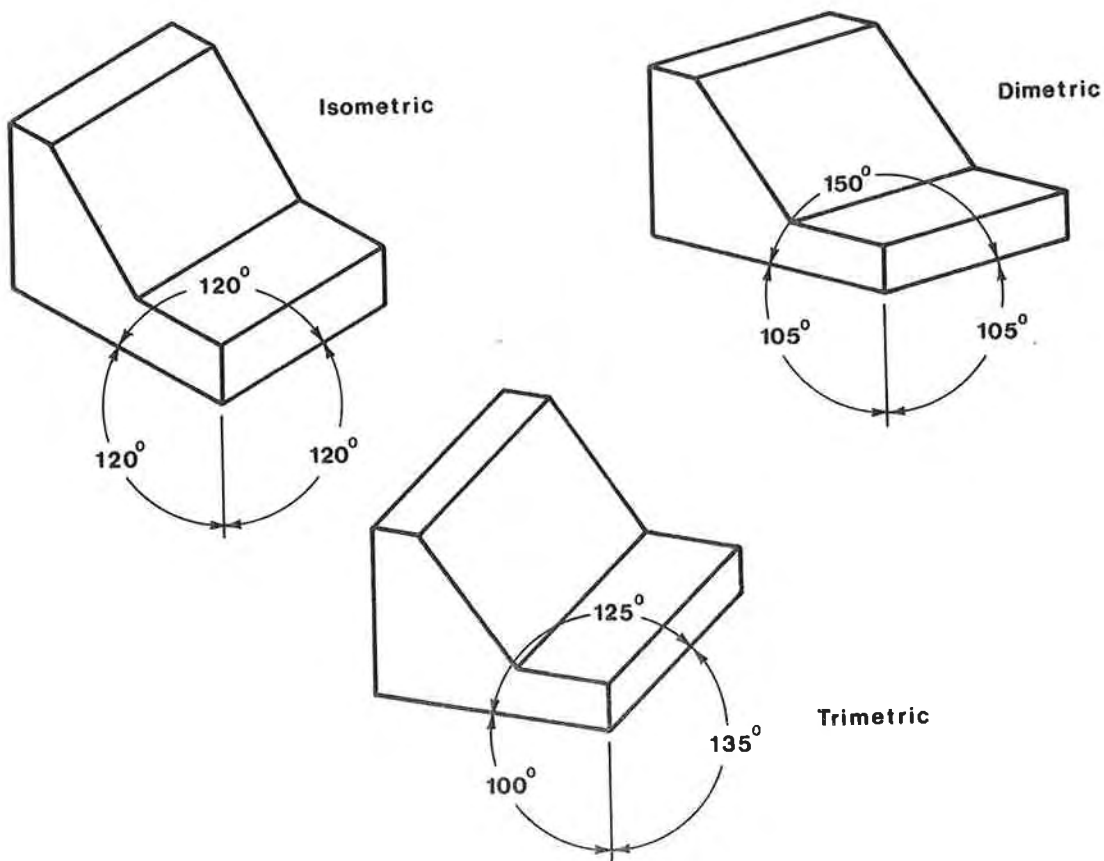


Figure 15-25 Examples of the three different types of axonometric drawings: isometric, dimetric, and trimetric.

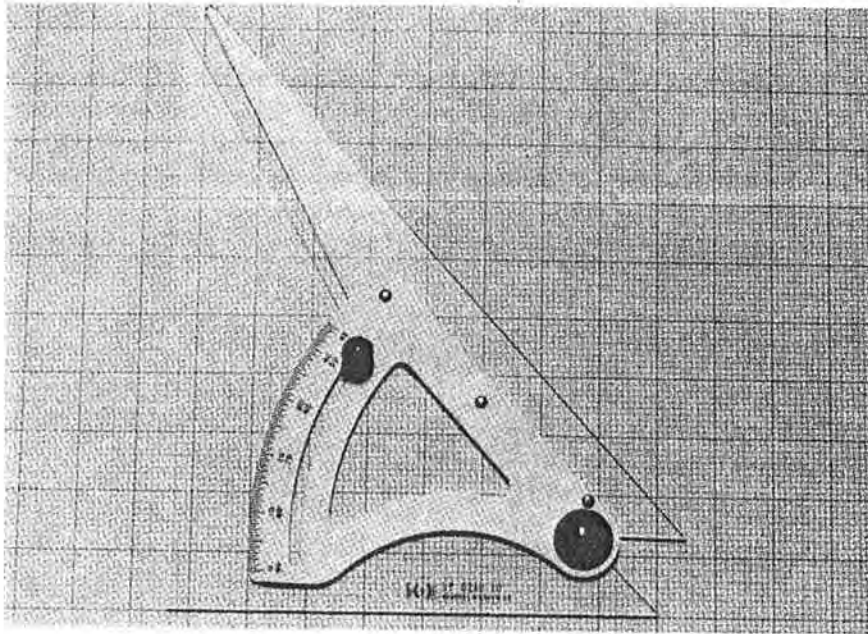


Figure 15-26 An adjustable triangle.

An adjustable triangle, such as the one shown in Figure 15-26, is useful when you are creating axonometric drawings because it may be set to any angle, thereby eliminating the need for constant measuring with a protractor.

15-9 EXPLODED DRAWINGS

Figure 15-27 is an example of an exploded drawing. Exploded drawings are useful because they enable the reader to visualize and understand technical information without requiring him (or her) to have a knowledge of orthographic projections. They are particularly well-suited to assembly drawings because they easily show the relationship between the various parts.

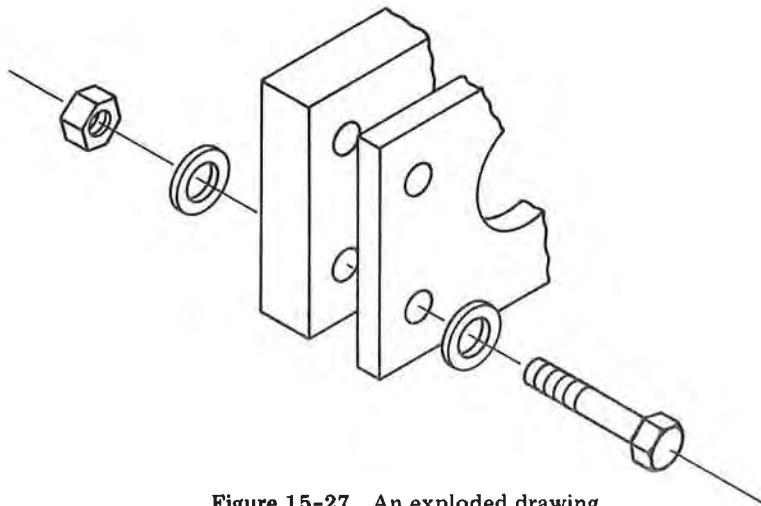


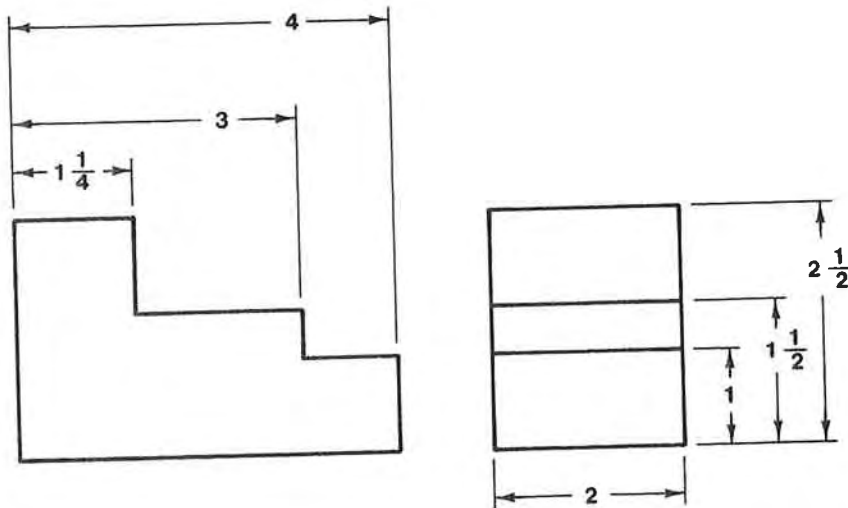
Figure 15-27 An exploded drawing.

Exploded drawings may be drawn by using any one of the axonometric axis systems provided that the system chosen helps present the information clearly. Exploded drawings rarely contain dimensions or hidden lines because they are usually intended more to be pictures of technical information than actual technical drawings. Parts in an exploded drawing are always labeled either by name or by part number.

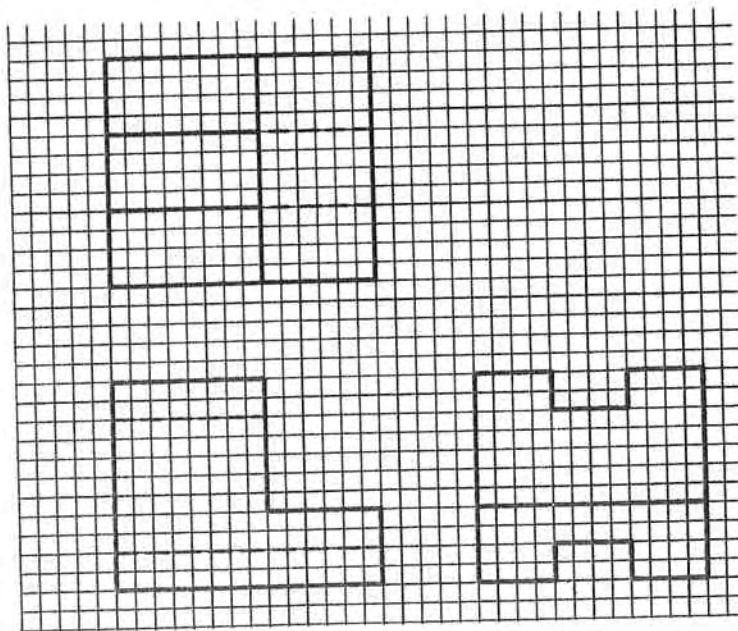
PROBLEMS

Create isometric drawings of the following objects. Dimetric and trimetric drawings may also be created if assigned by your instructor.

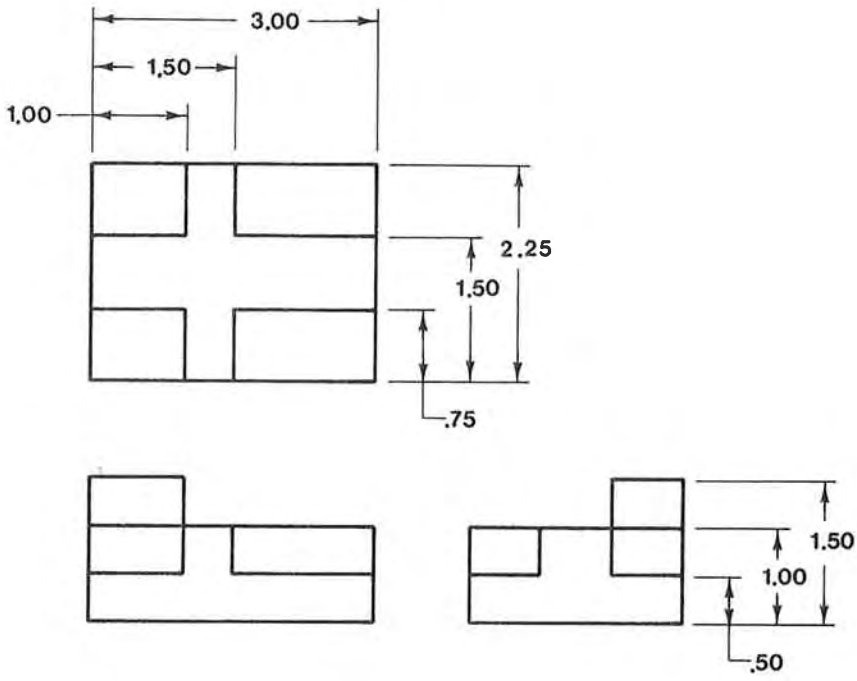
15-1



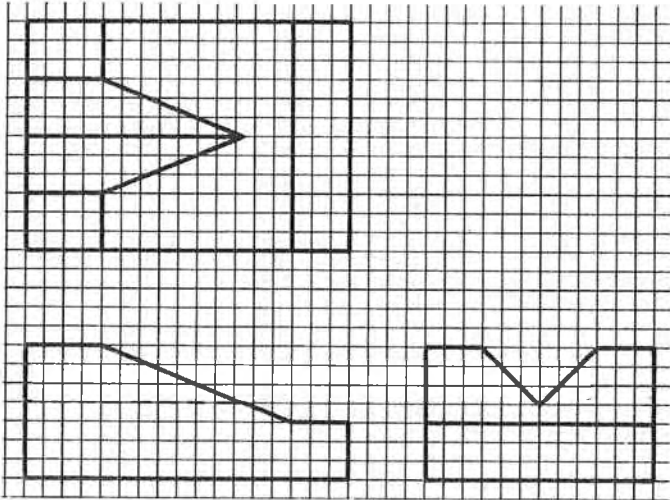
15-2



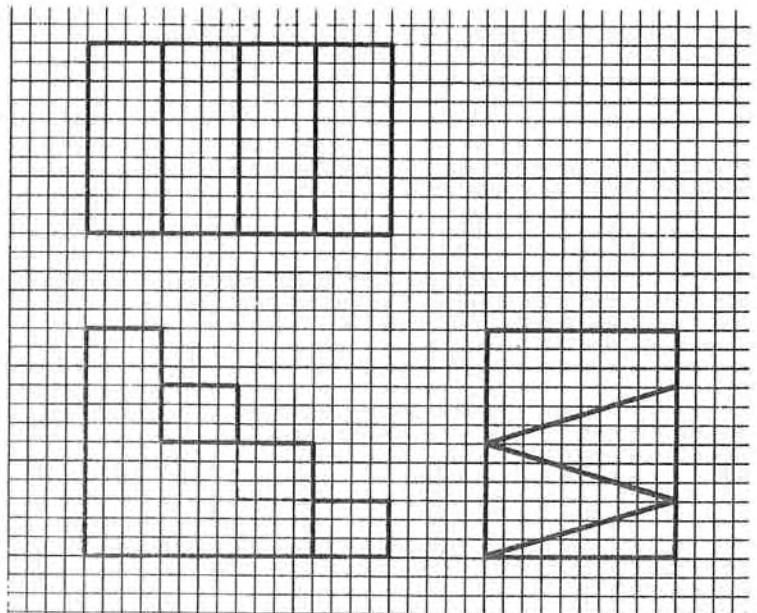
15-3



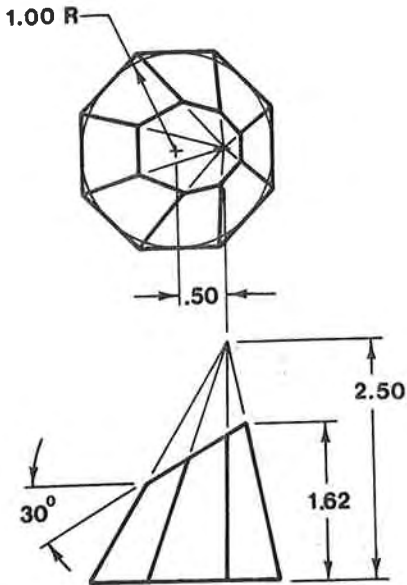
15-4



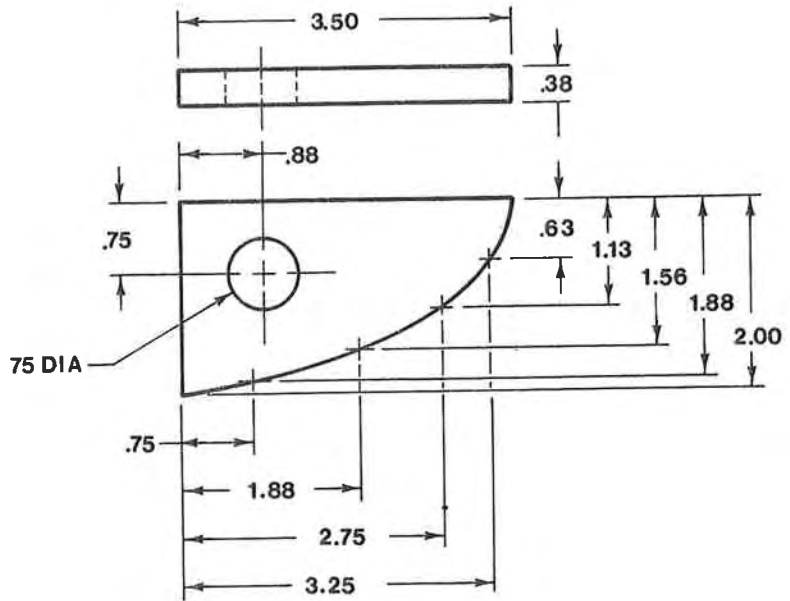
15-5



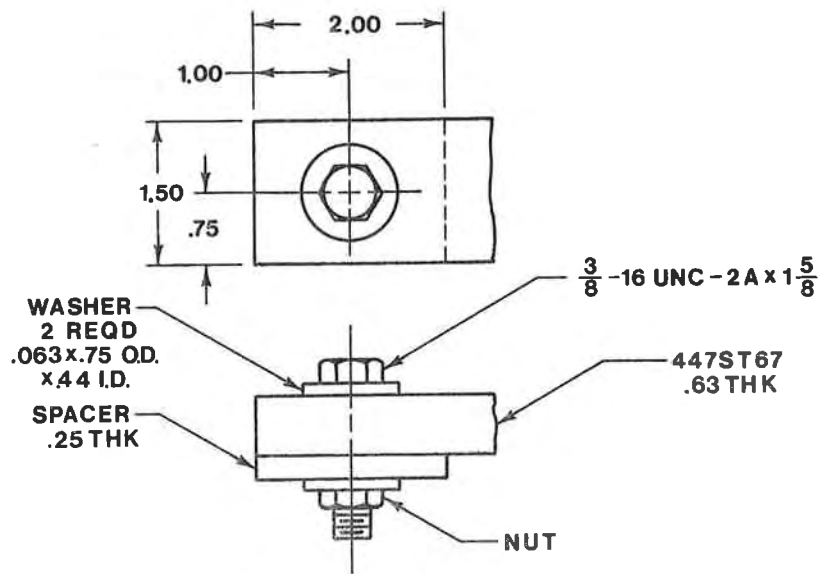
15-14



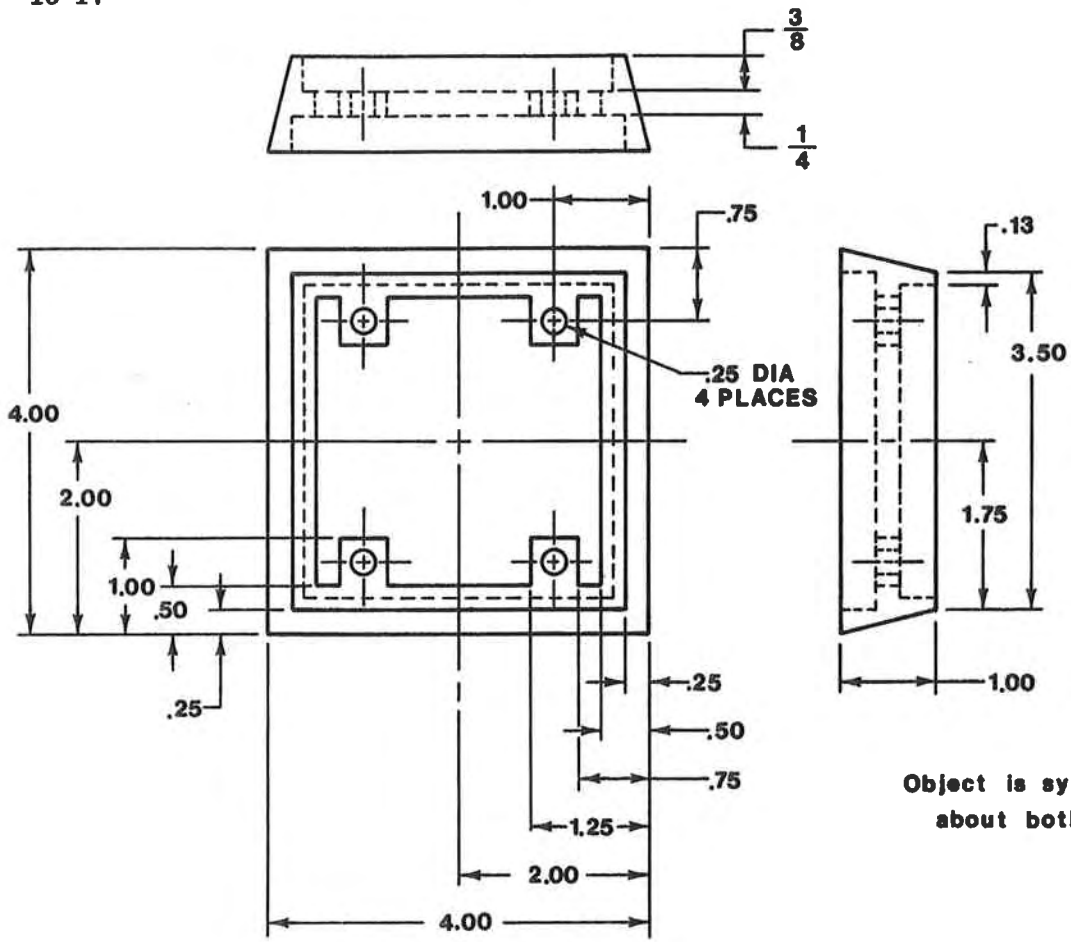
15-15



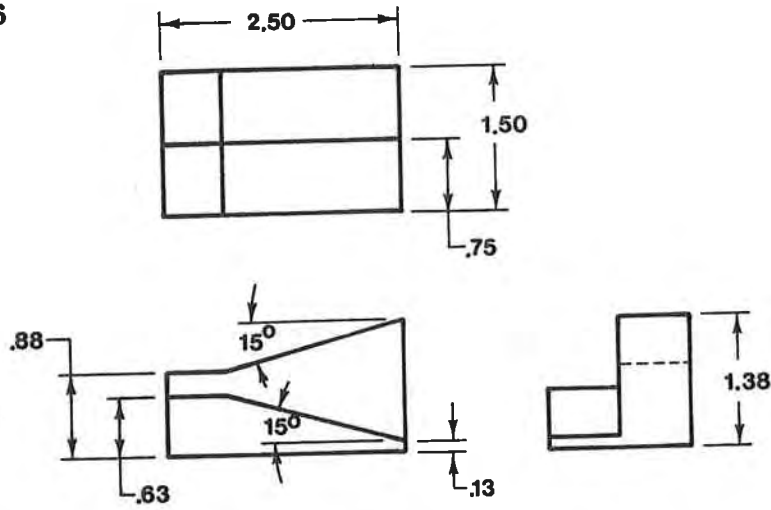
15-16 Draw an exploded isometric drawing of the following assembly. The washers are 1.00 O.D., 0.50 I.D., and 0.06 thick. Figure P15-16(a) illustrates how to draw an isometric representation of a bolt.



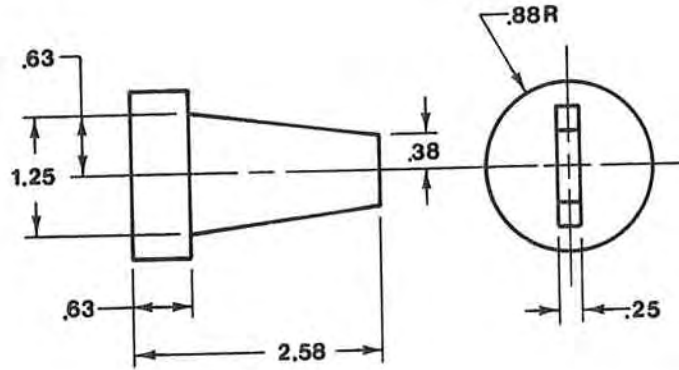
15-17



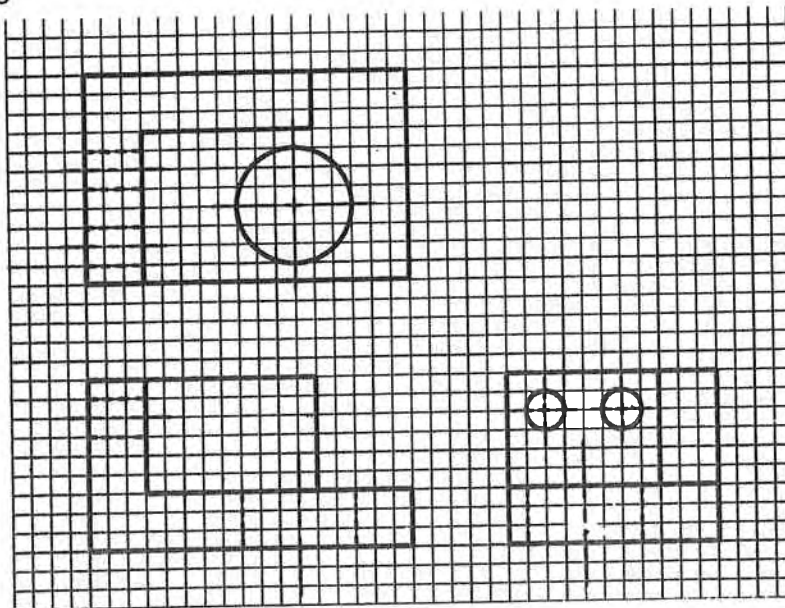
15-6



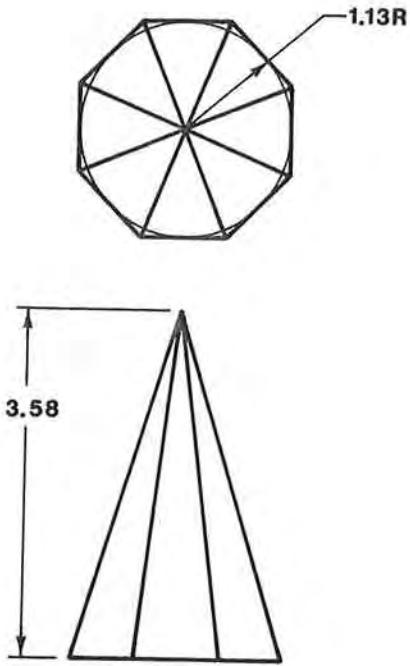
15-7



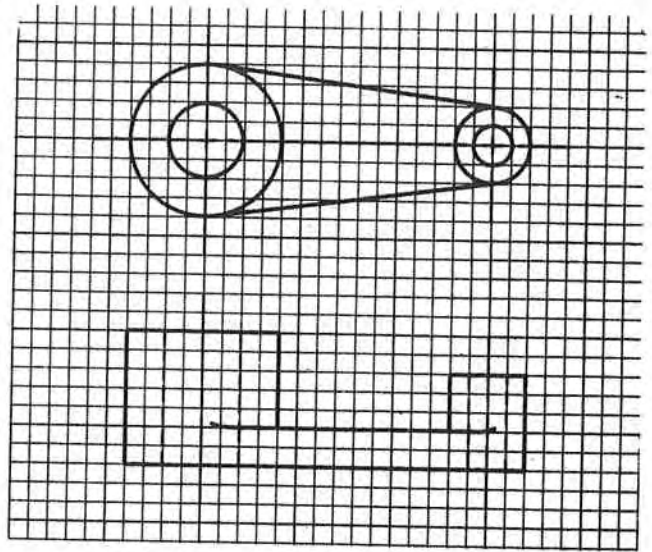
15-8



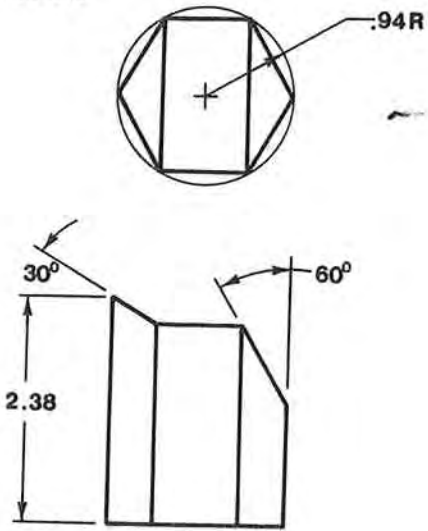
15-9



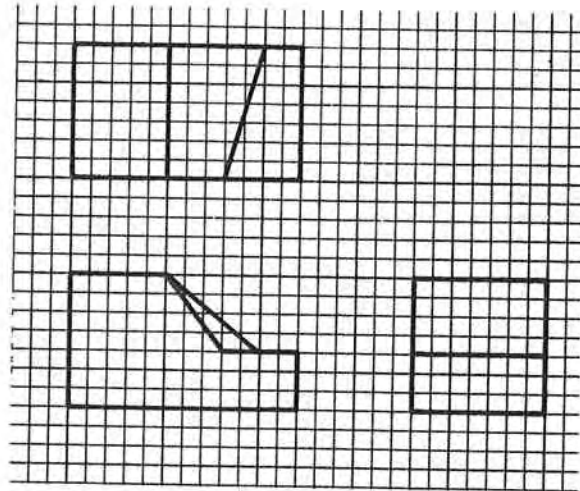
15-10



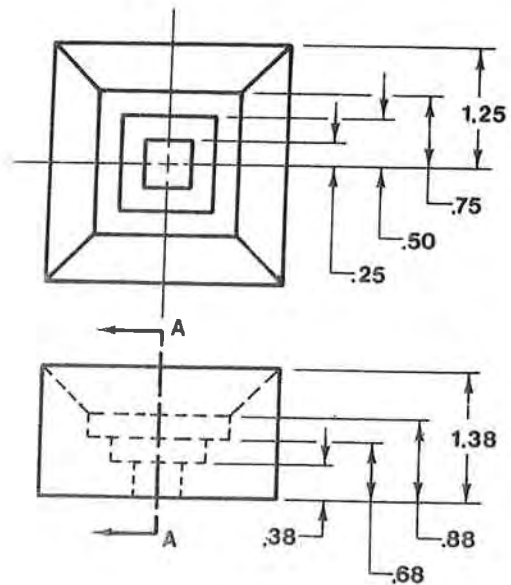
15-11



15-12



15-13



Object is symmetrical
about both
centerlines

OBLIQUE DRAWINGS 16

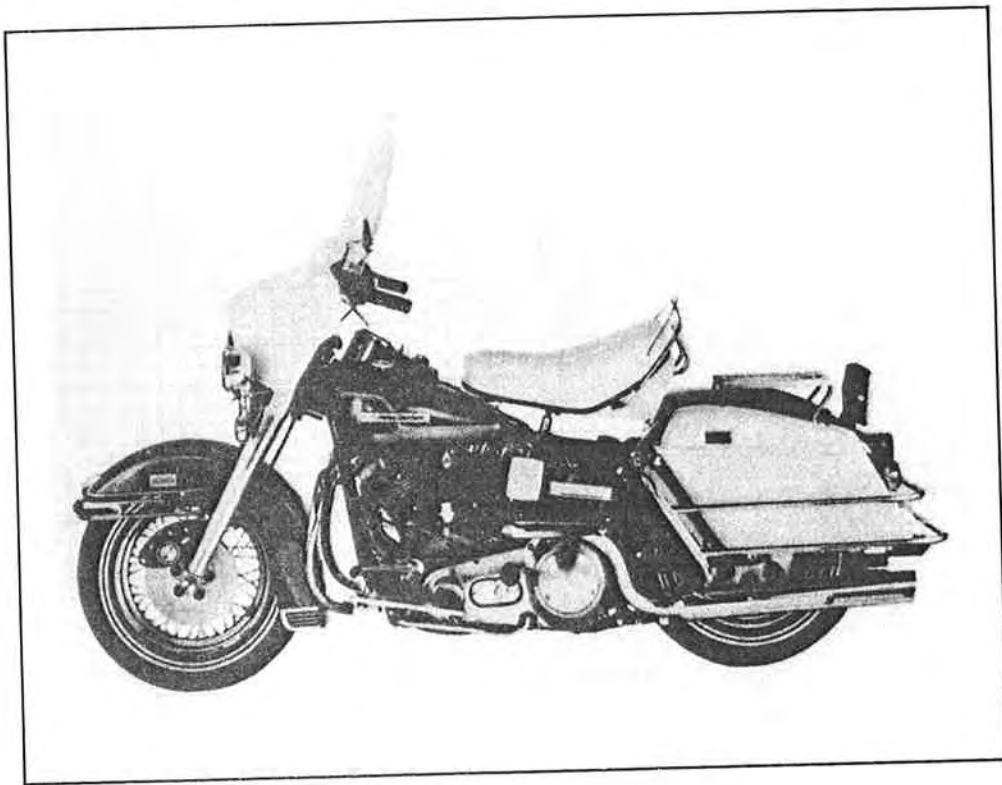


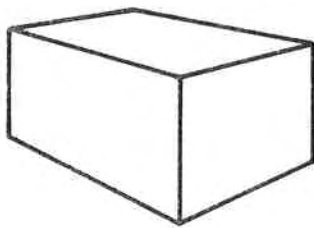
Figure 16-0 Photograph courtesy of AMF/Harley-Davidson.

16-1 INTRODUCTION

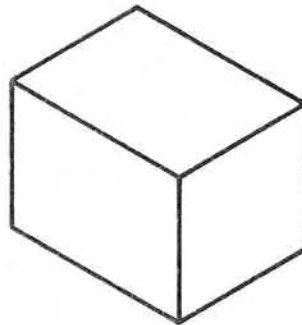
Oblique drawings are technical pictures that can be drawn with instruments. They are easier to draw than isometric drawings, but they contain more inherent visual distortion. Figure 16-1 compares oblique, isometric, and pictorial drawings of the same object and illustrates the visual difference among the three drawings.

The basic reference system for oblique drawings is shown in Figure 16-2. The most distinct characteristic of the oblique axis is the 90° relationship between the left-hand axis and the vertical axis. Because of this 90° relationship, the front view and all surfaces parallel to it are almost identical to the front view of an orthographic drawing. This makes it very easy to transfer information between the two different front views.

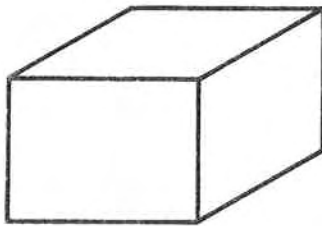
Figure 16-1 A comparison between an isometric, a pictorial, and an oblique drawing. Note the amount of visual distortion in each.



Pictorial



Isometric



Oblique

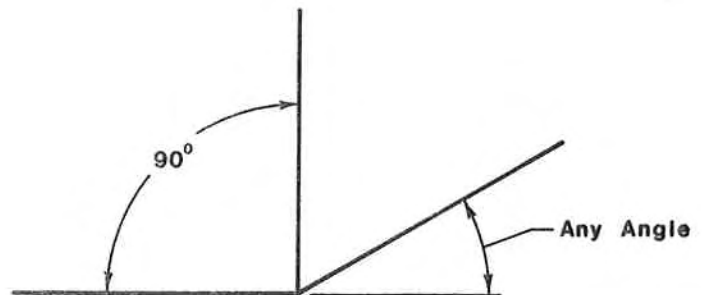


Figure 16-2

The receding lines may be drawn at any convenient angle. (Upward and to the right at either 30° or 45° is most commonly used because these angles may be drawn with standard triangles.) The choice of which receding angle to use depends on which angle best shows the object involved.

Dimensional values are directly transferable from the front view of the orthographic drawing to the front view of the oblique drawing. Circles transfer as circles, not as ellipses as in isometric drawings, and angles transfer as the same angles. Dimensional values in all other views are *not* directly transferable. They can only be transferred from the orthographic views to the receding axis of the oblique drawing.

Sometimes when dimensional values are transferred to the receding axis of the oblique drawing, they are redrawn at a reduced scale. The scale reduction improves the visual quality of the drawing. Note that in Figure 16-3 the reduced scale of the receding axis changes the way the object looks. Although any scale reduction may be used, the most common is the half-scale reduction called a *cabinet projection*. If the dimensional values are transferred full scale, the resulting oblique drawing is called a *cavalier projection*.

Oblique drawings do not normally include hidden lines, although they may be used if special emphasis is required.

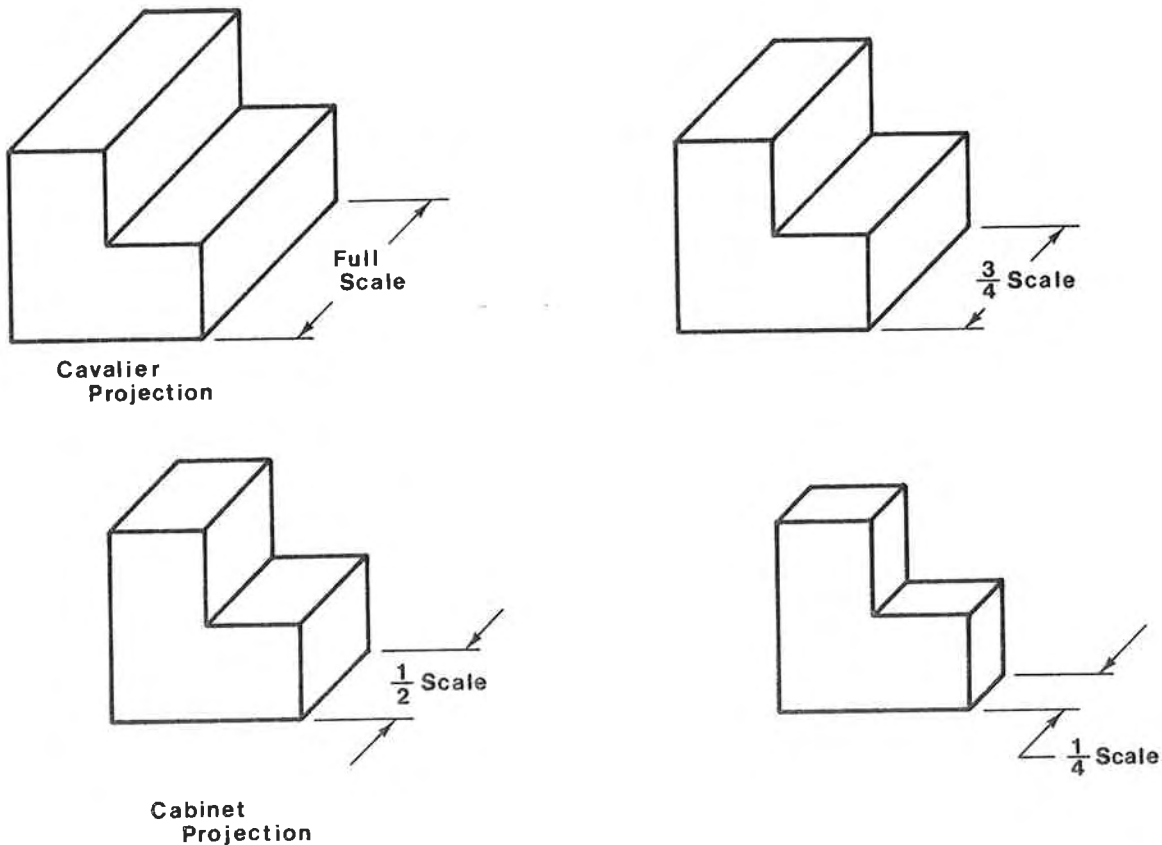


Figure 16-3 A comparison between different scaled receding lines on oblique drawings. Note the difference in visual distortion in each.

16-2 NORMAL SURFACES

Figure 16-4 is a sample problem that involves creating an oblique drawing from given orthographic views. Since all surfaces in the problem are normal (at 90° to each other), all dimensional values may be directly transferred from the orthographic views to the axis of the oblique drawing. All values are to be transferred at full value, which means that

GIVEN: Front, top, and side views.
PROBLEM: Draw an oblique drawing.

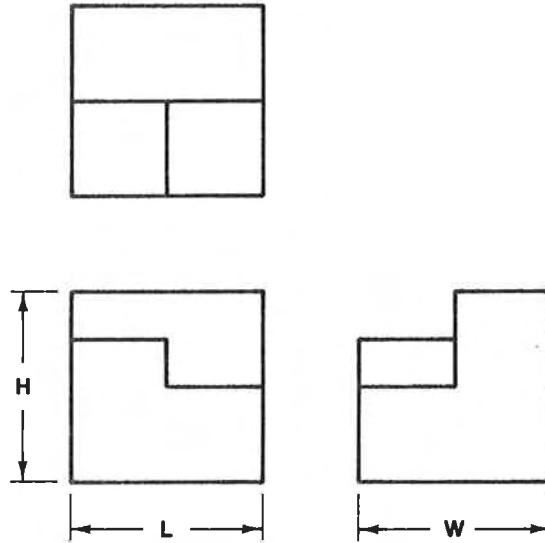


Figure 16-4

the resulting oblique drawing is a cavalier projection. Figure 16-5 is the solution to Figure 16-4 and was derived by using the following procedure:

SOLUTION:

1. Make, to the best of your ability, an oblique freehand sketch of the proposed solution.

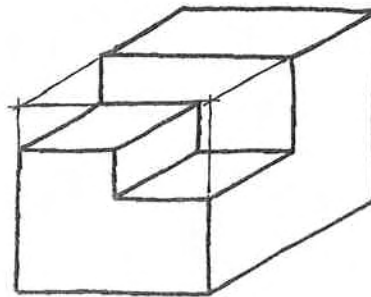


Figure 16-5(a)

- Using very light lines, lay out a rectangular box whose height, width, and length correspond to the height, width, and length given in the orthographic views. In this case, a receding axis of 30° was chosen.

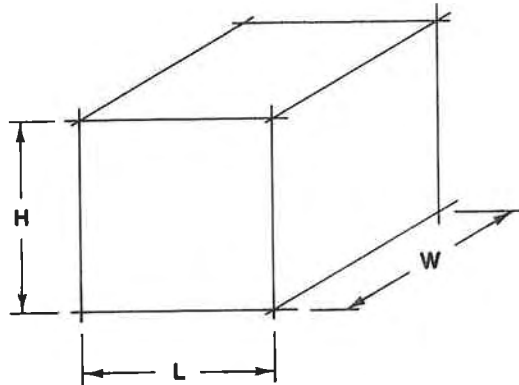


Figure 16-5(b)

- Using very light lines, lay out the specific details of the object. Transfer the dimensional values directly from the orthographic views to the axis of the oblique drawing. For example, use a pair of dividers and verify all other dimensional values.

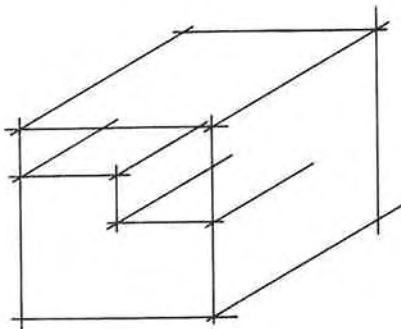


Figure 16-5(c)

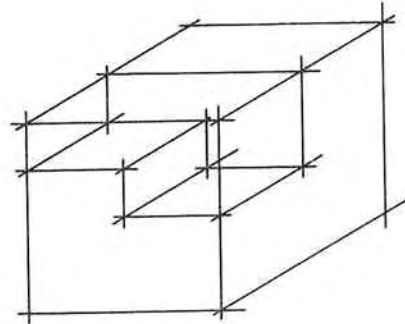


Figure 16-5(d)

- Erase all excess lines and smudges; check your work; and draw in all lines to their final color and configuration.

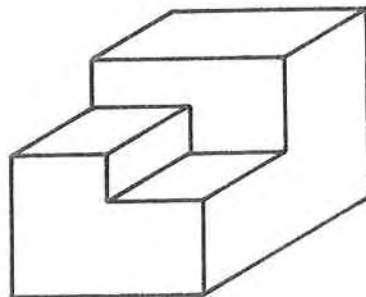


Figure 16-5(e)

Figures 16-6, 16-7, and 16-8 are further examples of oblique drawings created from given orthographic views.

GIVEN: Front, top, and side views.
PROBLEM: Draw an oblique drawing.

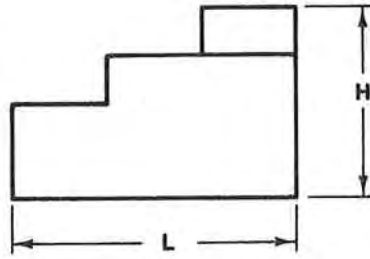
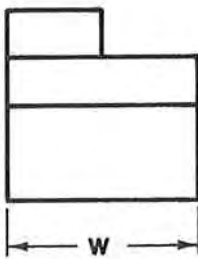
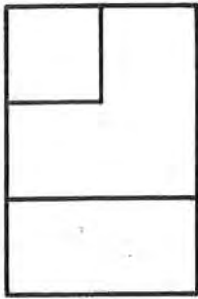


Figure 16-6(a)

SOLUTION:

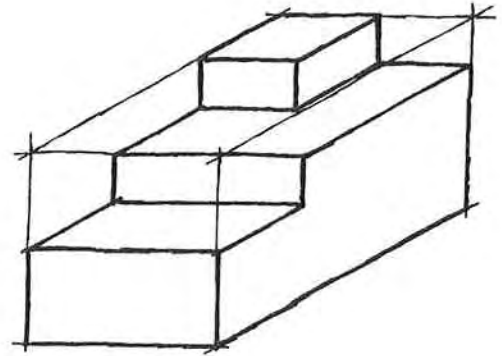


Figure 16-6(b)

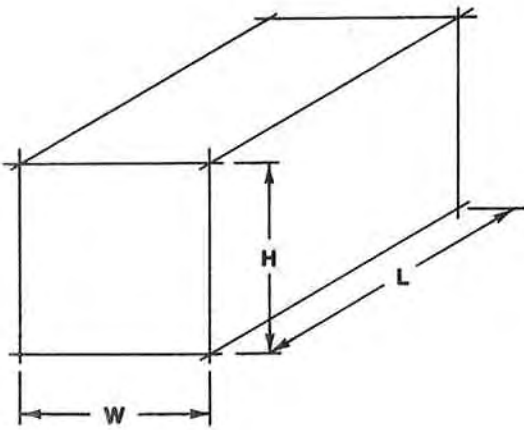


Figure 16-6(c)

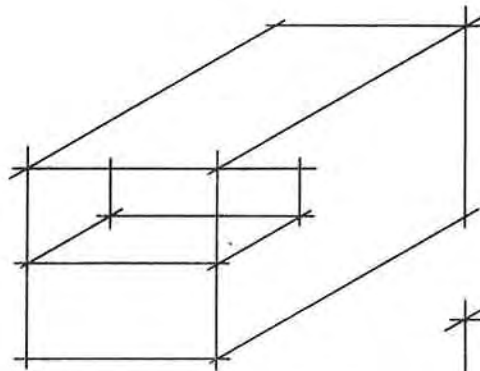


Figure 16-6(d)

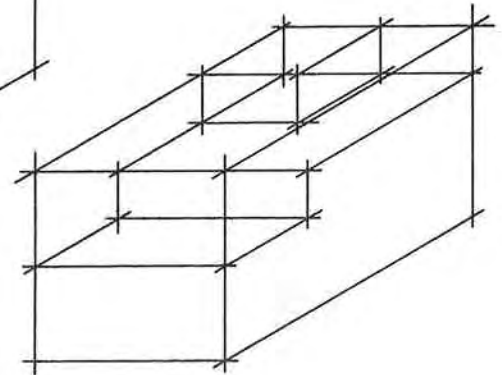


Figure 16-6(f)

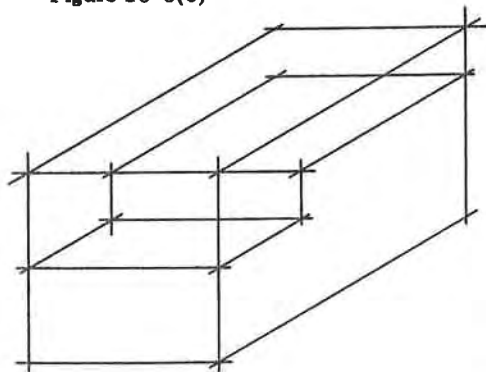


Figure 16-6(e)

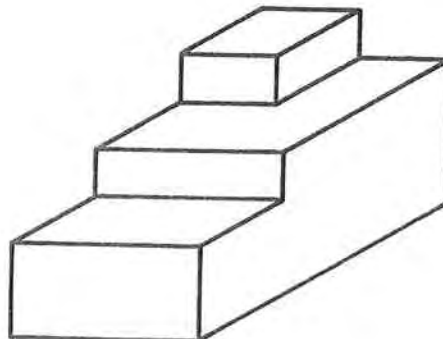
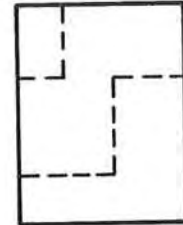
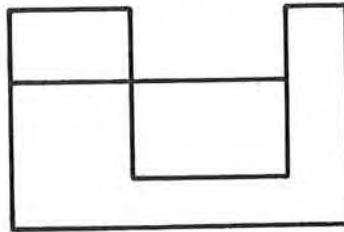
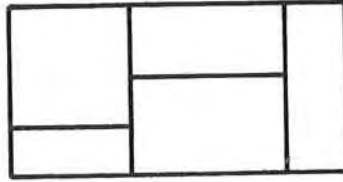


Figure 16-6(g)

GIVEN: Front, top and side views.
PROBLEM: Draw a cabinet oblique drawing.



SOLUTION:

Figure 16-7(a)

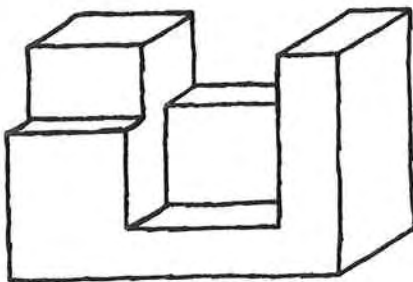


Figure 16-7(b)

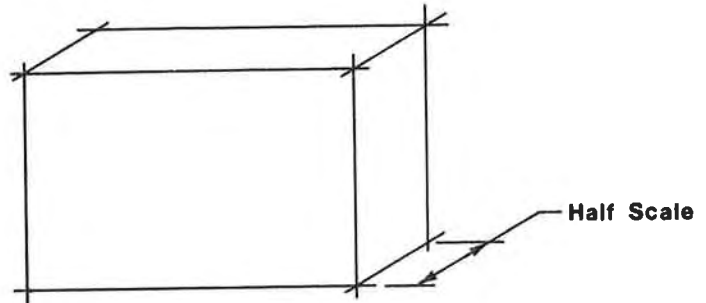


Figure 16-7(c)

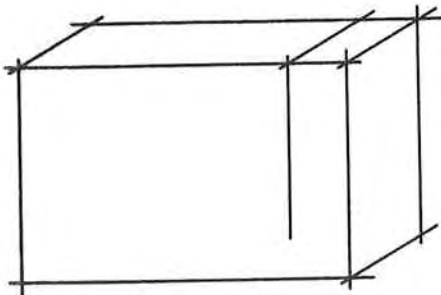


Figure 16-7(d)

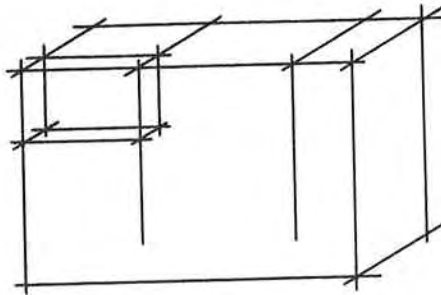


Figure 16-7(e)

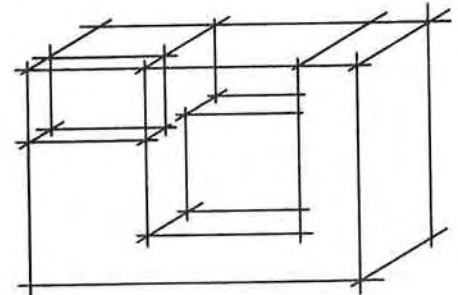
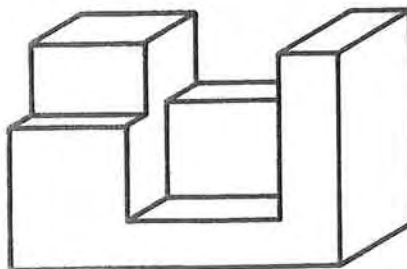


Figure 16-7(f)

Cabinet Projection

Figure 16-7(g)



GIVEN: Front, top, and side views.

PROBLEM: Draw an oblique drawing with the receding axis slanted 45° to the left.

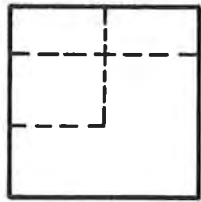
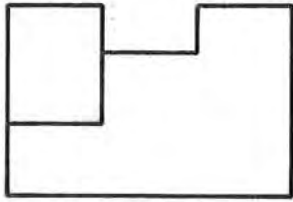
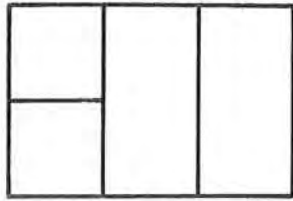


Figure 16-8(a)

SOLUTION:

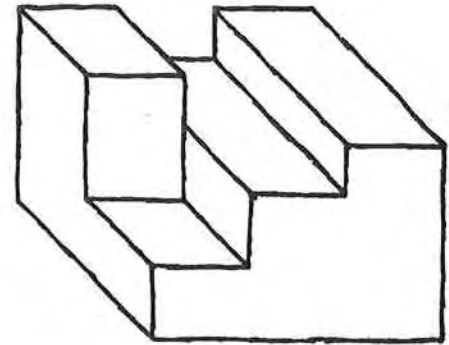


Figure 16-8(b)

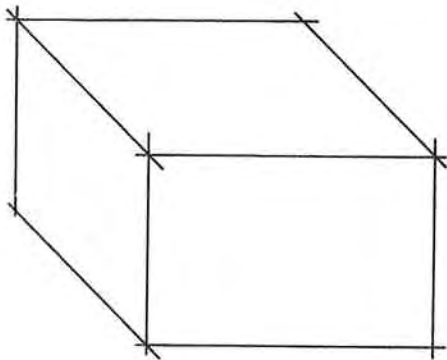


Figure 16-8(c)

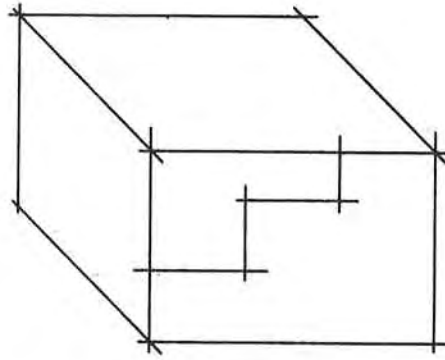


Figure 16-8(d)

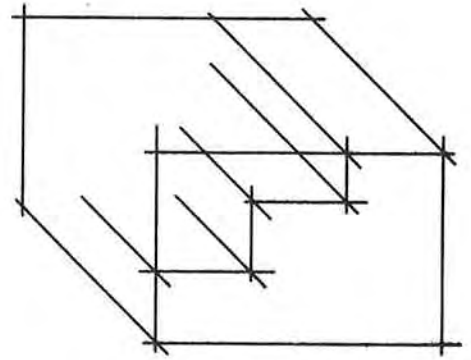


Figure 16-8(e)

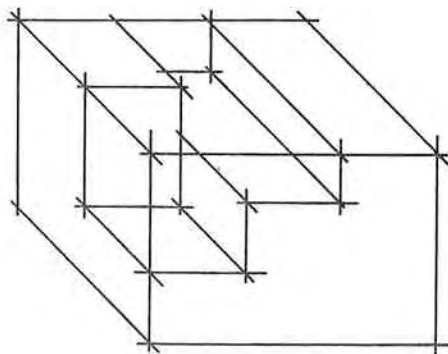


Figure 16-8(f)

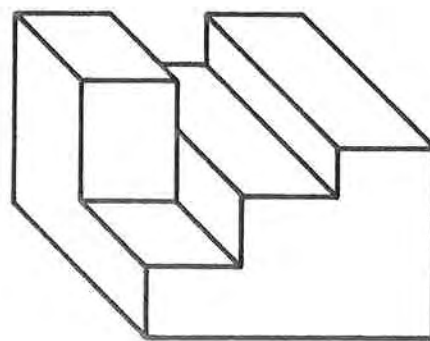


Figure 16-8(g)

16-3 INCLINED AND OBLIQUE SURFACES

Figure 16-9 is a sample problem that involves creating an oblique drawing from given orthographic views that contain an inclined surface. Unlike isometric drawings, angular dimensions may be directly transferred from the front orthographic view to the front oblique view, thereby eliminating the need for supplementary layouts. Remember that this direct transfer *only* works on the front views and on surfaces parallel to the front view.

GIVEN: Front, top, and side views.

PROBLEM: Draw a cabinet oblique drawing.

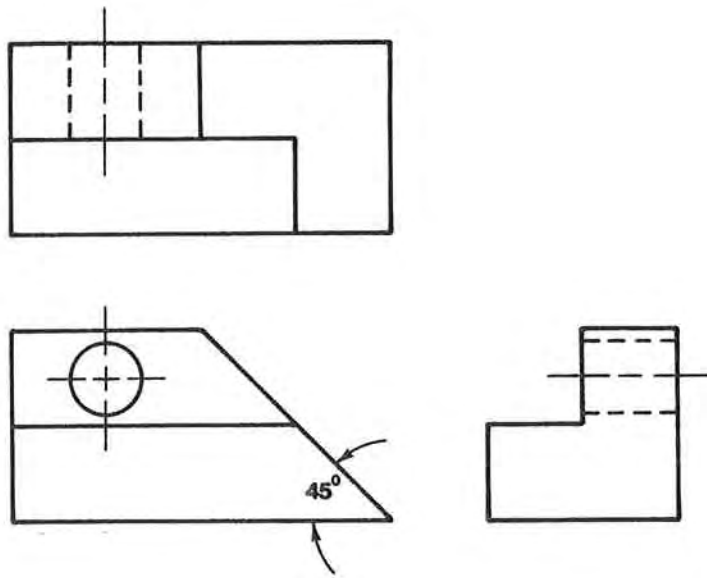


Figure 16-9

SOLUTION:

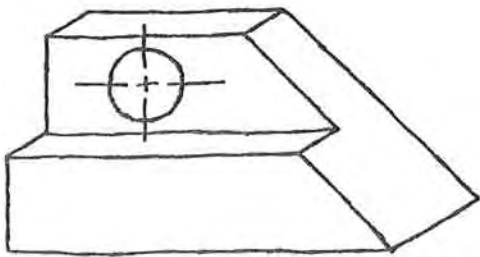


Figure 16-10(a)

Figure 16-10 is the solution to Figure 16-9 and was derived by using the same procedure presented for normal surfaces in Section 16-2.

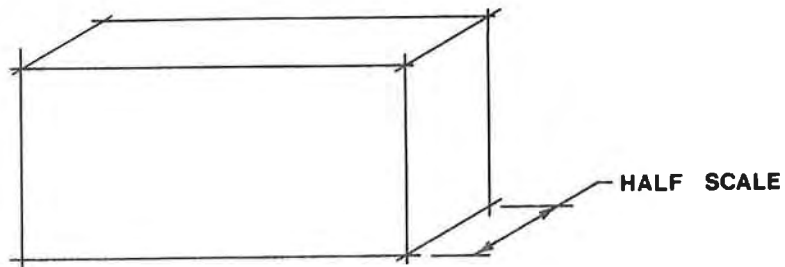


Figure 16-10(b)

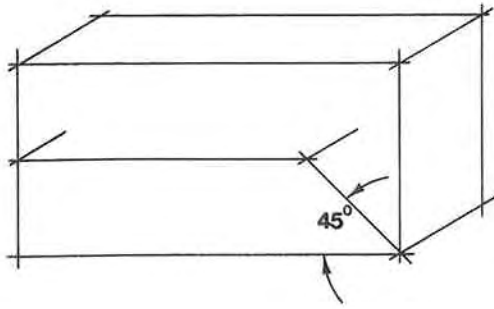


Figure 16-10(c)

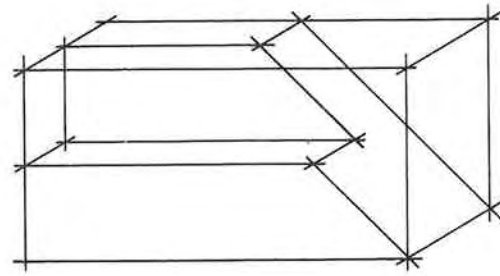


Figure 16-10(d)

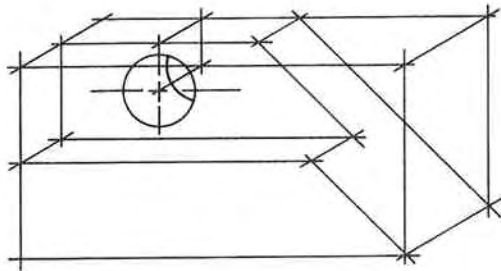


Figure 16-10(e)

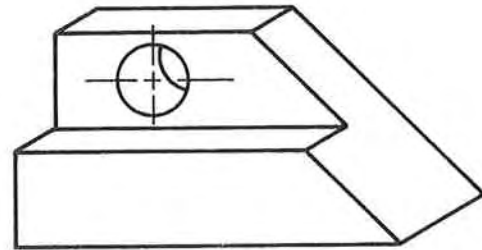


Figure 16-10(f)

Figure 16-11 is a sample problem that involves an object that includes an oblique surface. The angle must be broken down into its linear components, and then the linear components may be transferred to the axis of the oblique drawing. Figure 16-12 is the solution to Figure 16-11 and was derived by using the same procedure outlined for Figure 16-4 in Section 16-2.

GIVEN: Front, top, and side views.
 PROBLEM: Draw an oblique drawing.

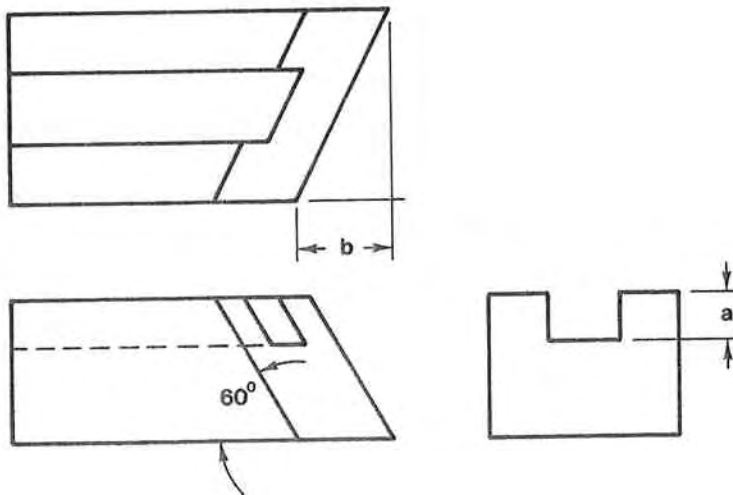


Figure 16-11

SOLUTION:

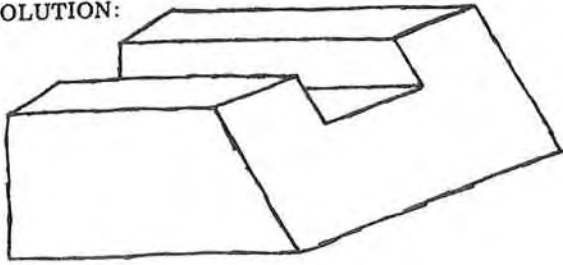


Figure 16-12(a)

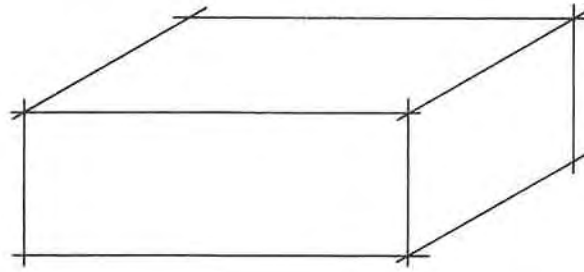


Figure 16-12(b)

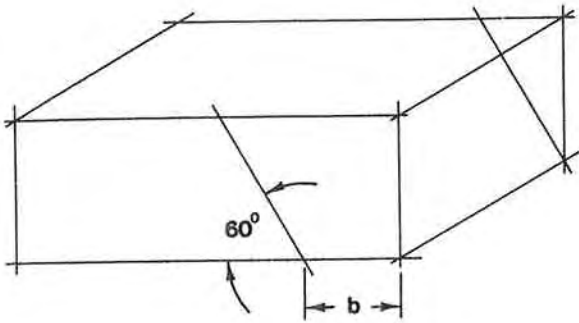


Figure 16-12(c)

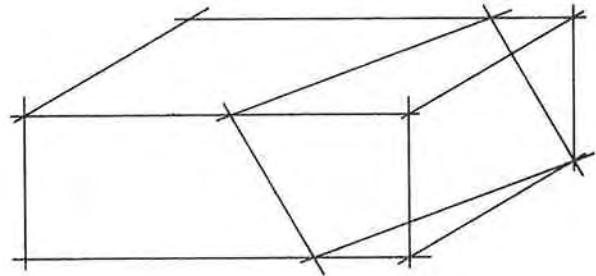


Figure 16-12(d)

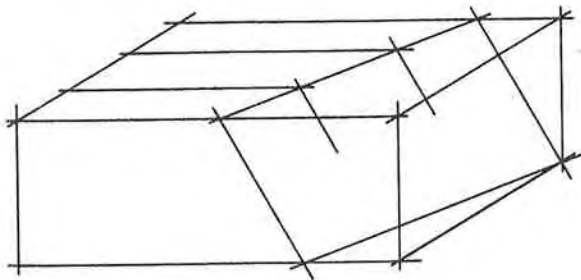


Figure 16-12(e)

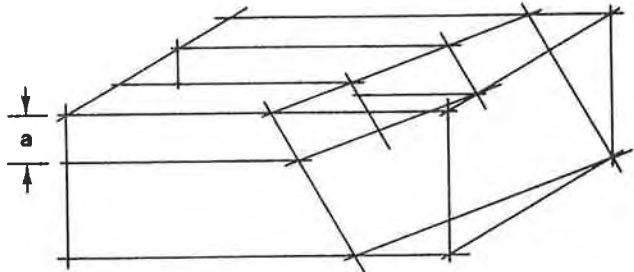


Figure 16-12(f)

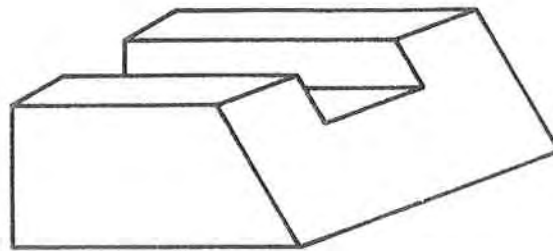


Figure 16-12(g)

16-4 HOLES IN OBLIQUE DRAWINGS

The techniques required to draw holes in oblique drawings vary according to the surface on which you are working. On the front surface and on all surfaces parallel to the front surface, holes are perfectly round and may be drawn with the aid of a compass or a circle template. On any other surface elliptical holes must be drawn. Elliptical holes may be drawn by using either the four-center ellipse method or by using an elliptical template as a guide. Remember that when you use an elliptical template, use only a template cut to the correct hole size, at the correct angle, which has been correctly aligned to the elliptical hole's center line.

When you are creating oblique drawings, take advantage, if possible, of the unique characteristics of the front view by positioning the object with as many holes as possible located in the front view. Figure 16-13 shows two oblique drawings of the same object and demonstrates the value of correct object positioning. In the drawing on the left the object is positioned so that all holes are located in the front view; in the drawing on the right the object is positioned so that the holes are located in one of the receding surfaces. This difference in positioning enables the left drawing to be drawn by using circles for holes; the right drawing requires elliptical holes. Because of the elliptical hole requirement, the drawing on the right takes about four times as long to draw as the drawing on the left. In addition, there is no appreciable gain in technical clarity. It is, however, important to remember that in positioning an object your first consideration should be technical clarity and ease of understanding for the reader and not ease of drawing for the draftsman.

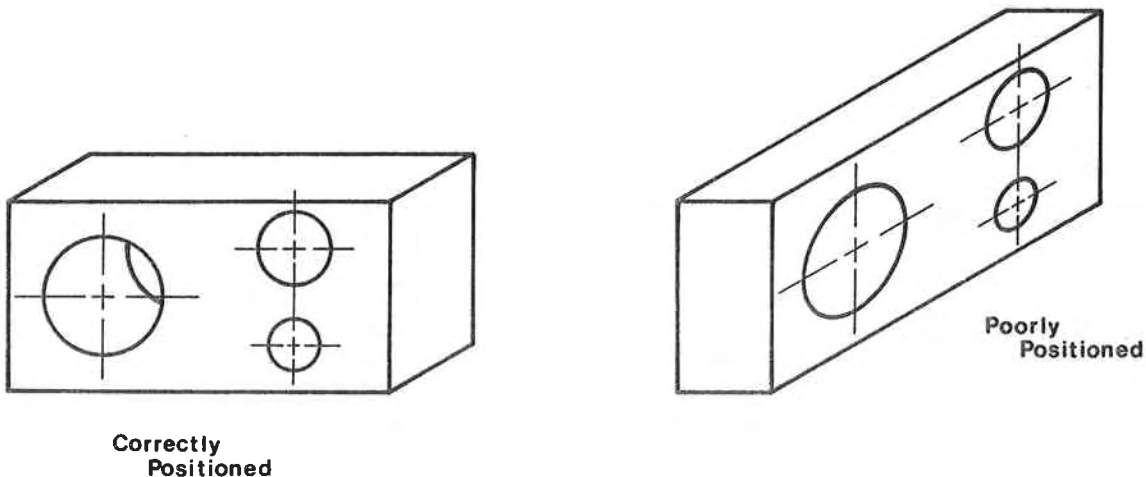


Figure 16-13 Two oblique drawings of the same object, one correctly positioned and one poorly positioned.

16-5 ROUNDED AND IRREGULAR SURFACES

Figure 16-14 is a sample problem that involves creating an oblique drawing from given orthographic views that contain a rounded surface.

GIVEN: Front and side views.

PROBLEM: Draw an oblique drawing.

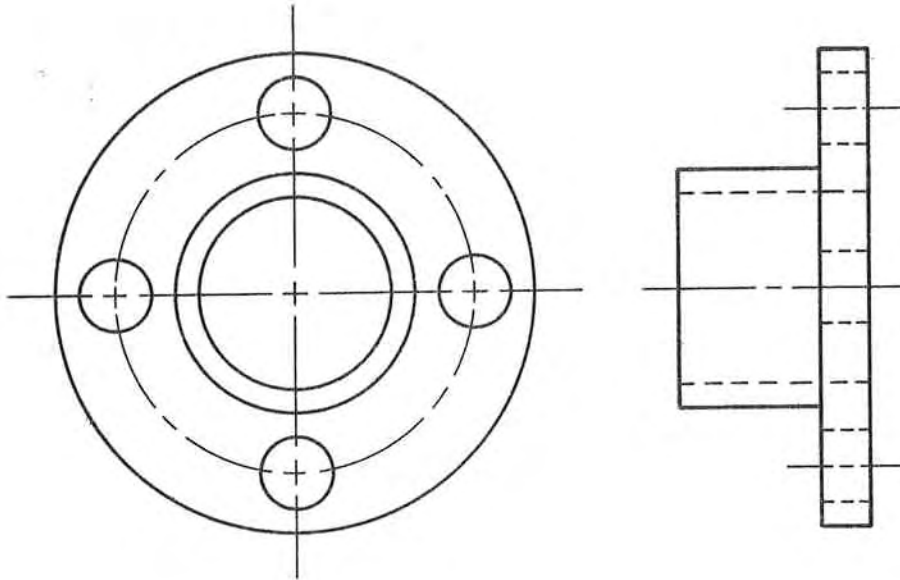


Figure 16-14

Figure 16-15 is the solution and was derived by using the following procedure:

SOLUTION:

1. Make, to the best of your ability, an oblique freehand sketch of the solution.

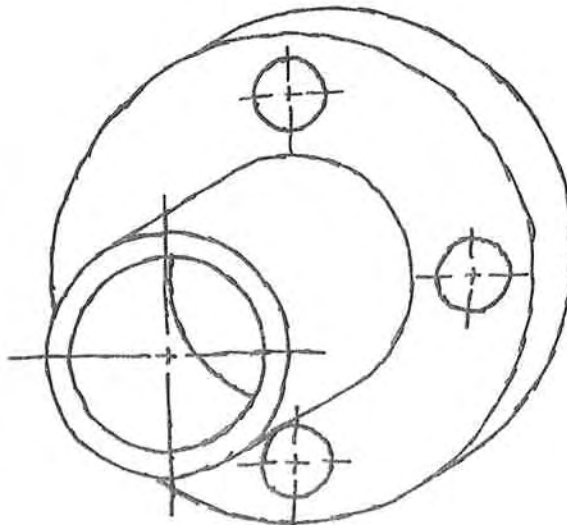


Figure 16-15(a)

- Using very light lines, lay out a rectangular box whose height, width, and length correspond to the height, width, and length given in the orthographic views. In this example a basic cylinder shape was substituted for the rectangular shape used.

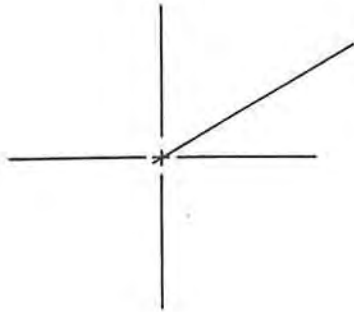


Figure 16-15(b)

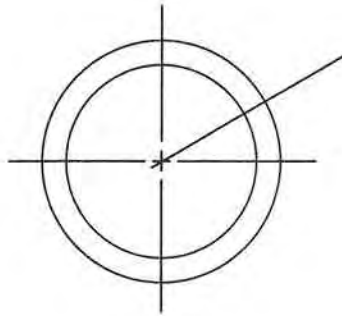


Figure 16-15(c)

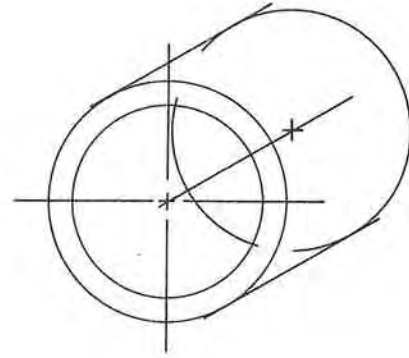


Figure 16-15(d)

- Using very light lines, lay out the specific details of the object. In this example the round portions of the object are all positioned so that they appear in the front view or in views parallel to the front view. This positioning makes the object easier to draw.

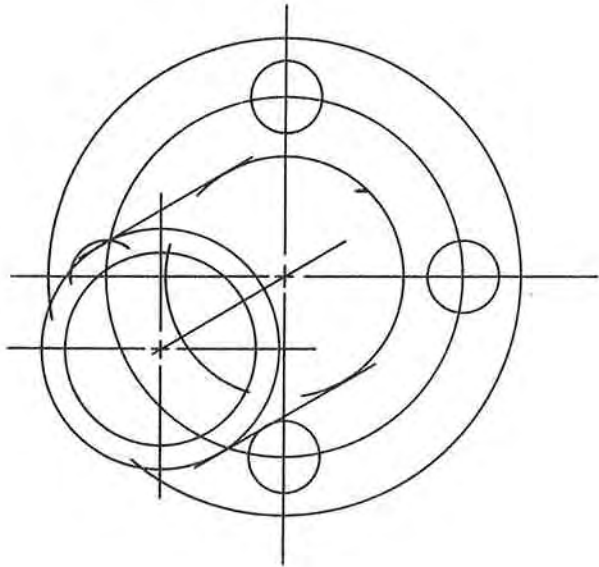


Figure 16-15(e)

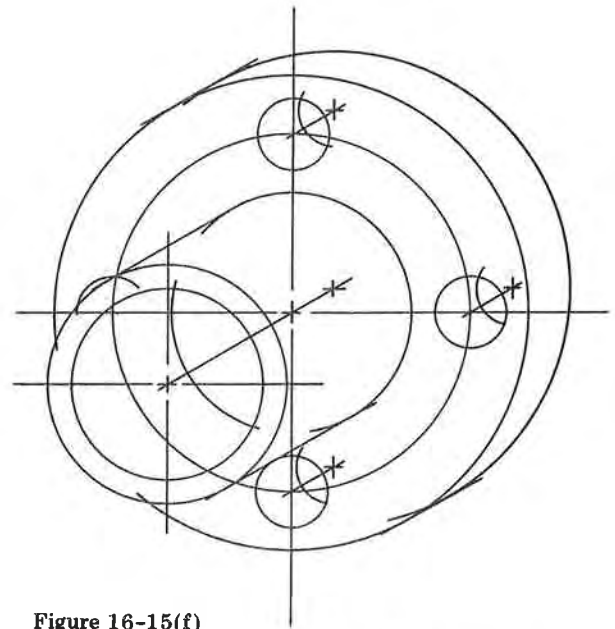


Figure 16-15(f)

- Erase all excess lines and smudges, and draw in all lines to their final color and configuration.

Figure 16-15(g)

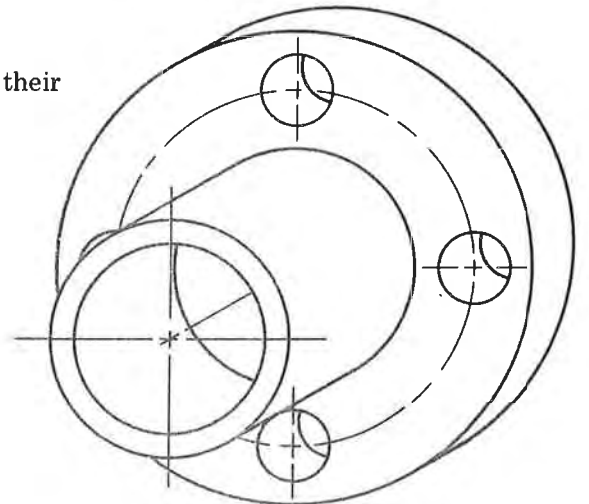
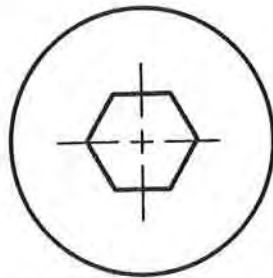


Figure 16-16 is another example of a rounded surface problem.

Figure 16-17 is a sample problem that involves creating an oblique drawing from given orthographic views that contain an irregular surface. Figure 16-18 is the solution and was derived by breaking down the irregular surface into its defining points, locating these points in terms of the oblique axis system, transferring the points to the oblique drawing, and then reconnecting the points to form the oblique drawing of the irregular surface. The remainder of the oblique drawing is created as previously described. Figure 16-19 is the supplementary layout that was used to locate the irregular surface in terms of the oblique axis system.

GIVEN: Front view and material thickness.
PROBLEM: Draw an oblique drawing.

SOLUTION:



MAT'L
2.00 AL 6064-T4

Figure 16-16(a)

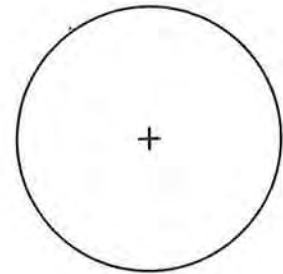


Figure 16-16(b)

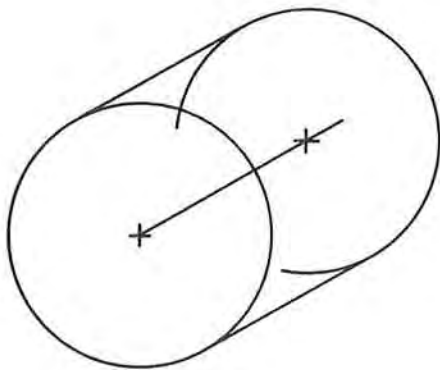


Figure 16-16(c)

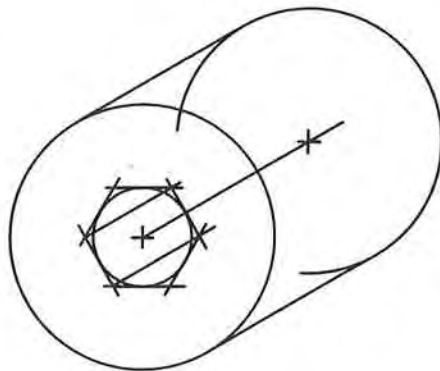


Figure 16-16(d)

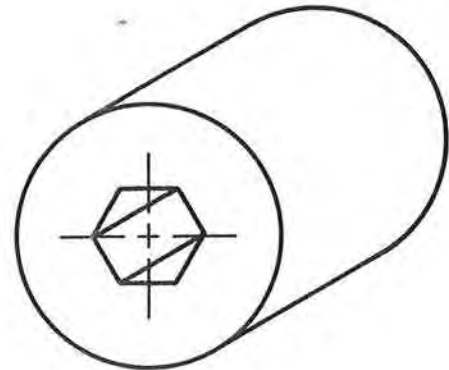
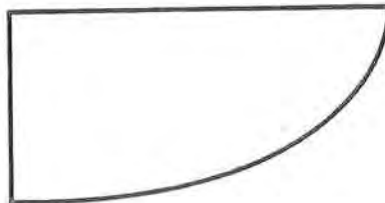


Figure 16-16(e)

GIVEN: Front view and material thickness.
PROBLEM: Draw an oblique drawing.



MAT'L
.75 THK

Figure 16-17

SOLUTION:

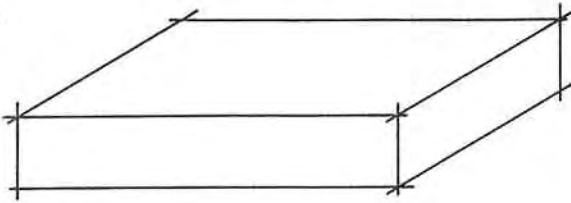


Figure 16-18(a)

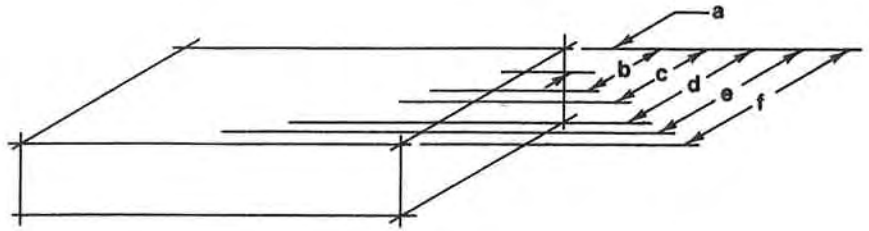


Figure 16-18(b)

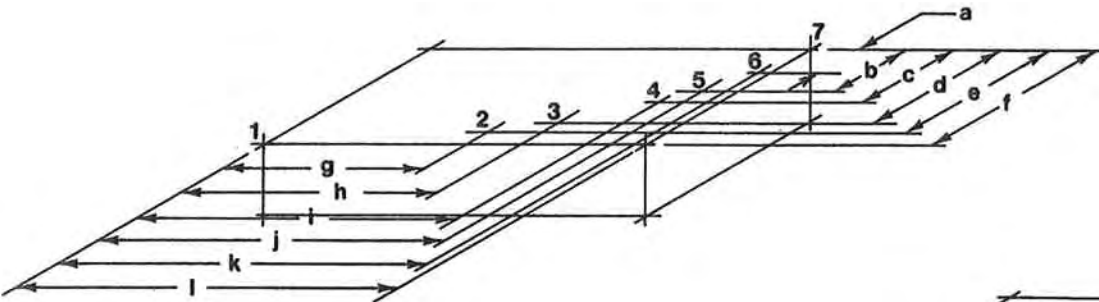


Figure 16-18(c)

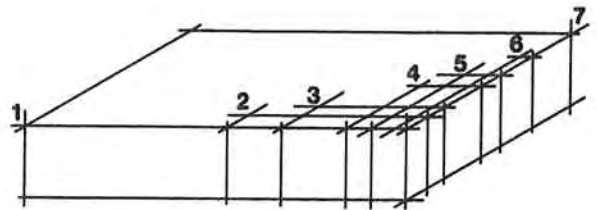


Figure 16-18(d)

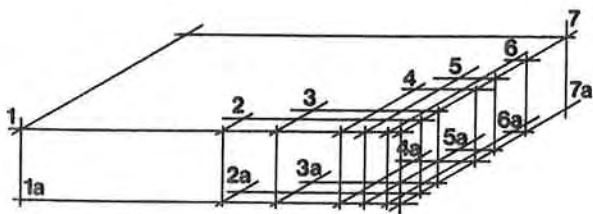


Figure 16-18(e)

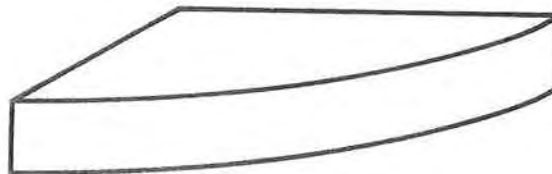


Figure 16-18(f)

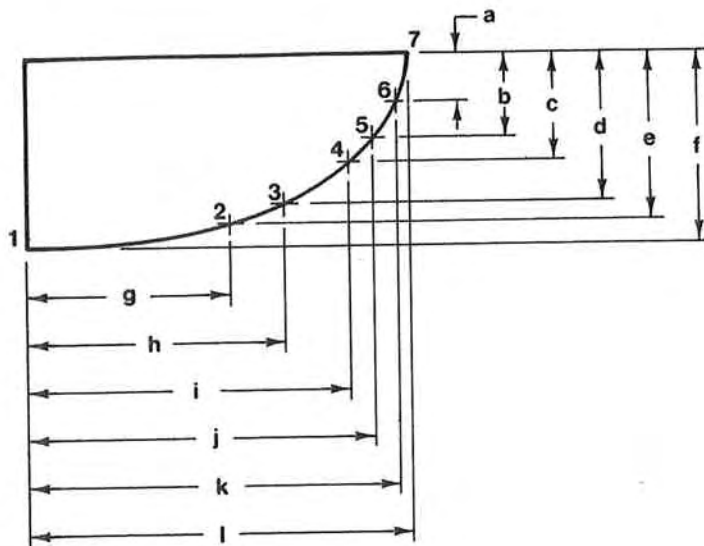


Figure 16-19 Supplementary layout used to define the irregular surface in terms of its linear components.

16-6 DIMENSIONING AN OBLIQUE DRAWING

Oblique drawings may be dimensioned by using either the unidirectional or aligned systems. The front view and all other surfaces parallel to it are dimensioned in the same way that they were in the orthographic views (see Chapter 6), but dimensions along the receding axis must be drawn in the same oblique plane as the surface they are defining.

In the aligned system, guidelines for dimensions that define receding surfaces must be drawn parallel to the receding axis. Guidelines for dimensions that define surfaces in the front view or any surface parallel to the front view are drawn either horizontally or vertically depending on whether they are defining horizontal or vertical surfaces.

In the unidirectional system, all guidelines are drawn horizontally. In both systems, all letters and numbers are drawn either 1/8 or 3/16 in height.

Figure 16-20 is an example of an oblique drawing that has been dimensioned by using the unidirectional system.

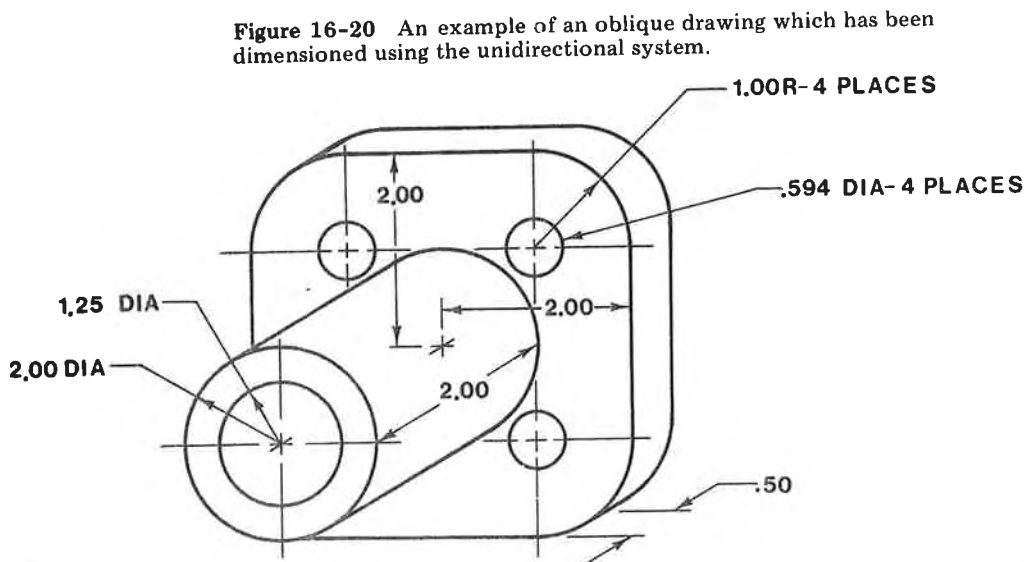


Figure 16-20 An example of an oblique drawing which has been dimensioned using the unidirectional system.

16-7 OBLIQUE SECTIONAL VIEWS

Figure 16-21 illustrates a full oblique sectional view, and Figure 16-22 illustrates a half oblique sectional view. Oblique sectional views are drawn in the same manner and for the same reasons that isometric sectional views are drawn. Since the only difference between the two sectional views is the defining axis system, the information given in Section 15-7 may also be applied to oblique sectional views.

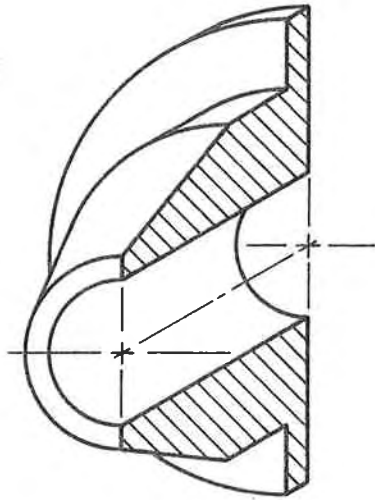


Figure 16-21 A full oblique section cut.

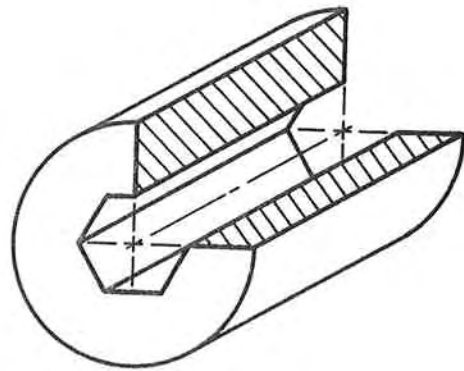
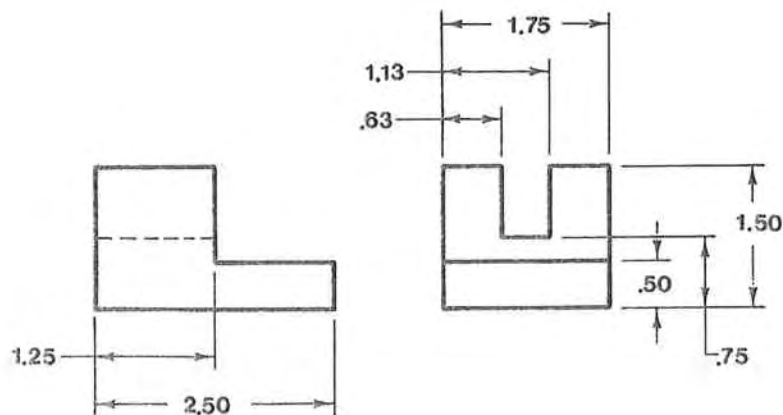


Figure 16-22 A half oblique section cut.

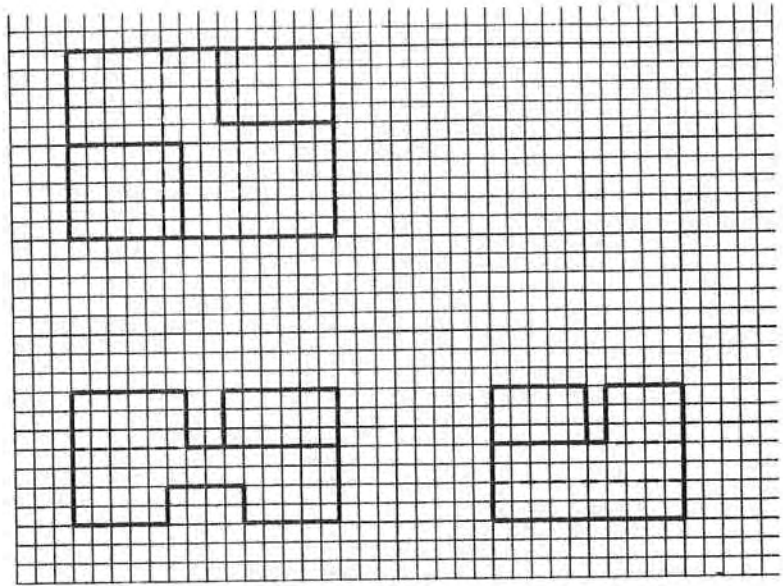
PROBLEMS

Create oblique drawings of the following objects. Each square on the grid background is 0.20 p.

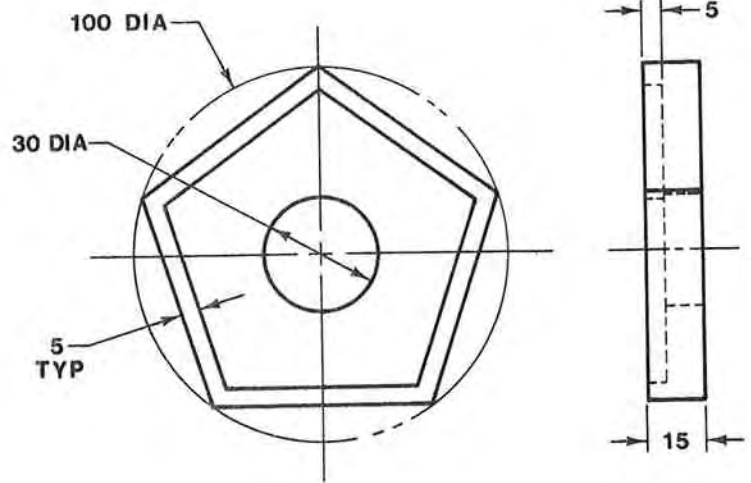
16-1



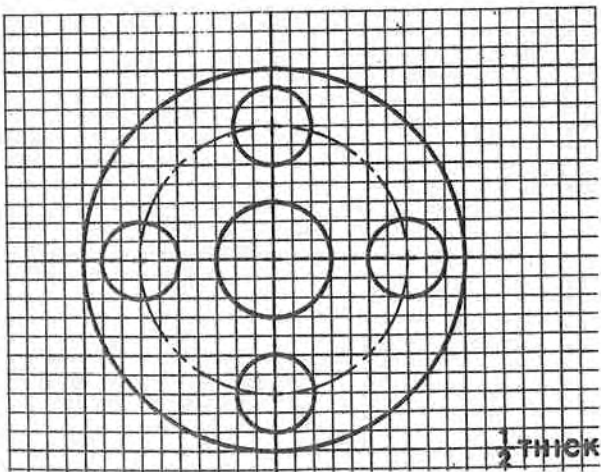
16-2



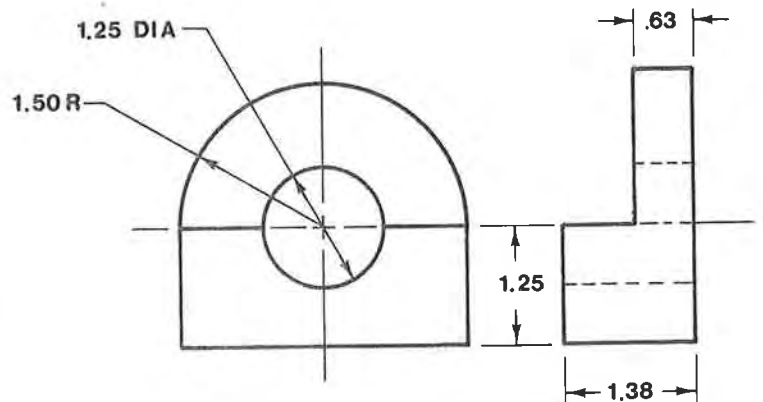
16-3 All dimensions are in millimeters.



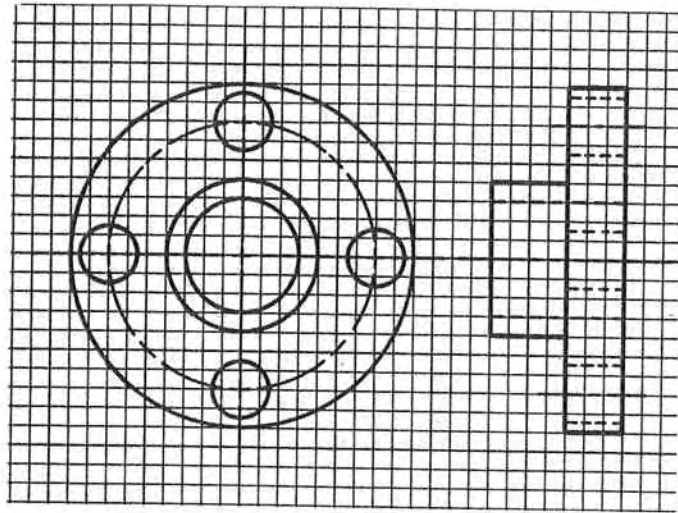
16-4



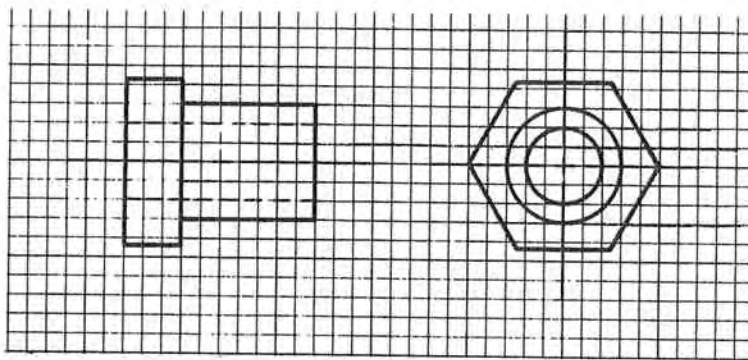
16-5



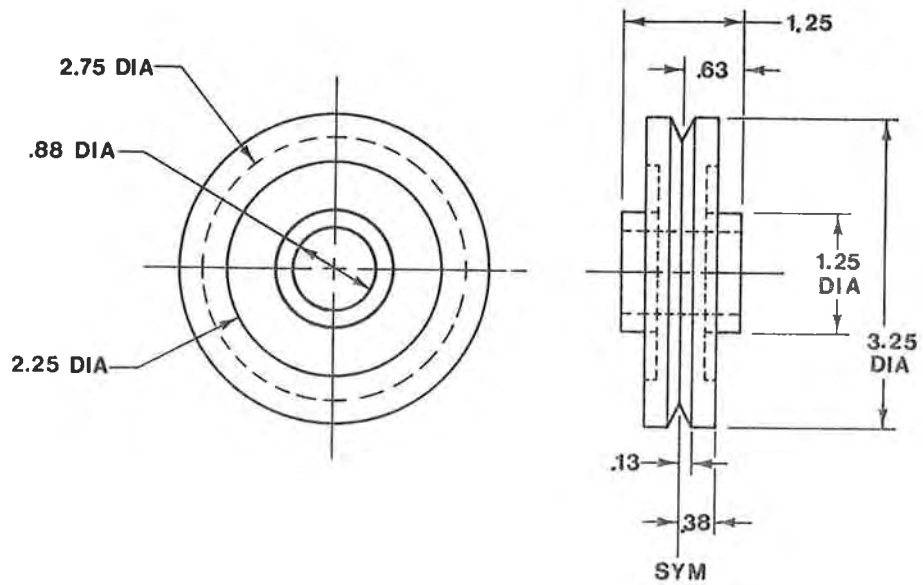
16-6



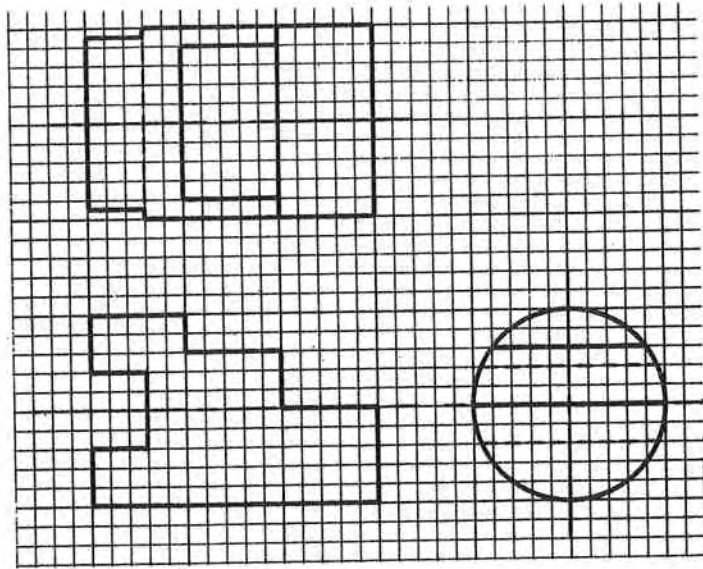
16-7



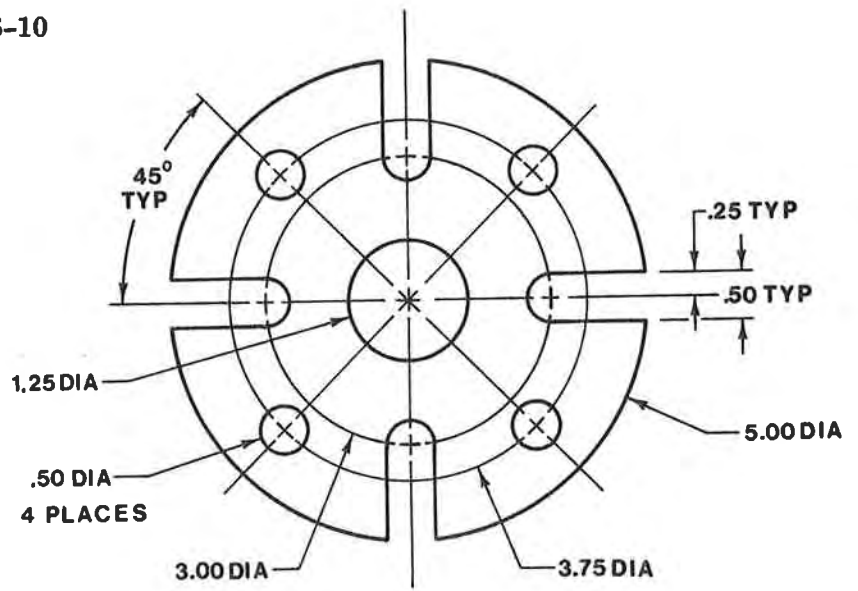
16-8



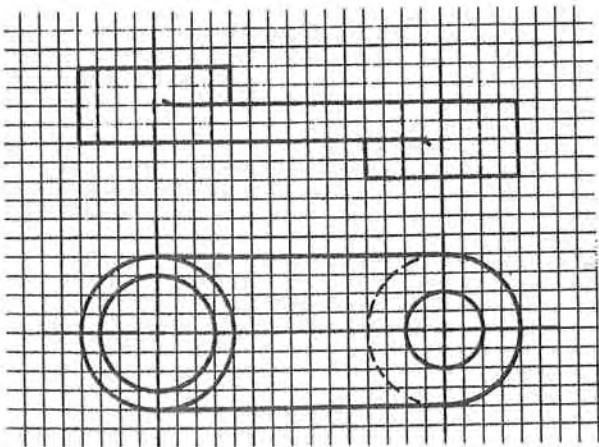
16-9



16-10

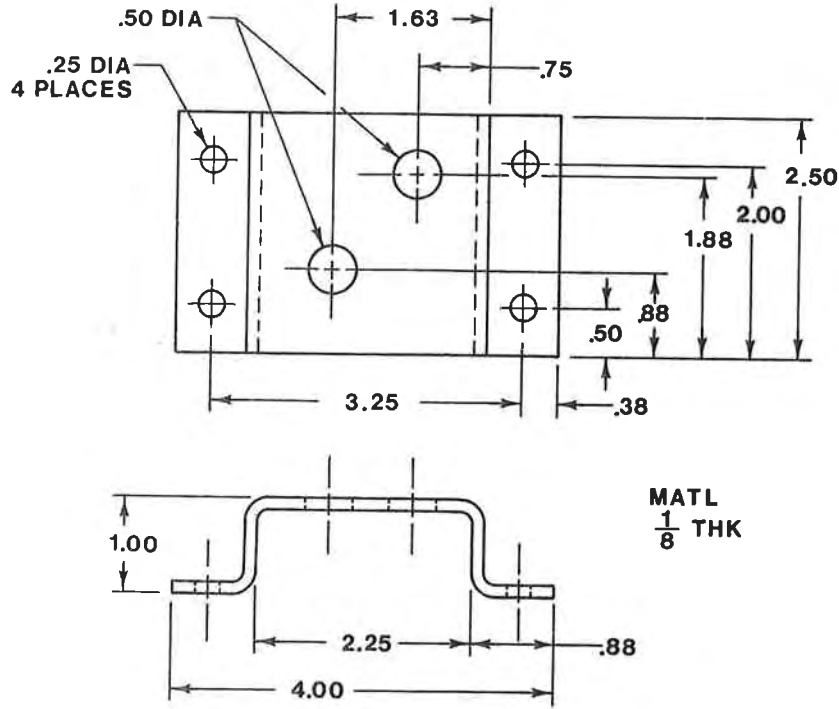


16-11

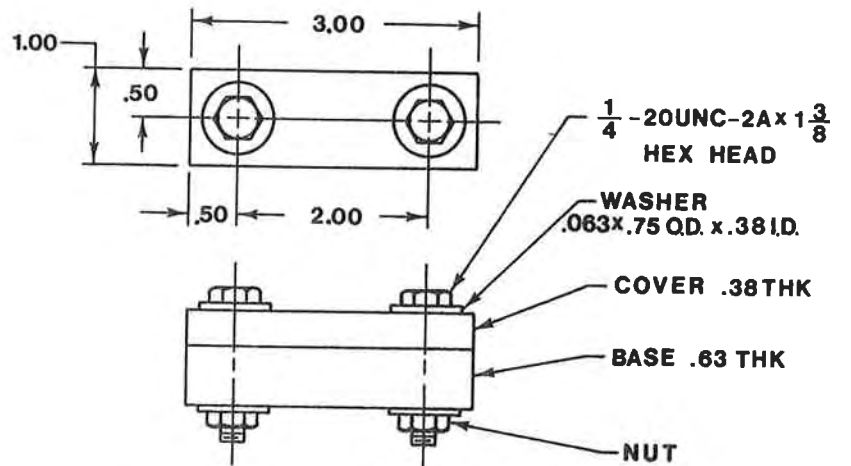


MATL .25 STEEL

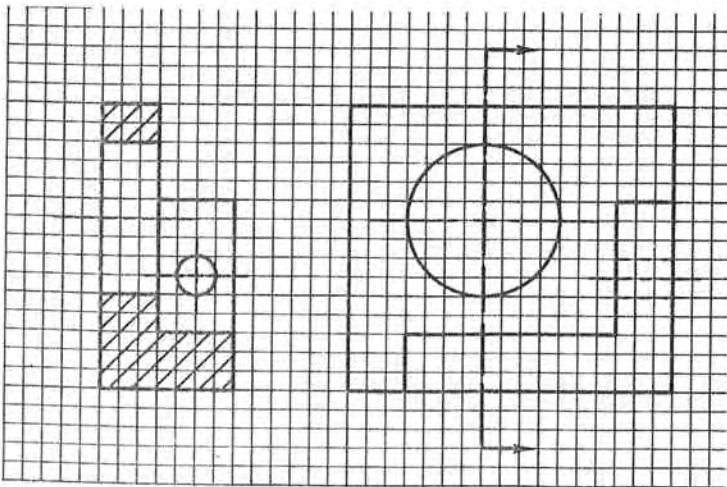
16-12



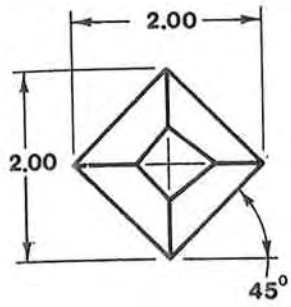
16-13



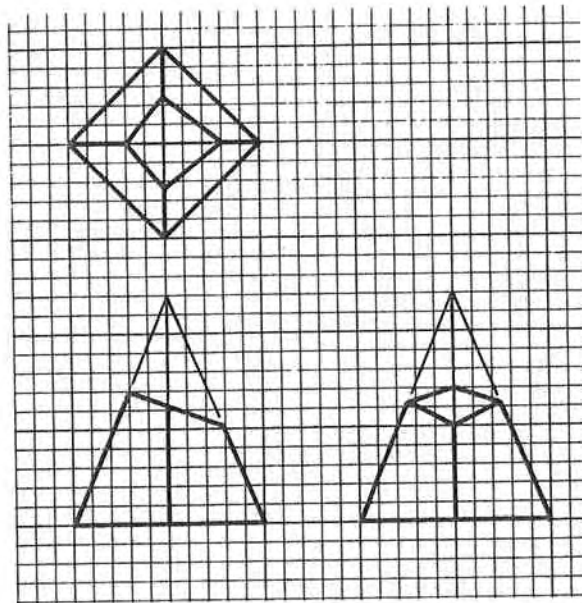
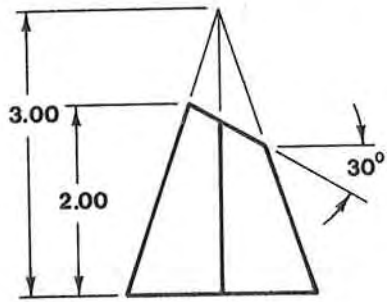
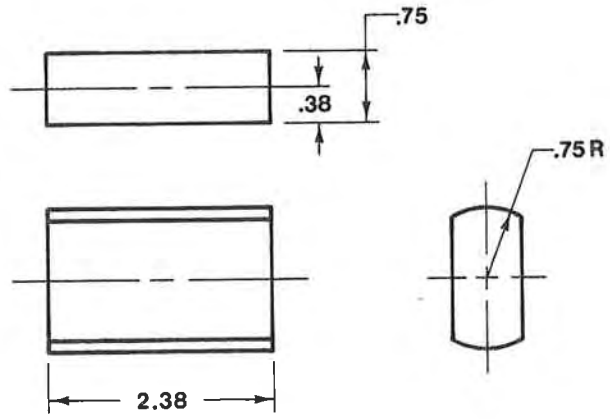
16-14



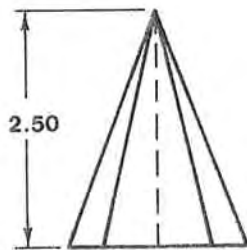
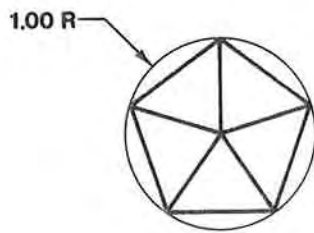
16-15



16-16



16-18



DEVELOPMENT DRAWINGS 17

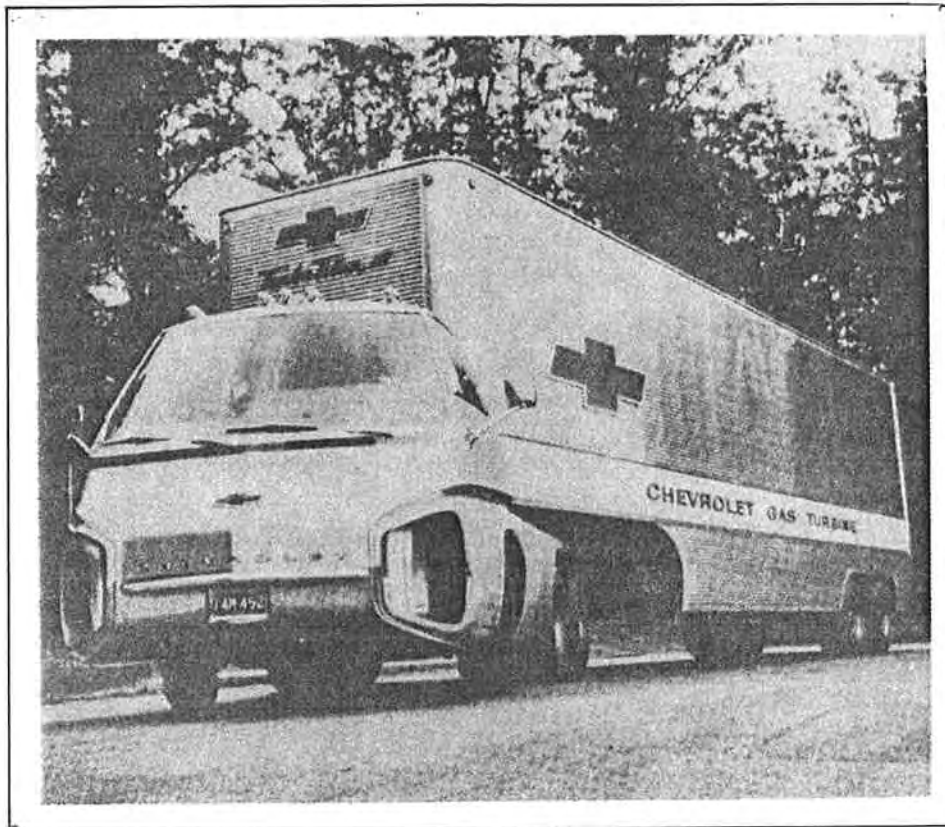


Figure 17-0 Photograph courtesy of General Motors Corp.

17-1 INTRODUCTION

Development drawings are flat patterns which, when folded in an appropriate manner, form a desired object. They are most commonly used in sheet metal work.

There are four major categories of development drawings: prisms, cylinders, pyramids, and cones. Prism and cylinder development drawings are created by using the same basic drawing techniques. Pyramid and cone development drawings also use the same basic drawing technique. This chapter will explain and present solved sample problems of each category.

When you make actual patterns, your development drawing will usually include extra metal for bend and seam allowances. The amount of extra metal to be included depends on the kind of metal being fabricated, the thickness of the metal, and the kind of seam to be used. This chapter does not include information on bend or seam allowance; it presents only the information required to develop a given object into its ideal flat pattern.

GIVEN: An object.
PROBLEM: Develop the flat pattern.

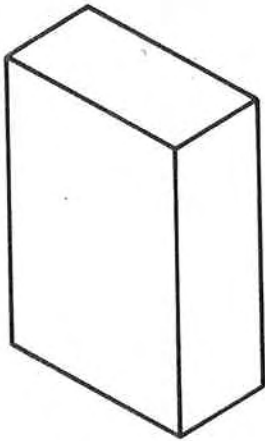


Figure 17-1

17-2 RECTANGULAR PRISMS

Figure 17-1 is an example of a problem that involves a rectangular prism. All surfaces are 90° to each other. The problem is to develop a flat pattern which, when folded properly, will form the desired rectangular prism. Assume that the object is completely enclosed and that there are no open surfaces. Figure 17-2 is the solution and was derived by the following procedure:

SOLUTION:

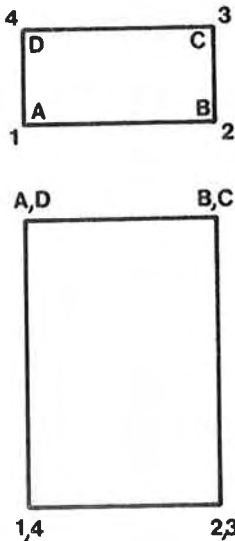


Figure 17-2(a)

1. Draw as many orthographic views as are necessary to completely define every surface of the given object. In this example two views (front and top) are sufficient, but for most objects more than two views are needed. Partial orthographic views, including auxiliary views are sometimes used to insure a complete definition of surfaces not clearly defined in the given orthographic views.
Position the orthographic views on the left side of the drawing paper.
2. Define all points of the object. Use numbers for the points along the bottom edges and letters for the points along the top edges. This identification system will prevent confusion as you develop the surfaces.
3. From the front orthographic view, extend a very light layout line from every labeled point as shown in Figure 17-2(c). All of these lines should be parallel to each other. These lines are called *stretchout lines*.

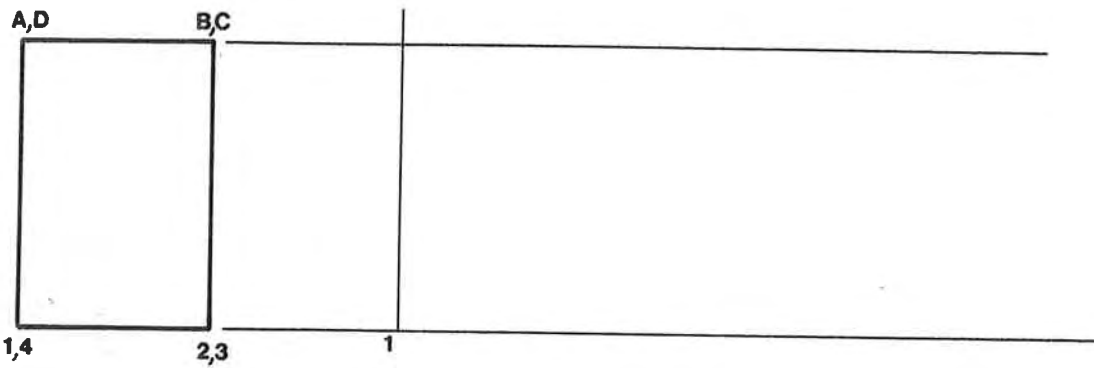
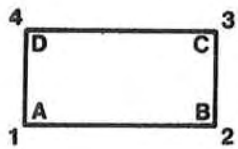


Figure 17-2(b)

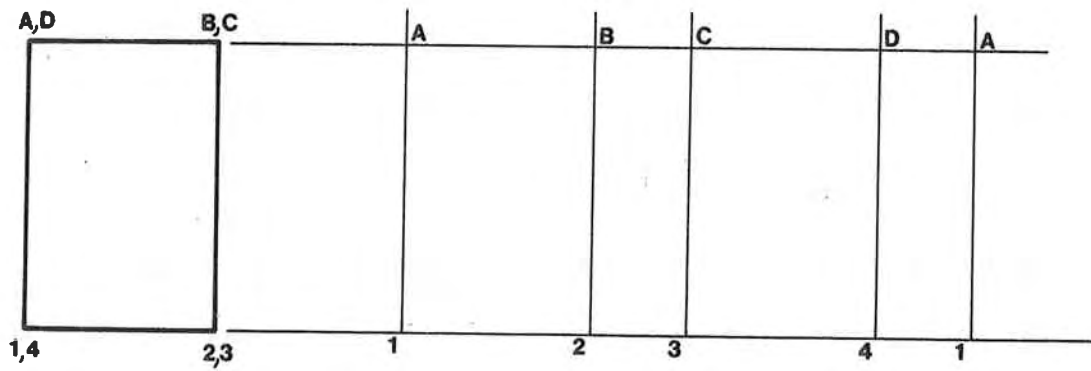
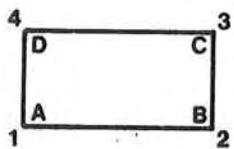


Figure 17-2(c)

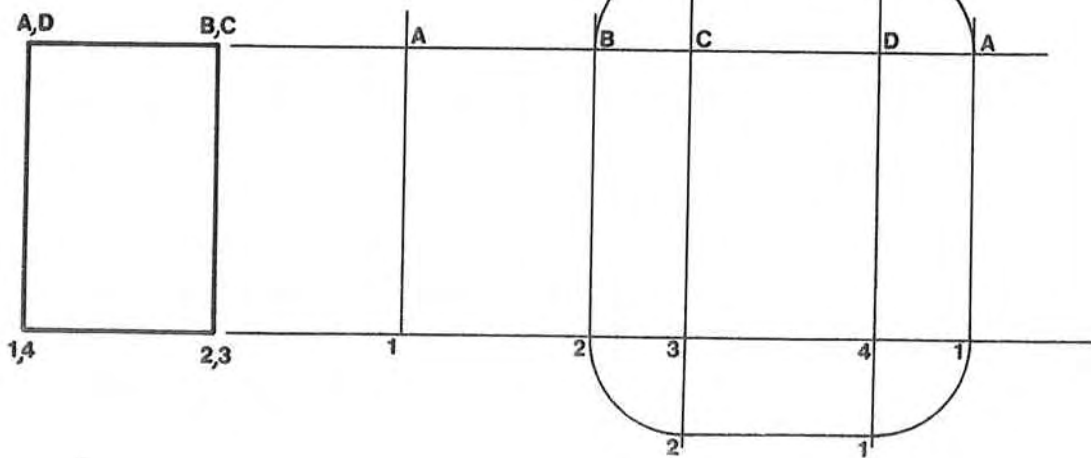
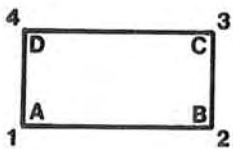


Figure 17-2(d)

4. Somewhere along the bottom (lowest) stretchout line, define point 1. Then, using point 1 as a starting mark, lay out (along the bottom stretchout line) the remaining points that define the bottom edges of the object. This may be done by transferring the line distances found in the orthographic views. Label each point as you mark it off. There should be two point 1s along the stretchout line because the object must end at the same point at which it started in order for the object to be completely enclosed. Remember that line 4-1 is also part of the object.
5. Draw lines, perpendicular to the stretchout lines, from each point located on the stretchout line.

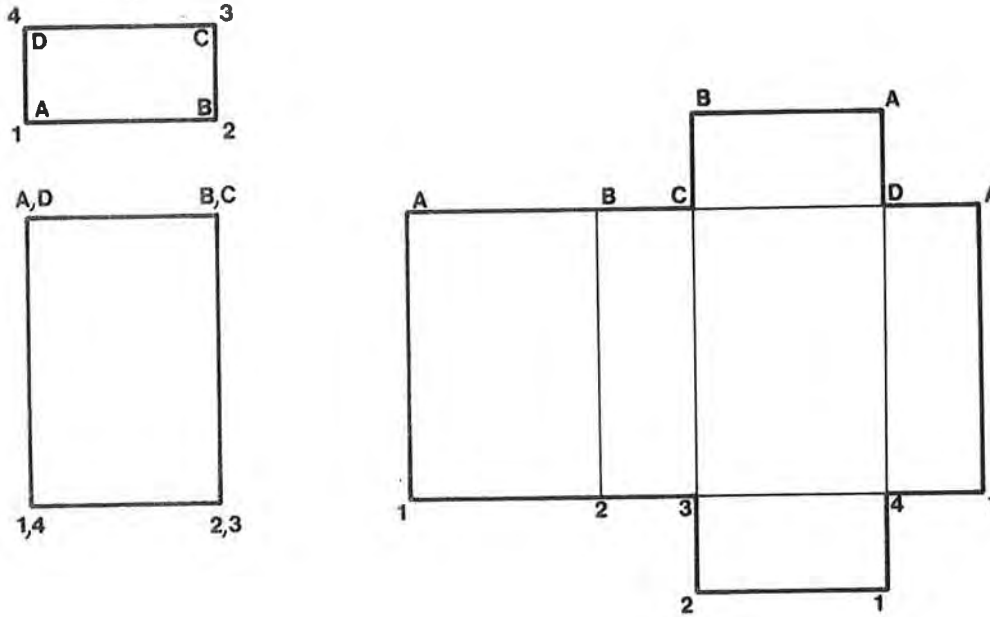


Figure 17-2(e)

6. Identify and label all points originally defined in the orthographic views on the flat pattern portion of the drawing by using the stretchout lines drawn in step 3 and the perpendicular lines drawn in step 5. For example, point A is known (from the information found in drawing the orthographic views) to be located directly above point 1. We also know that point A is somewhere along the stretchout line drawn from point A in step 3. Where the point A stretchout line intersects the perpendicular line from point 1 is point A in the flat pattern. Point A could also have been found by directly transferring the distance A-1 from the front orthographic view to the line perpendicular to point 1 on the stretchout line.
7. Lay out the top and bottom of the object as shown in Figure 17-2(d). This can be done by either transferring the distance and angles from the orthographic views or by drawing lines perpendicular to lines C-D and 3-4 located on the flat pattern

and then, using a compass, drawing arcs of lengths $B-C$, $D-A$, $2-3$, and $4-1$ from points C , D , 3 , and 4 , respectively. The compass method was used in this example.

8. Erase all excess layout lines. Darken in the outside periphery of the flat pattern with heavy visible lines. Do not erase the layout lines that represent the lines along which the pattern is to be folded. The point labels may or may not be erased, depending on the individual shop requirements.

Figure 17-3 is another example of a problem that involves a rectangular prism. Figure 17-4 is the appropriate development drawing and was derived by using the same procedure outlined for Figure 17-2. Note how the top surfaces were developed in this example.

SOLUTION:

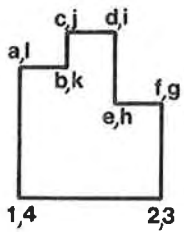
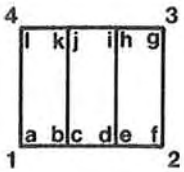


Figure 17-4(a)

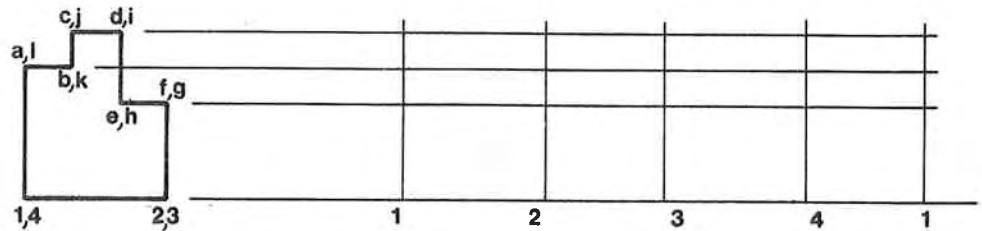
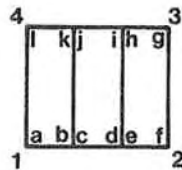


Figure 17-4(b)

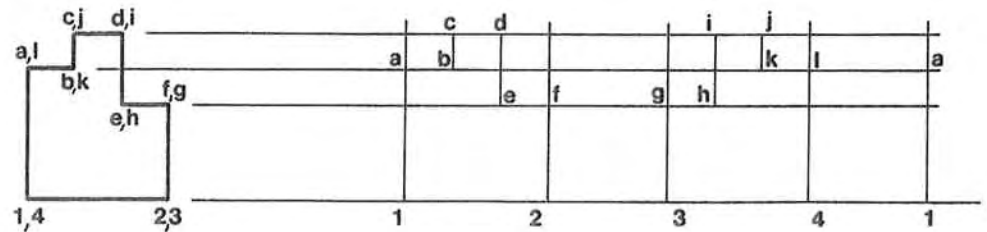
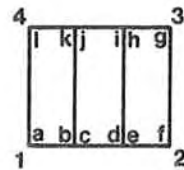


Figure 17-4(c)

GIVEN: An object.
PROBLEM: Develop the flat pattern.

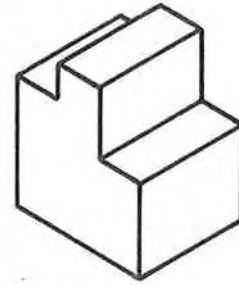


Figure 17-3

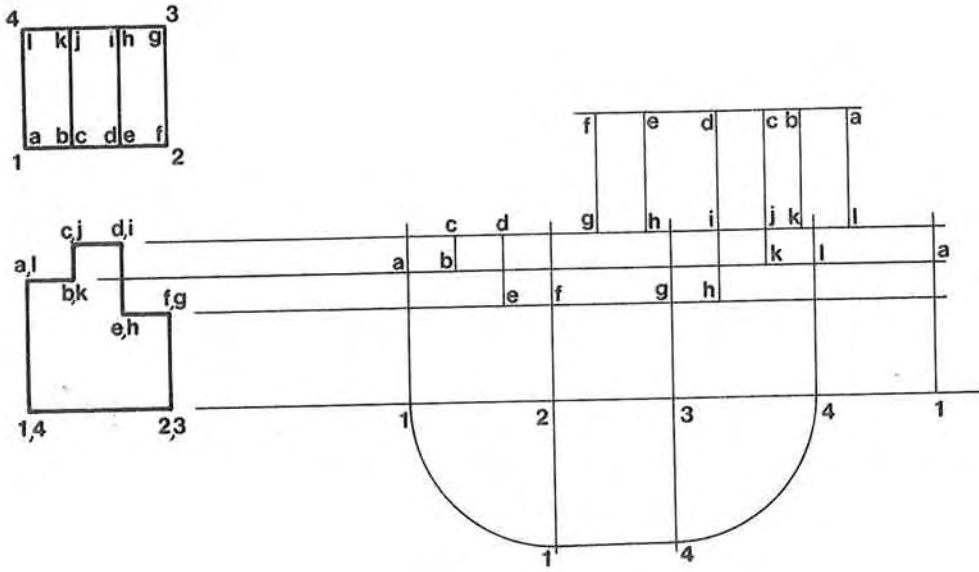


Figure 17-4(d)

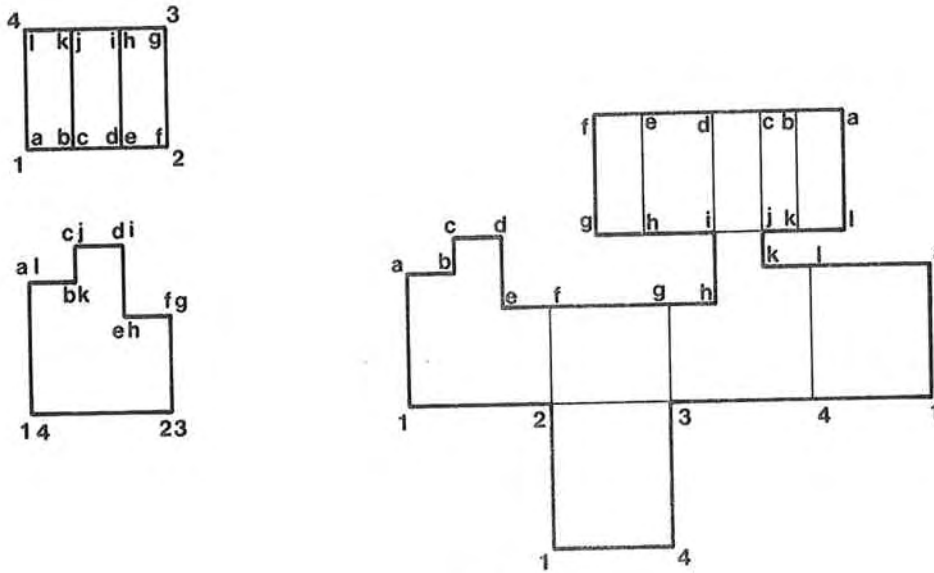


Figure 17-4(e)

17-3 INCLINED PRISMS

Figure 17-5 is an example of a problem that involves an inclined prism. In this example a supplementary partial auxiliary view was needed in addition to the two standard views (front and top) to completely define the inclined surface. Figure 17-6 is the development drawing for the object shown in Figure 17-5 and was derived by using basically the same procedure that was outlined for Figure 17-2. Note that in the flat pattern portion of the development drawing the four corners of the inclined surface are 90°.

GIVEN: An object.
 PROBLEM: Develop the flat pattern.

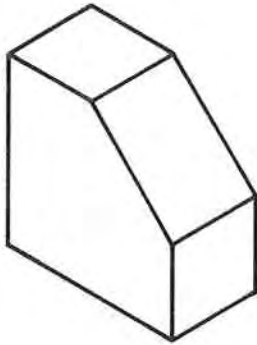


Figure 17-5

SOLUTION:

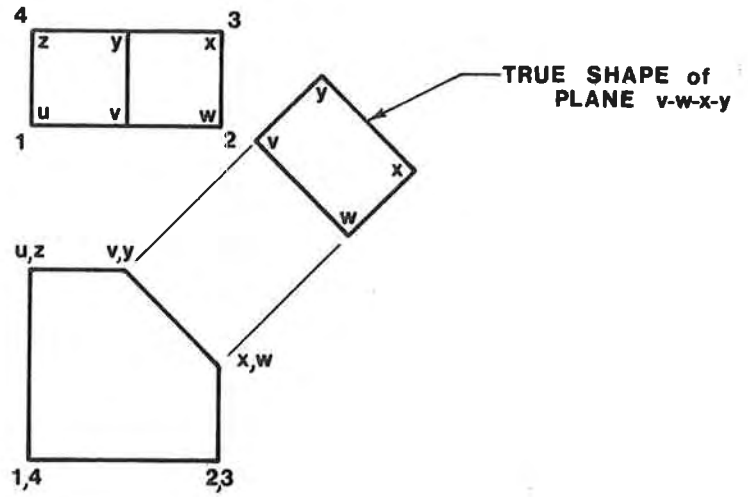


Figure 17-6(a)

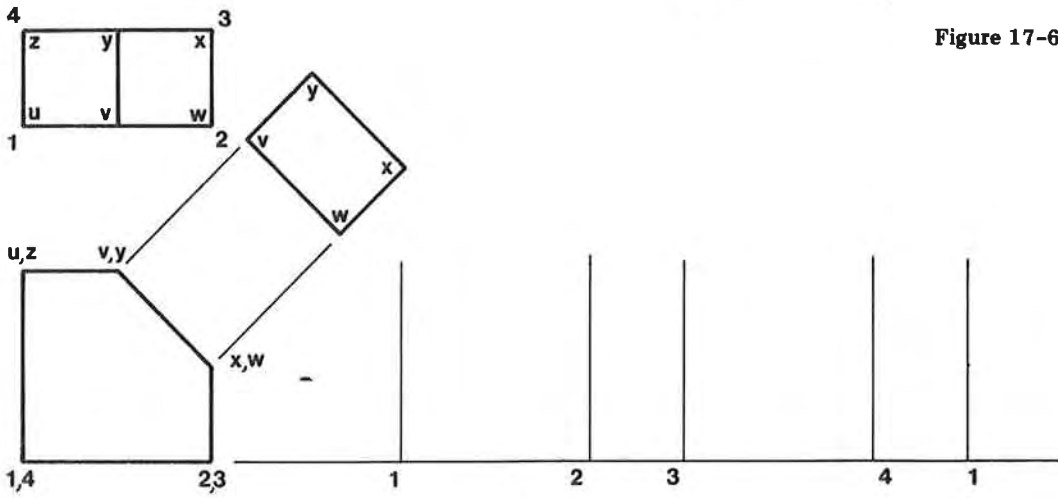


Figure 17-6(b)

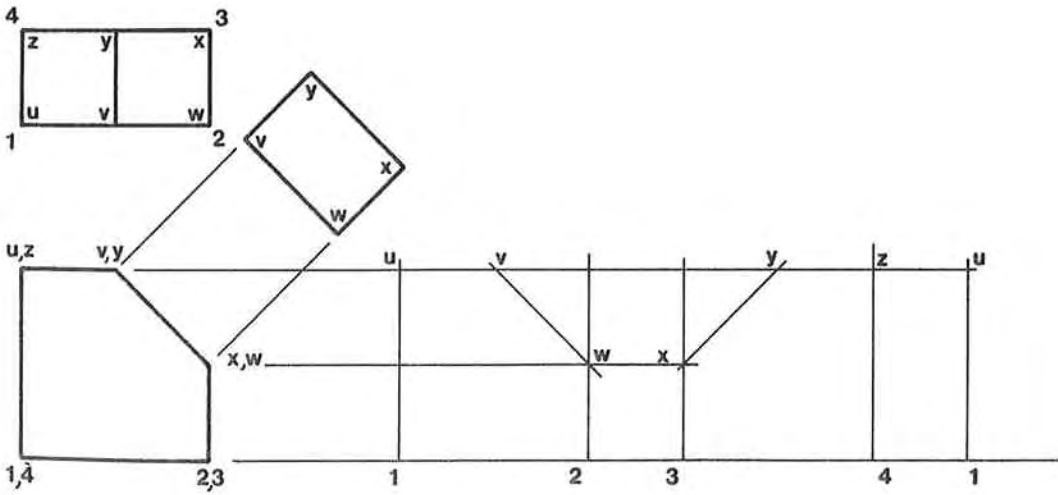


Figure 17-6(c)

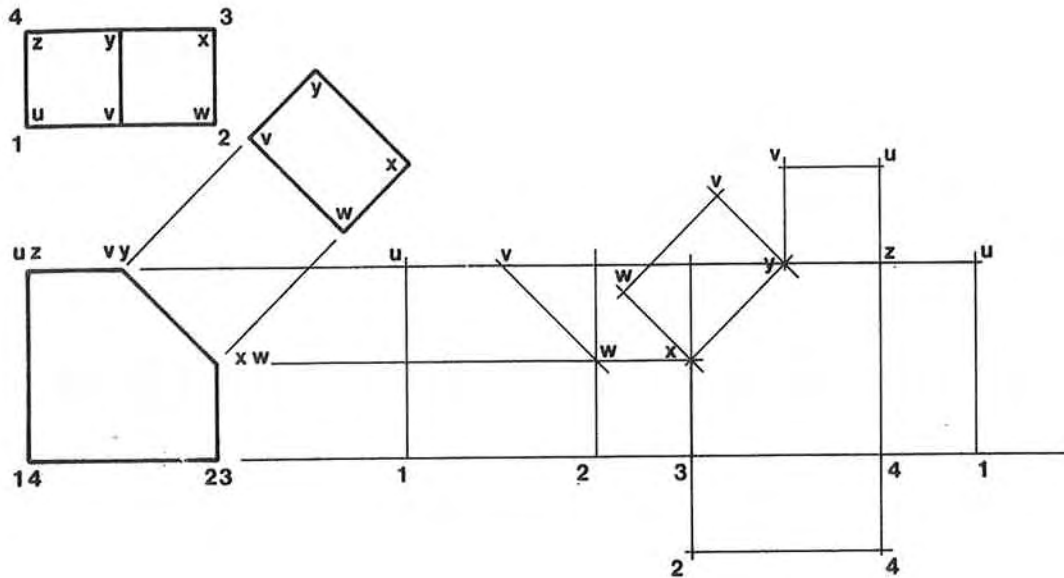


Figure 17-6(d)

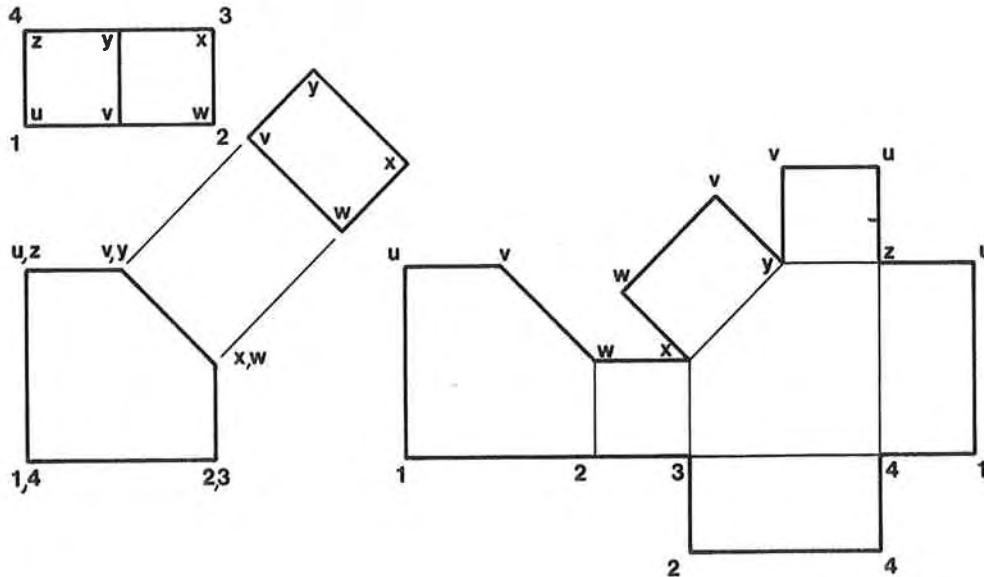


Figure 17-6(e)

17-4 OBLIQUE PRISMS

Figure 17-7 is an example of a problem that involves an oblique prism, that is, a prism that contains an oblique surface 1-2-3. In order to develop a correct flat pattern, you must know the exact shape of surface 1-2-3. To find the exact shape of surface 1-2-3, draw a secondary auxiliary view. The true shape of surface 1-2-3, once completely defined, may be transferred to the flat pattern. Figure 17-8 is the development drawing for Figure 17-7 and is derived by using basically the same method outlined for Figure 17-2. Figure 17-9 is the solution to this problem.

GIVEN: An object.
PROBLEM: Develop the flat pattern.

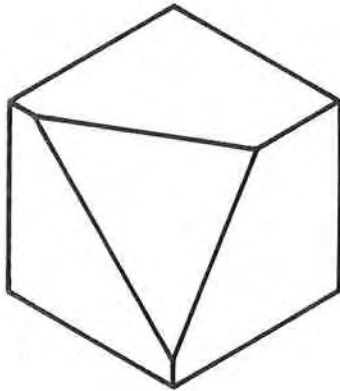


Figure 17-7

SOLUTION:

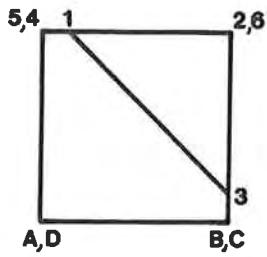
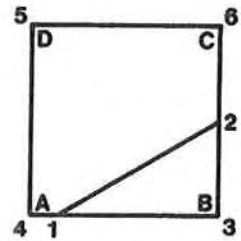


Figure 17-9(a)

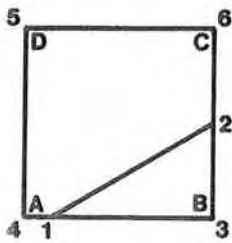


Figure 17-9(b)

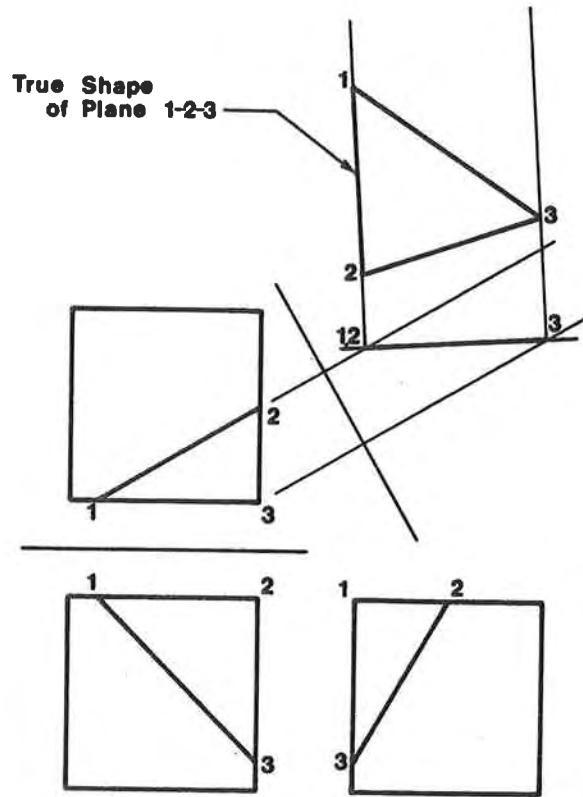
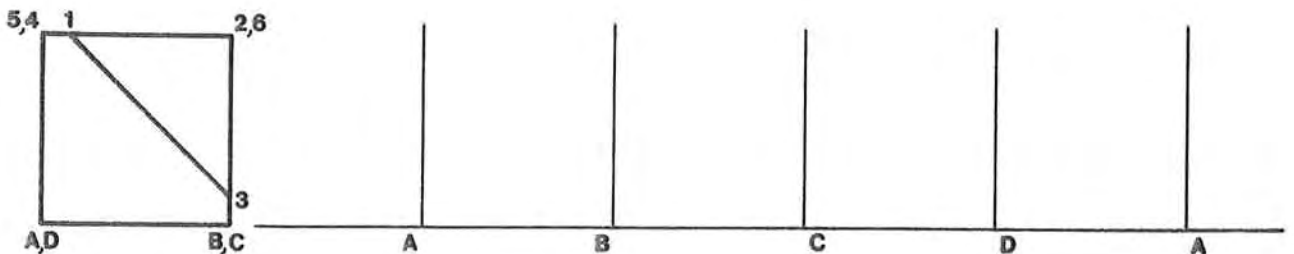


Figure 17-8 A supplementary layout used to determine the true shape of surface 1-2-3.

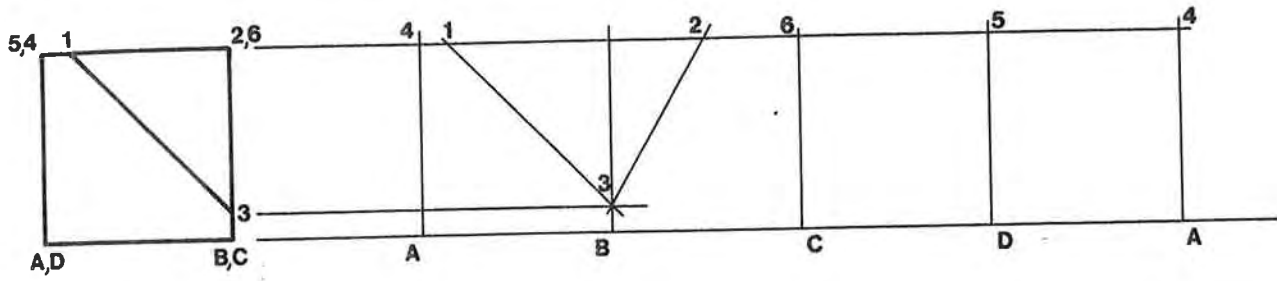
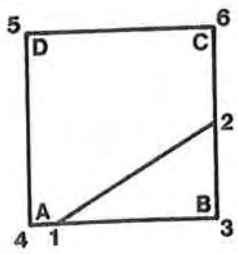


Figure 17-9(c)

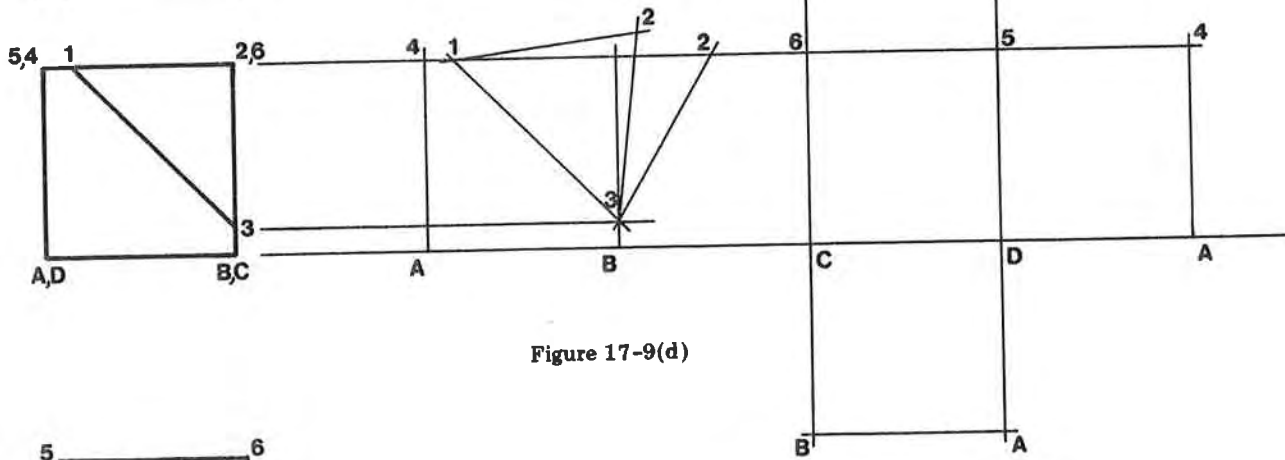
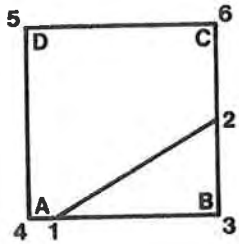


Figure 17-9(d)

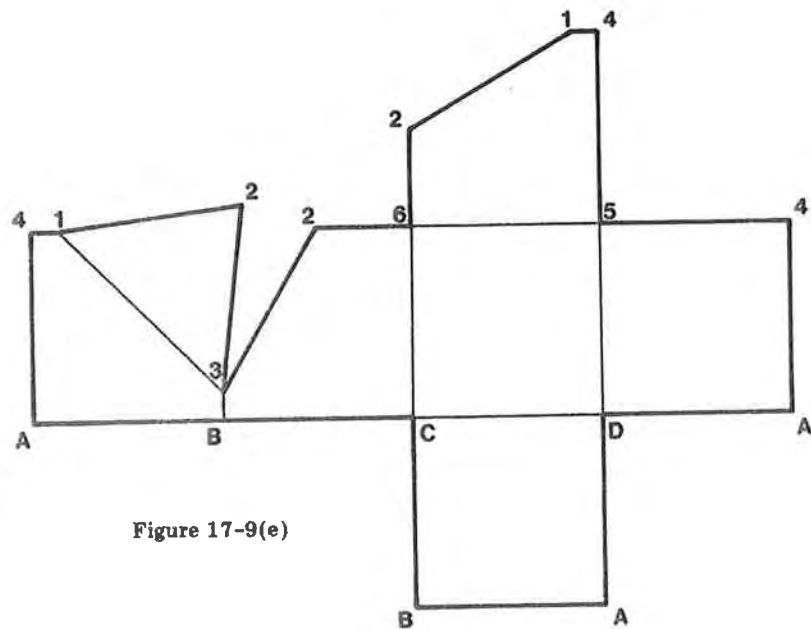
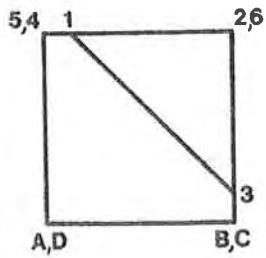
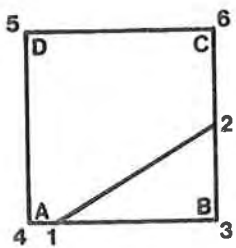


Figure 17-9(e)

17-5 CYLINDERS

Figure 17-10 is an example of a problem that involves a cylinder. Figure 17-11 is the development drawing derived from Figure 17-10 and was created by using basically the same procedure as was outlined for Figure 17-2.

The stretchout length of the cylinder is equal to its circumference. If, for example, the cylinder in Figure 17-10 had a diameter of 1.38, the stretchout length of the flat pattern would be 4.33.

$$\begin{aligned} \text{circumference} &= \pi \text{ diameter} \\ C &= \pi (\text{dia}) \\ &= (3.14)(1.38) \\ &= 4.33 \end{aligned}$$

If the cylinder size had been given in terms of its radius, 0.69 R, the stretchout length calculations would have been

$$\begin{aligned} \text{circumference} &= 2\pi \text{ radius} \\ C &= 2\pi R \\ &= 2(3.14)(0.69) \\ &= 4.33 \end{aligned}$$

The top and bottom surfaces of the cylinder in Figure 17-10 are circles that ideally join the rest of the flat pattern at tangency points. Tangency points are infinitesimal points that have no physical size and are therefore impossible to manufacture. In reality, the top and bottom surfaces of a cylindrical flat pattern are made separately and then joined to the cylinder during assembly of the cylinder. For our study, assume that tangency points can be manufactured and draw in the top and bottom surfaces as shown in Figure 17-11.

GIVEN: An object.
PROBLEM: Develop the flat pattern.

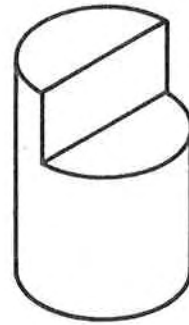


Figure 17-10

SOLUTION:

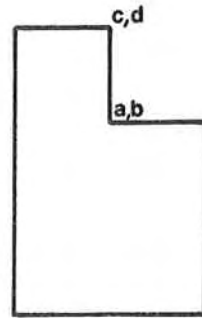
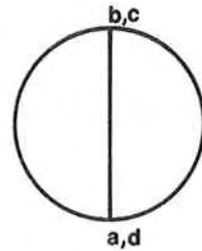


Figure 17-11(a)

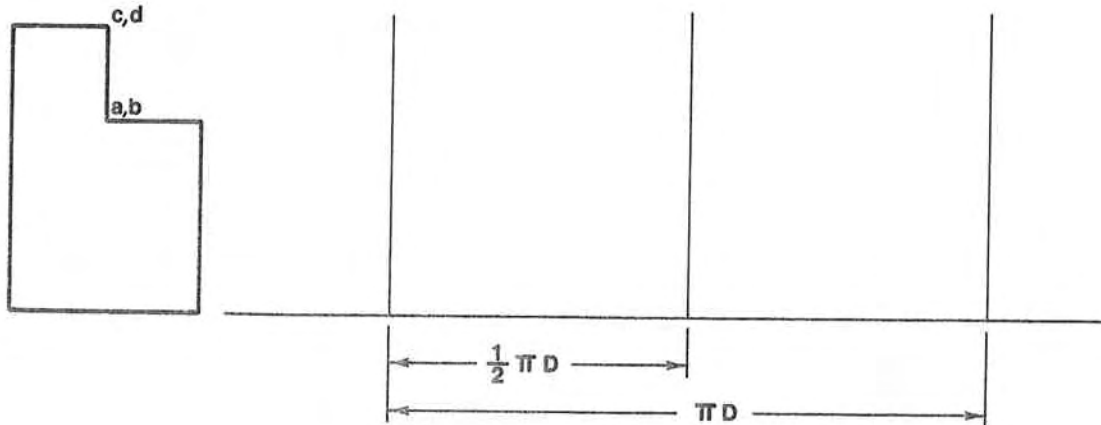
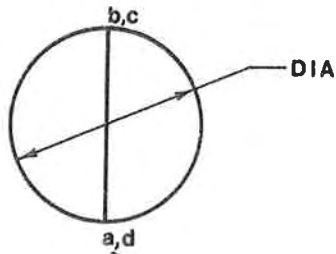


Figure 17-11(b)

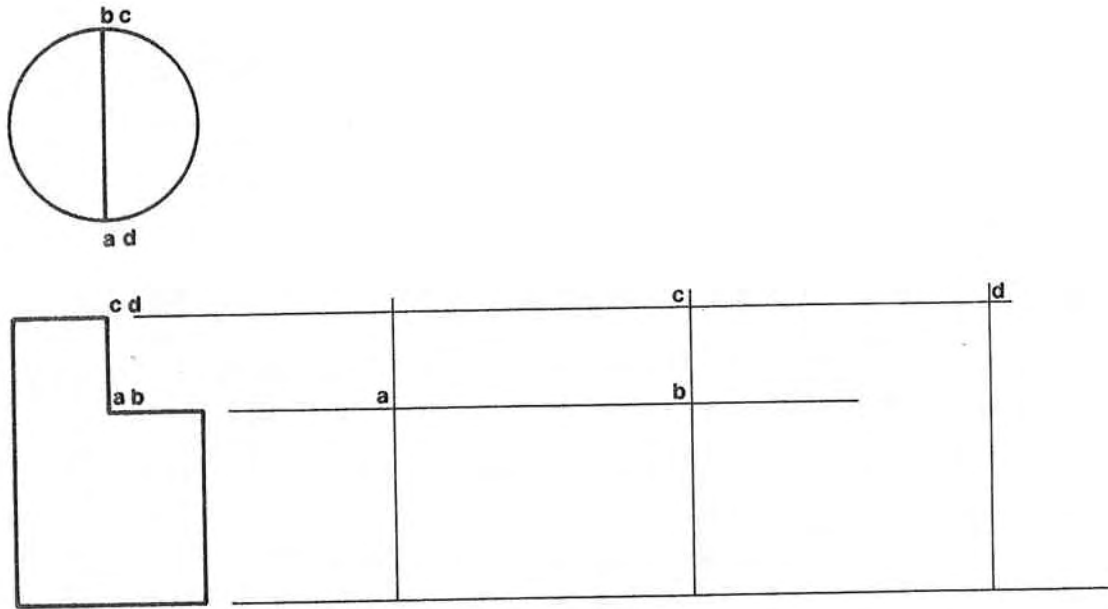


Figure 17-11(c)

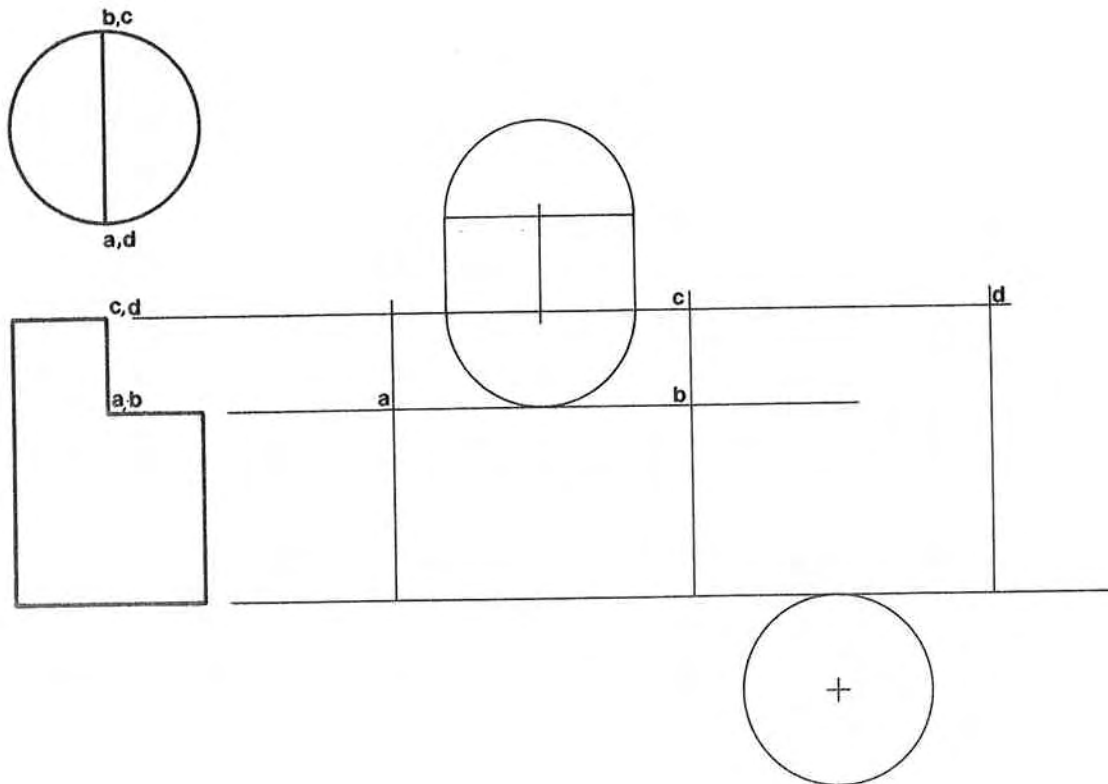


Figure 17-11(d)

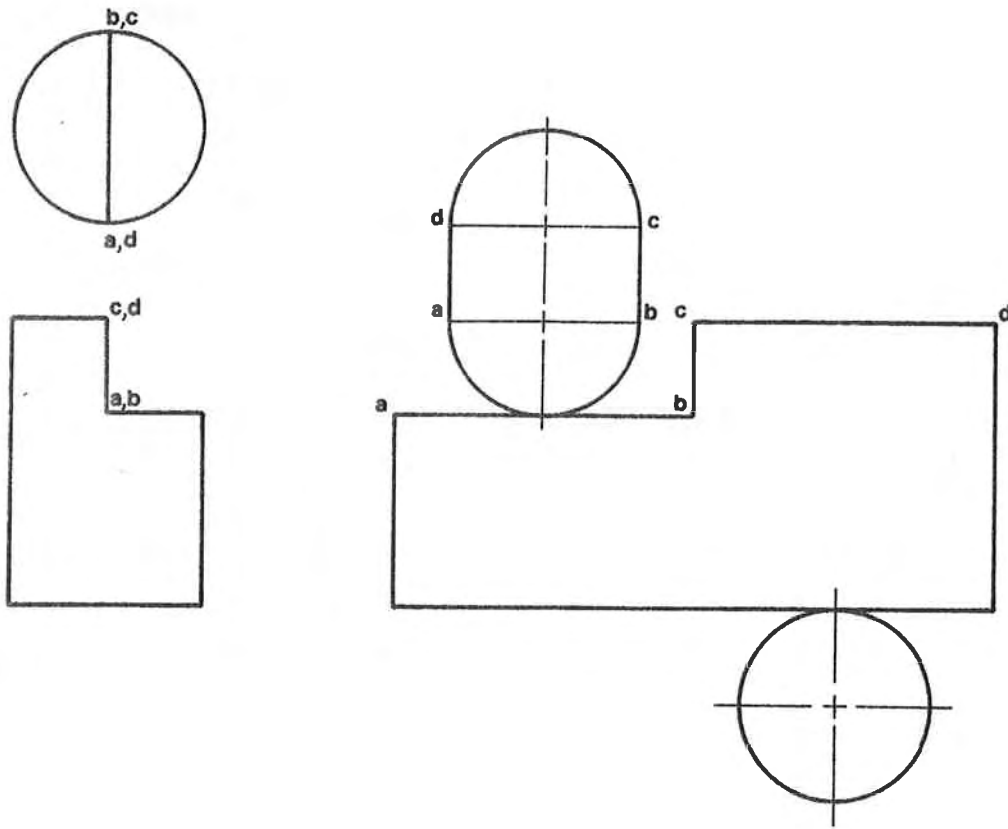


Figure 17-11(e)

Figure 17-12 is a cylinder that contains an inclined surface. Figure 17-13 is the development drawing derived from Figure 17-12 by using the procedure outlined for Figure 17-2. The orthographic views include a partial auxiliary view of the inclined surface that was created by using the procedure explained in Section 14-9 and is illustrated in Figure 17-14. As with the top and bottom surfaces of Figure 17-12, the top and bottom surfaces join the rest of the flat pattern at tangency points which we assume are possible to manufacture.

GIVEN: An object.

PROBLEM: Develop the flat pattern.

SOLUTION:

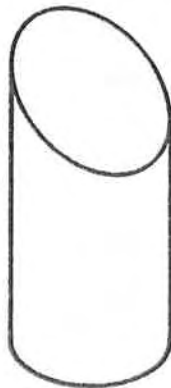
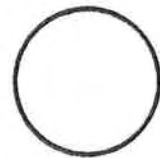


Figure 17-12

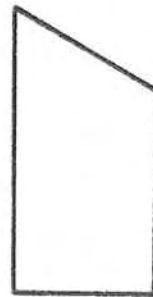


Figure 17-13(a)

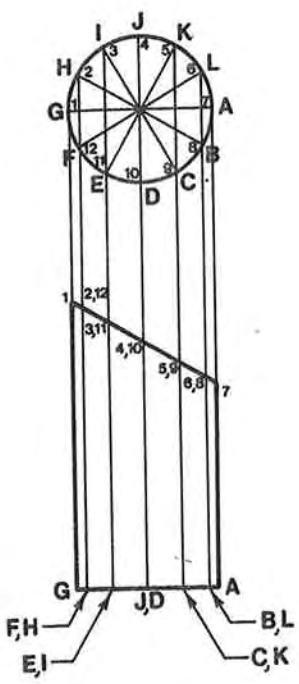


Figure 17-13(b)

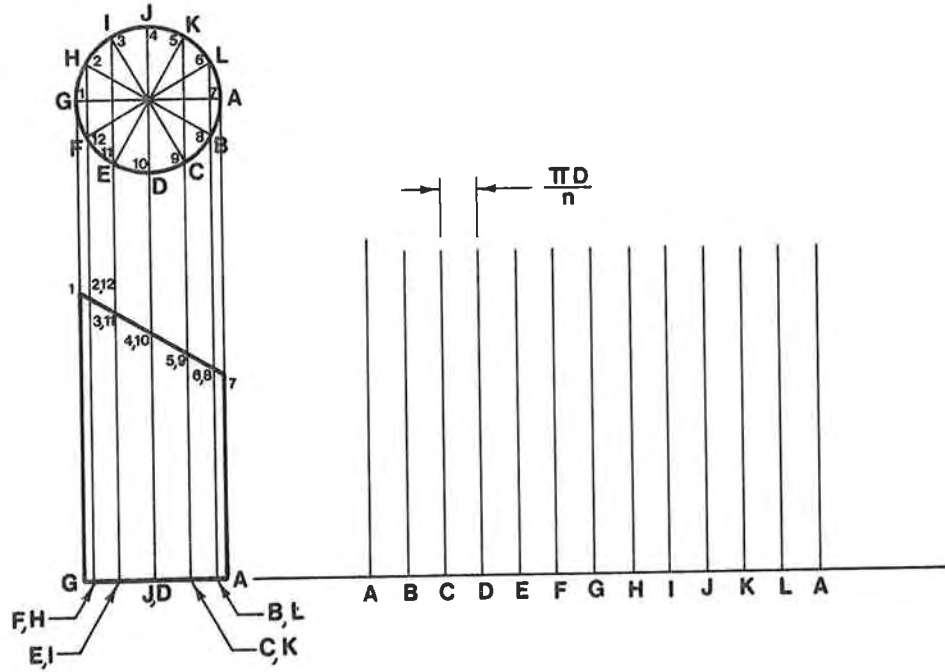


Figure 17-13(c)

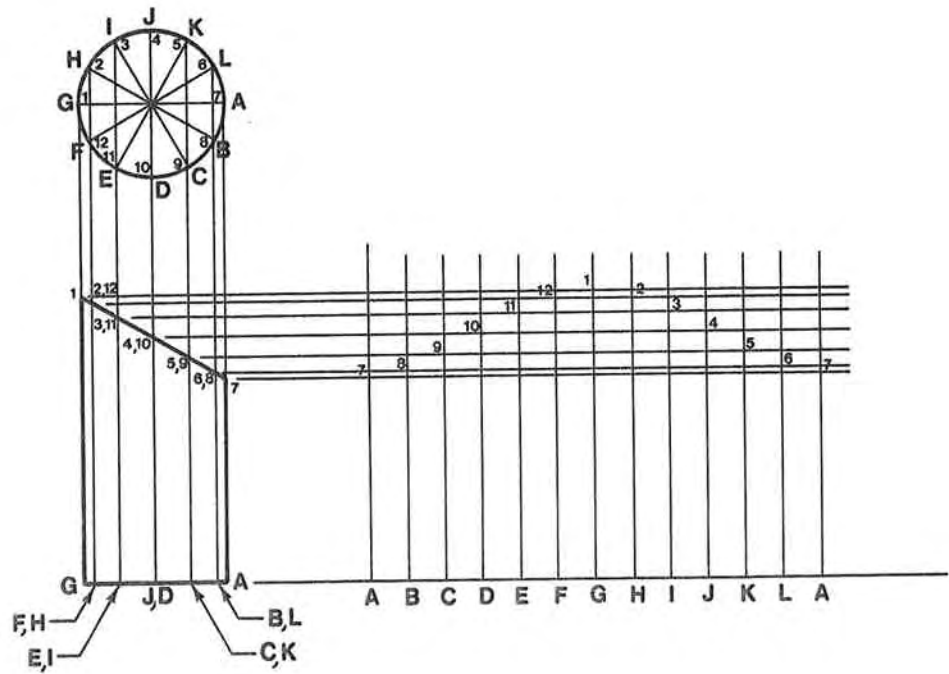


Figure 17-13(d)

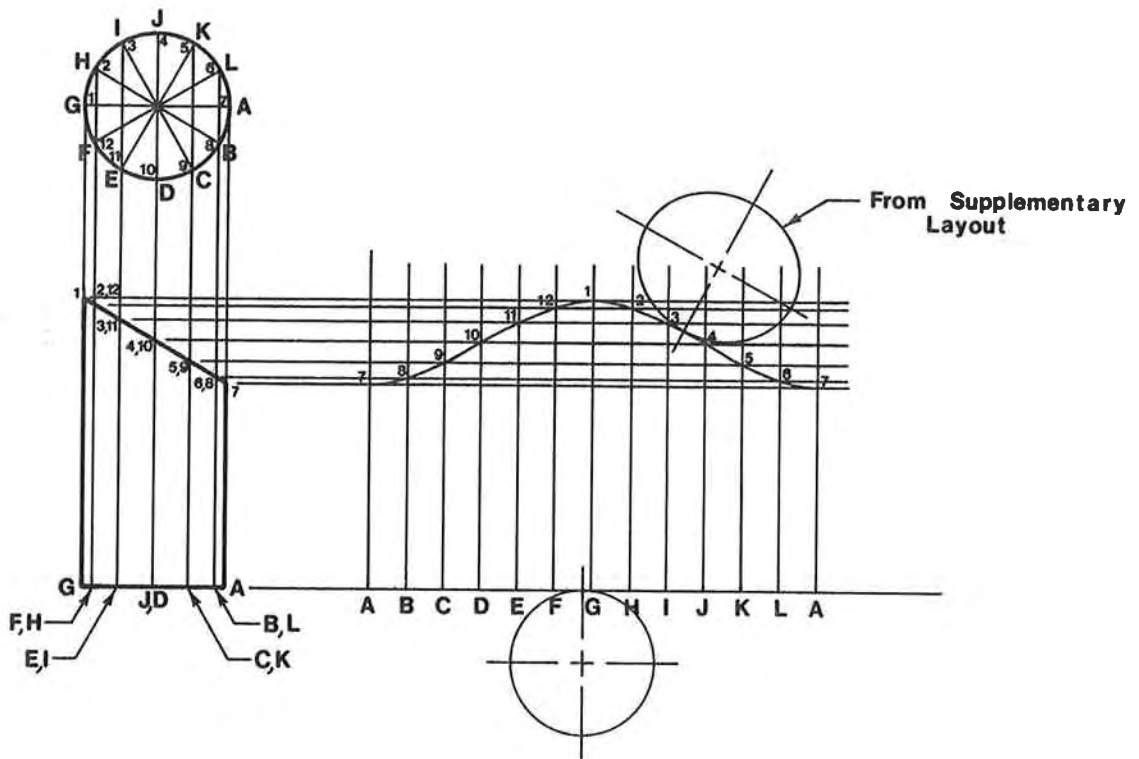


Figure 17-13(e)

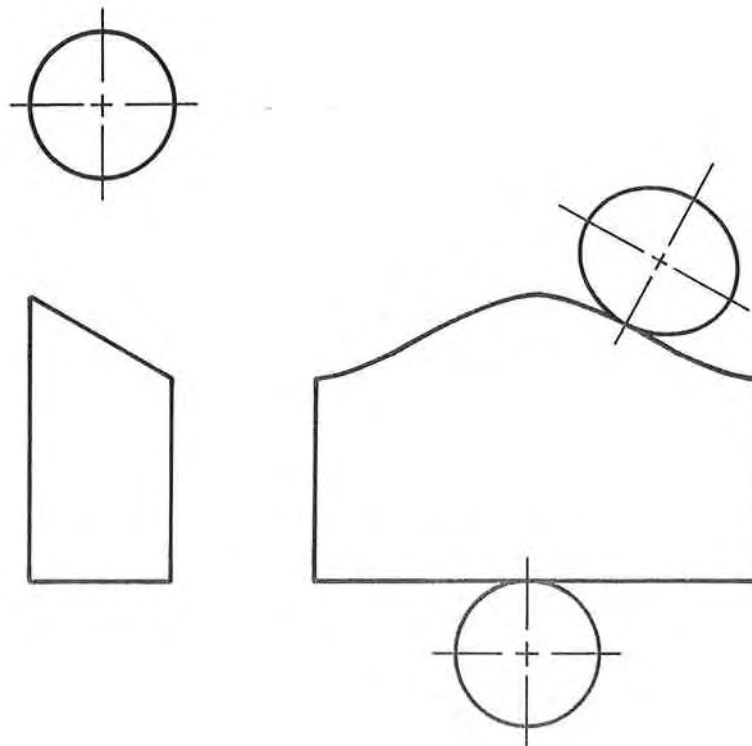


Figure 17-13(f)

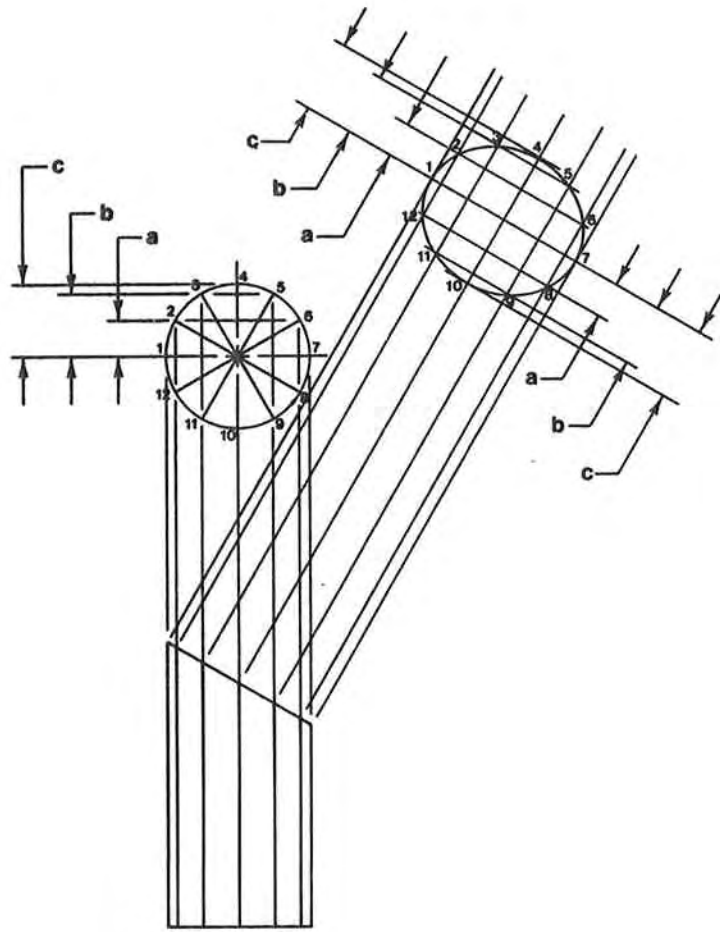


Figure 17-14 A supplementary layout used to derive the true shape of the top surface.

17-6 PYRAMIDS

The flat patterns of pyramids are developed differently from the patterns of prisms and cylinders. Figure 17-15 is an example of a problem that involves a pyramid and Figure 17-16 is the development drawing. It was created by using the following procedure:

GIVEN: An object.
PROBLEM: Develop the flat pattern.

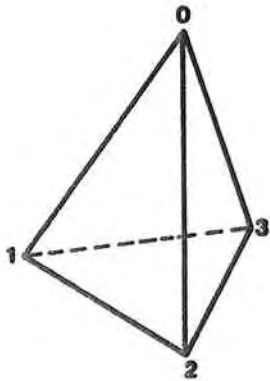


Figure 17-15

SOLUTION:

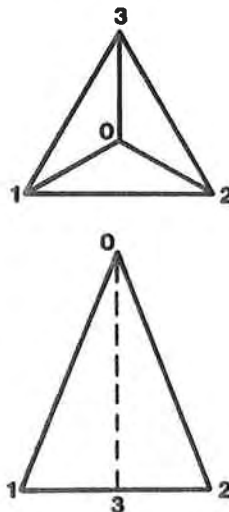


Figure 17-16(a)

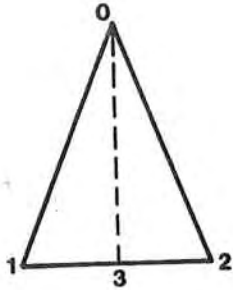
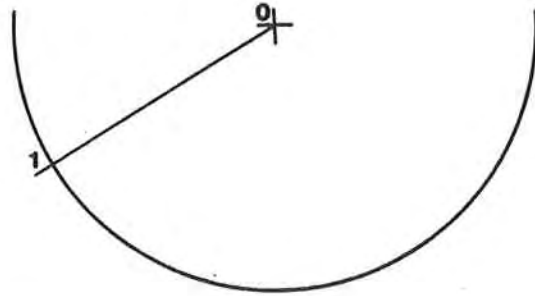
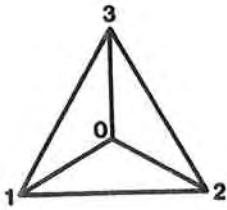


Figure 17-16(b) Use true length of line 0-1; see Figure 17-17.

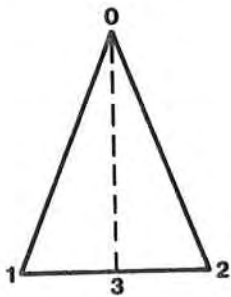
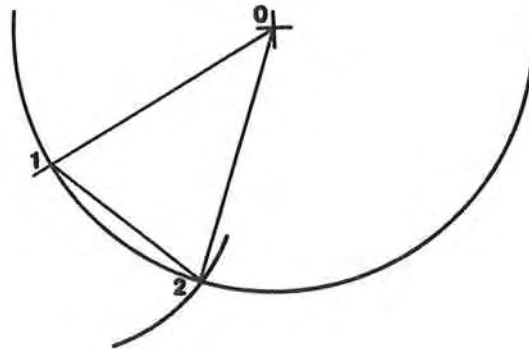
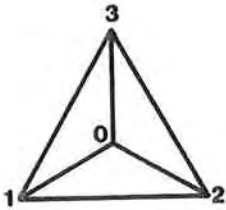


Figure 17-16(c)

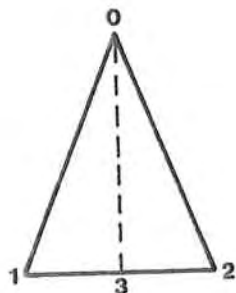
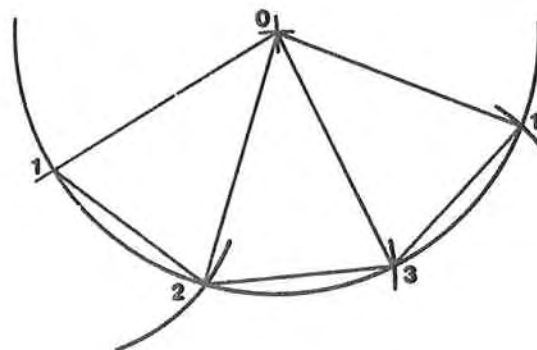
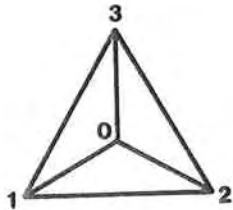


Figure 17-16(d)

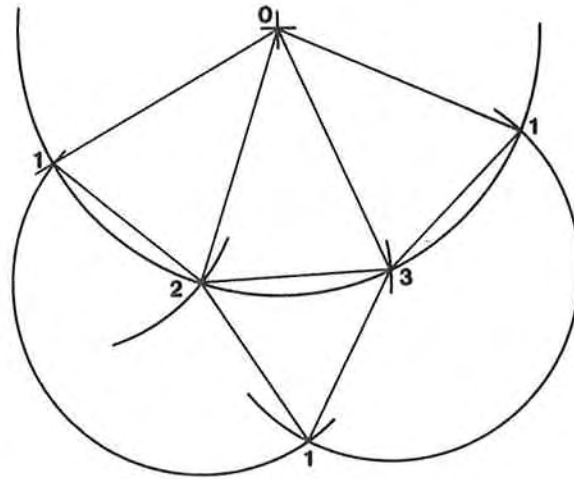
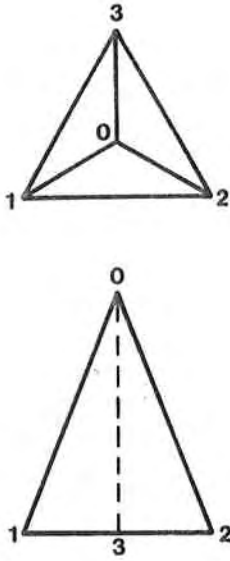


Figure 17-16(e)

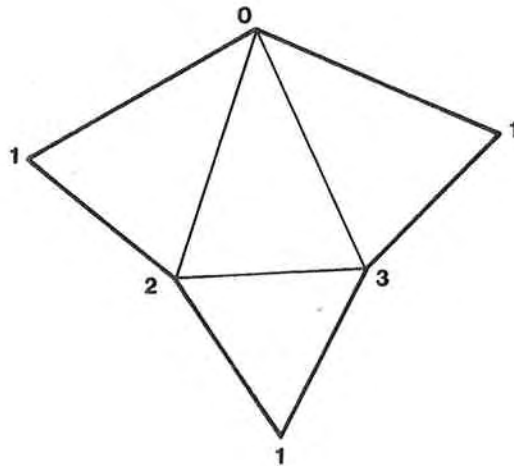
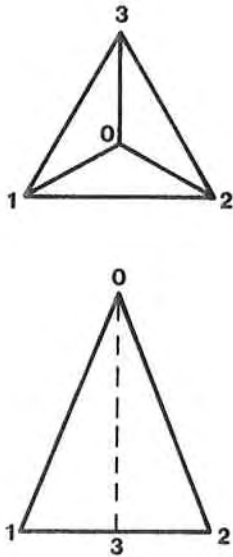


Figure 17-16(f)

1. Draw as many orthographic views as are necessary to completely define all surfaces of the object. Keep the views on the left side of the drawing. Unfortunately, the orthographic views, as presented, do not completely define the pyramid. We do not know the true lengths of lines 0-1, 0-2, or 0-3, and therefore we do not know the true shapes of the enclosed surfaces. To find the true length of lines 0-1, 0-2, and 0-3, we may either use the secondary auxiliary view method explained in Section 11-6 or the revolution method explained in Appendix A (il-

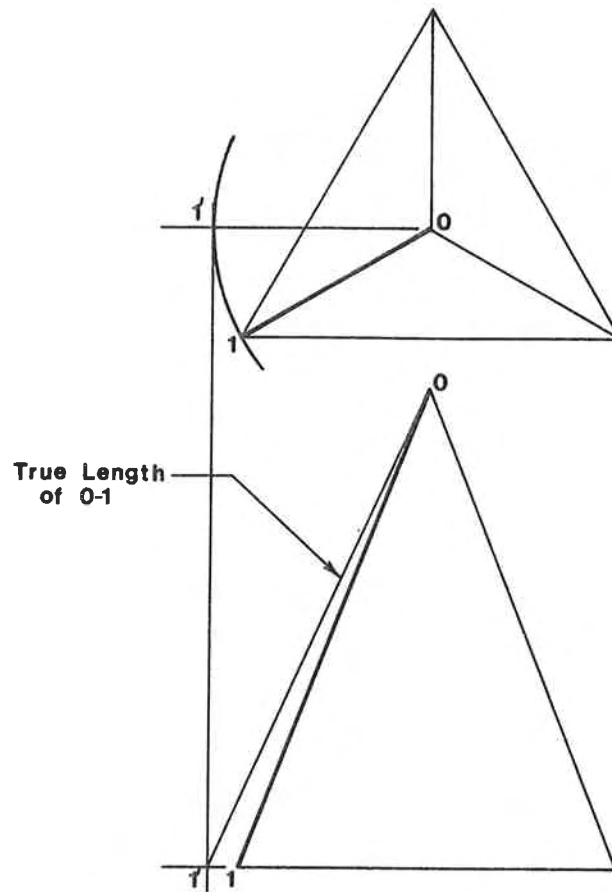


Figure 17-17 A supplementary layout which uses the revolution method to determine the true length of line 0-1.

- illustrated in Figure 17-17). In this example the revolution method was used. Regardless of which method you choose to use, the important thing to remember is that you must know exactly the true length of every line involved in the object.
2. Once the true length of all lines and the true shape of all surfaces have been determined, pick a point somewhere on the drawing and label it point 0. From point 0 draw an arc of radius 0-1. Mark a point 1 on the arc, and then draw in (using a very light layout line) line 0-1.
 3. From point 1 draw an arc of radius 1-2. Obtain the distance 1-2 from the orthographic views. Label the intersection of the large arc drawn from point 0 and the arc drawn from point 1 as point 2. Draw (using very light layout lines) lines 0-2 and 1-2.
 4. In a similar manner, complete the layout of the pyramid's flat pattern.
 5. Erase all excess lines and darken in the periphery of the flat pattern with heavy visible lines. Do not erase the lines that represent the folding lines of the pattern. The point labels may or may not be erased, depending on individual shop requirements.

This procedure may be used for any pyramid or cone problem.

GIVEN: An object.
 PROBLEM: Develop the flat pattern.

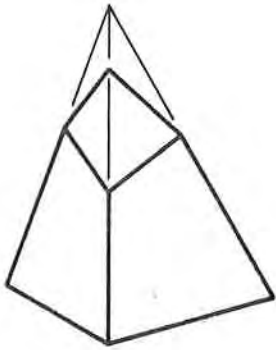


Figure 17-18

Figure 17-18 is a pyramid problem that includes an oblique surface. Figure 17-19 is the development drawing for the pyramid and was created by using the same procedure that was outlined for Figure 17-15. In this example we assume that the object has neither top nor bottom surfaces.

SOLUTION:

ALL Distances From
 Supplementary Layout

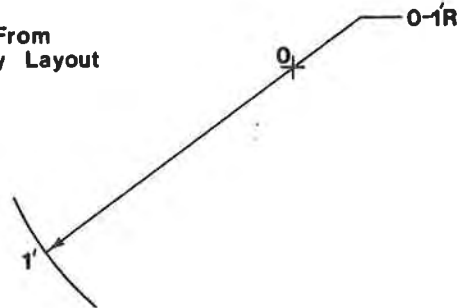


Figure 17-19(a)

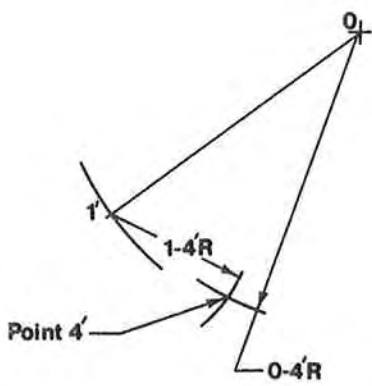


Figure 17-19(b)

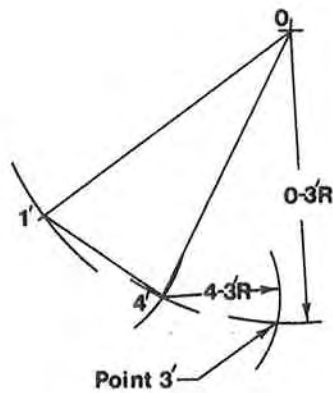


Figure 17-19(c)

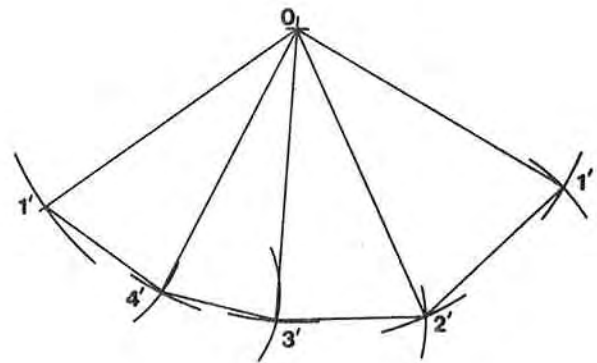


Figure 17-19(d)

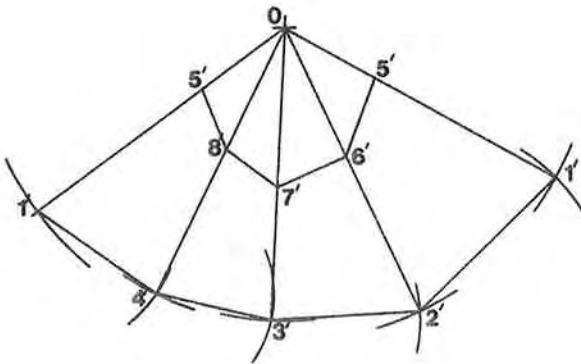


Figure 17-19(e)

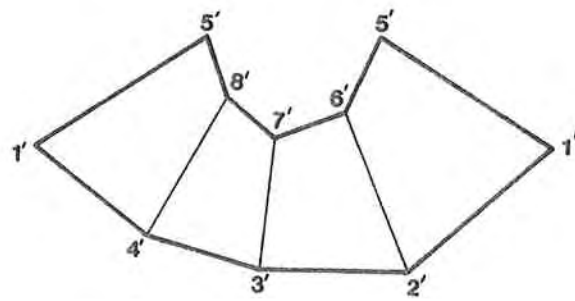


Figure 17-19(f)

As with other complicated problems, we may solve this problem by thinking of it in terms of the simpler components problems that comprise it. We can draw the basic flat pattern of the pyramid as was done for Figure 17-15 and then mark off on each leg the distance that represents the distance from the theoretical apex *O* to the oblique surface along that leg. To get these true distances, we start with the basic orthographic views and by using the revolution method outlined in Appendix A. For your convenience, the orthographic views, along with the appropriate revolution method layout lines, have been redrawn in Figures 17-20(a) and 17-20(b) so that you may see how each line was drawn. These supplementary layouts are commonly used by draftsmen to help insure accurate finished drawings.

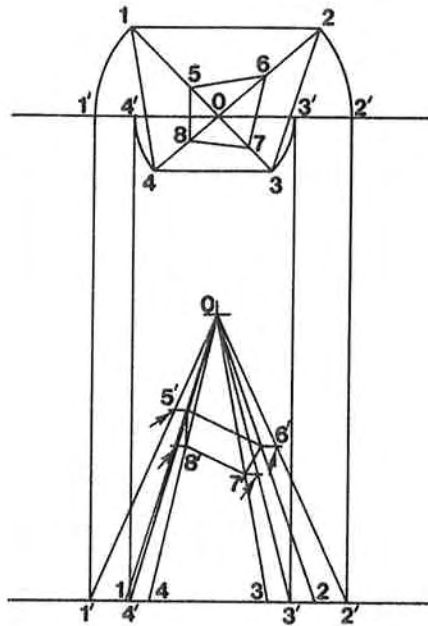
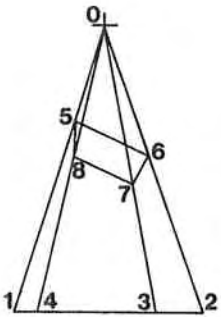
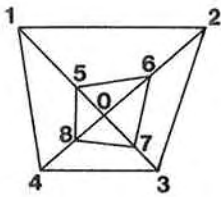


Figure 17-20(a) Supplementary layout used to determine the true length of all the legs.

Figure 17-20(b)

17-7 CONES

Figure 17-21 is an example of a problem that involves a cone. Figure 17-22 is the development drawing and was derived by using basically the same procedure as was outlined for Figure 17-15.

A unique feature of cones is that they have no natural edges to use as reference lines. To overcome this, we add theoretical lines as needed and work from them as if they were, in fact, edges on the object. In this example line *O-1* was added. Line *O-1* was located as shown because its top view is parallel to one of the principal plane lines. This means that its front view is true length (see Section 11-6 for further explanation). We need the true edge length of the cone in order to develop the flat pattern.

GIVEN: An object.
 PROBLEM: Develop the flat pattern.

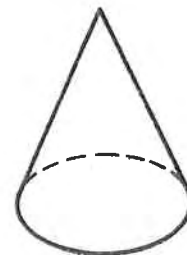


Figure 17-21

SOLUTION:

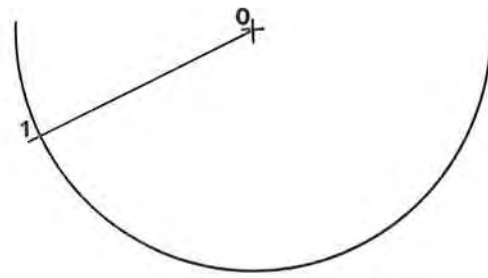
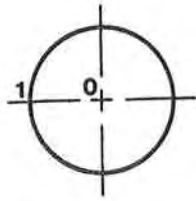


Figure 17-22(a)

The stretchout length of a cone's flat pattern, which is an arc, is found by the following equation:

$$SL = \frac{R}{TEL} (360^\circ) \quad (20-1)$$

where

- SL = stretchout length
- R = radius
- TEL = true edge length

This equation yields a value for SL in terms of *degrees*. This means that a protractor will be needed to lay out the SL value. The R/TEL part of the equation is a proportion between the radius of the flat pattern (equal to the true slant height of the cone) and the circumferential base distance of the cone. By multiplying this proportion by 360°, we can find out how many degrees of the full circle (360°) are needed for

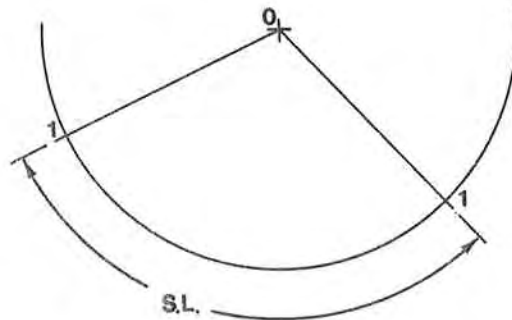
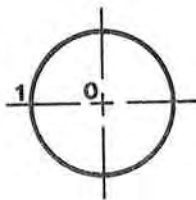


Figure 17-22(b)

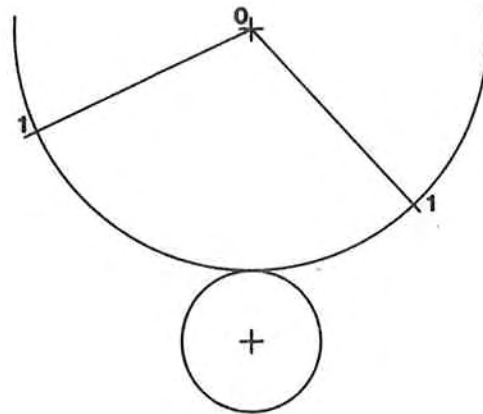
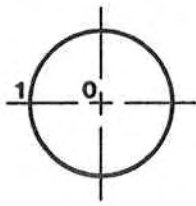


Figure 17-22(c)

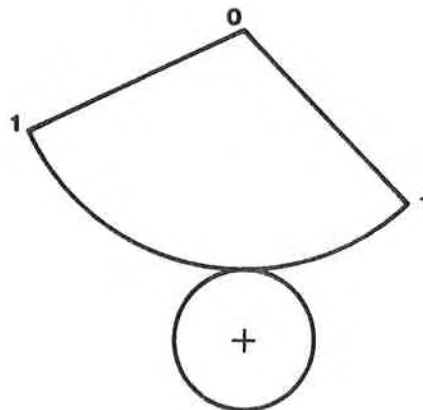
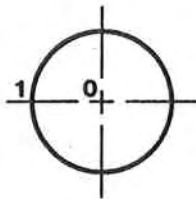


Figure 17-22(d)

the cone. In this example the slant height of the cone is 2.50 and the radius is 0.75. Substituting these values into Equation (20-1), we obtain

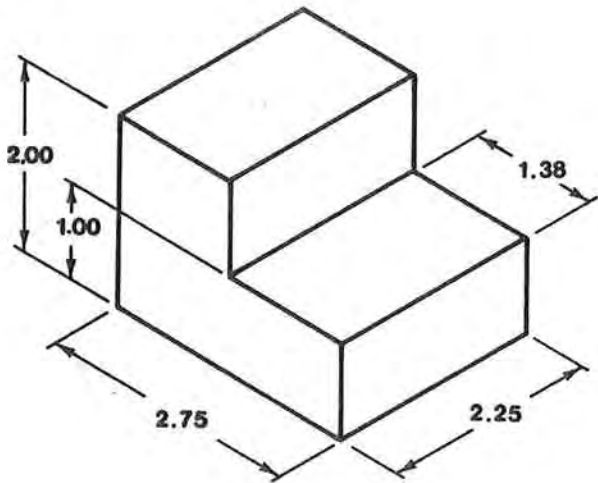
$$\begin{aligned}
 SL &= \frac{R}{TEL} (360^\circ) \\
 &= \frac{0.75}{2.50} (360^\circ) \\
 &= 0.30 (360^\circ) \\
 SL &= 108^\circ
 \end{aligned}$$

Therefore, the stretchout length, SL, is equal to 108°.

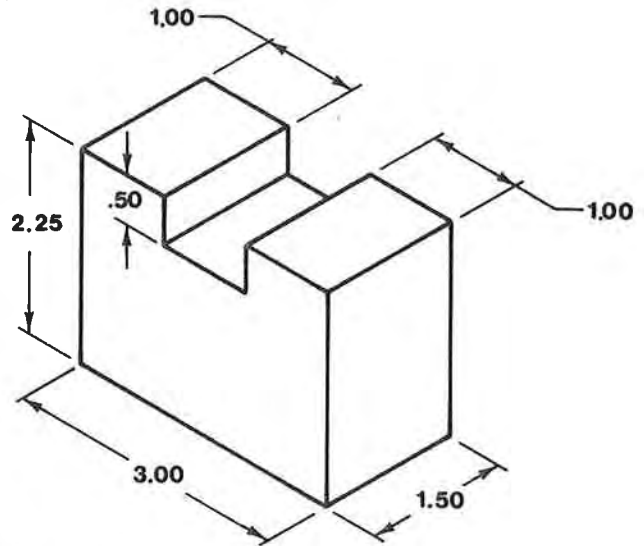
PROBLEMS

Develop the flat pattern for the following objects. Dimension the flat pattern. If assigned by your instructor, redraw the flat pattern onto heavy paper or cardboard and then cut out the pattern and fold it up to form a three-dimensional model.

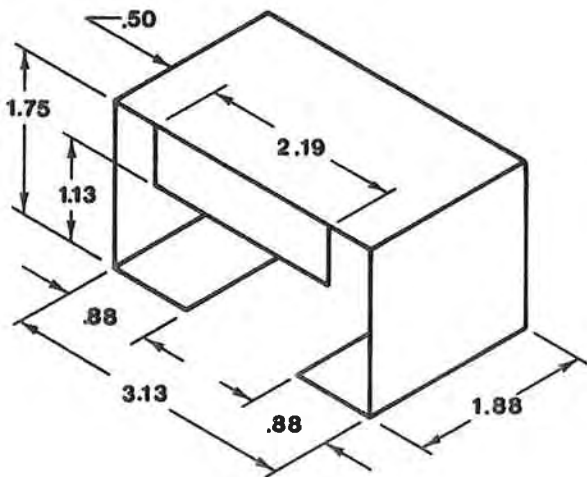
17-1



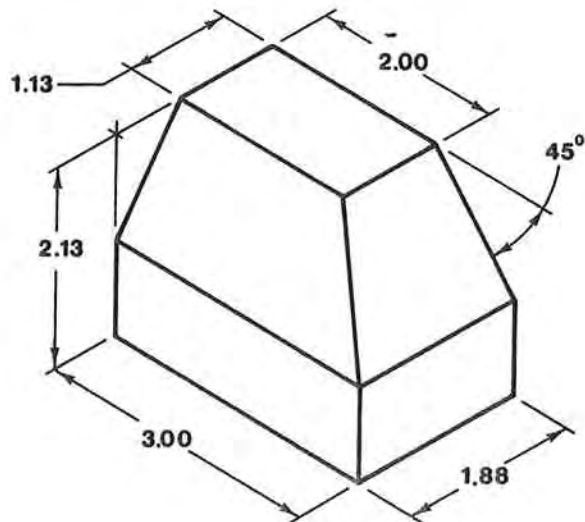
17-2



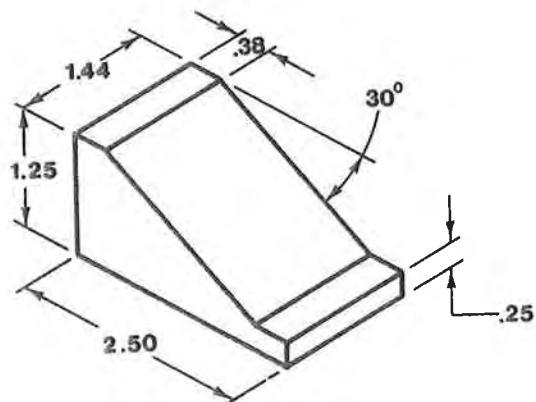
17-3



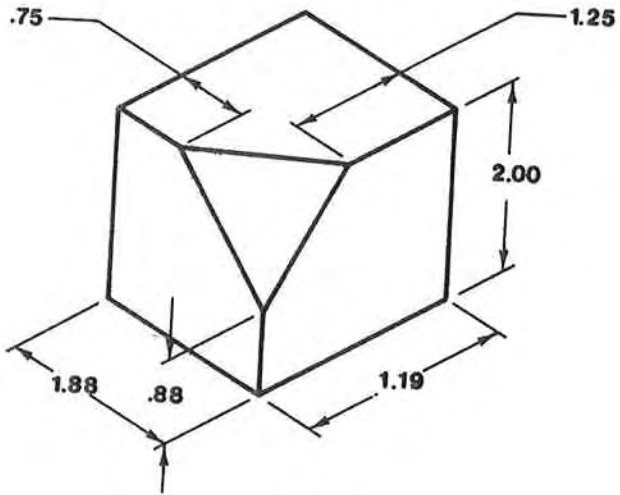
17-4



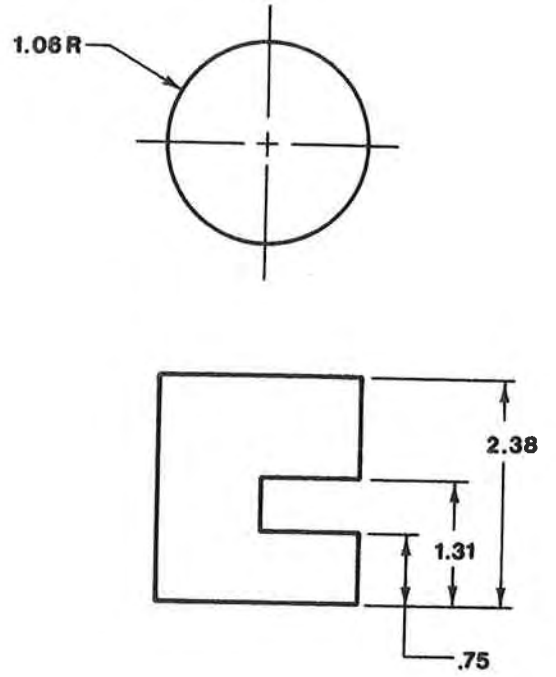
17-5



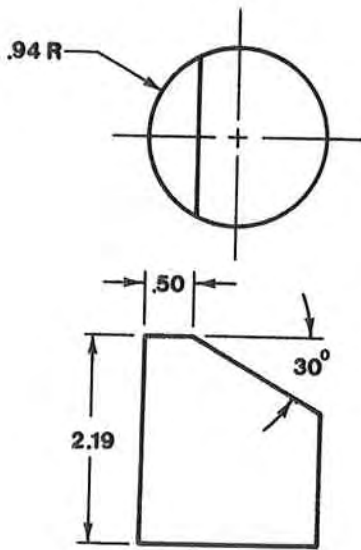
17-6



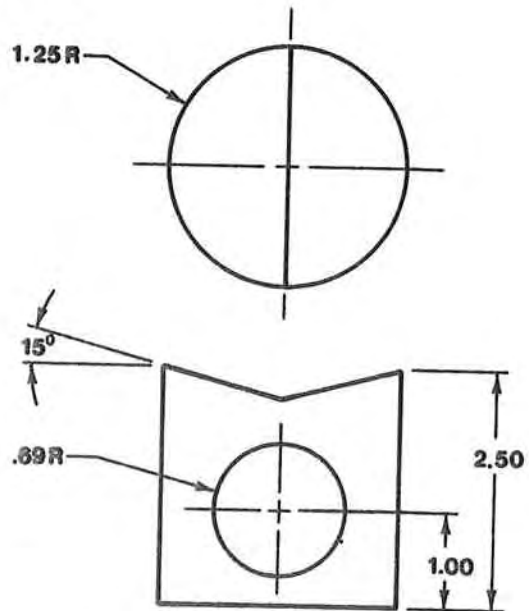
17-7



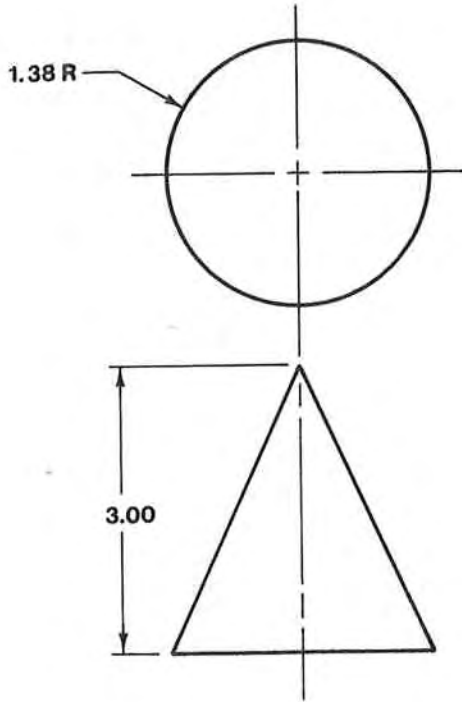
17-8



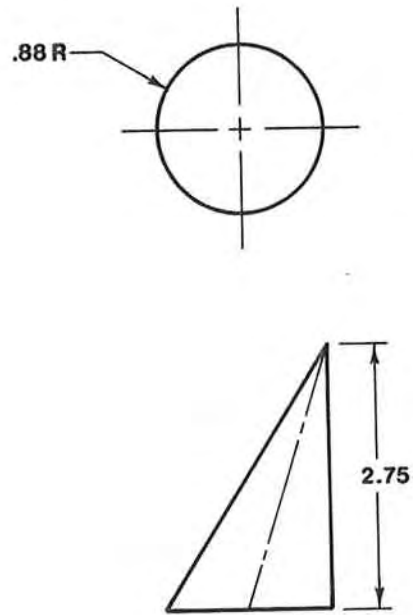
17-9



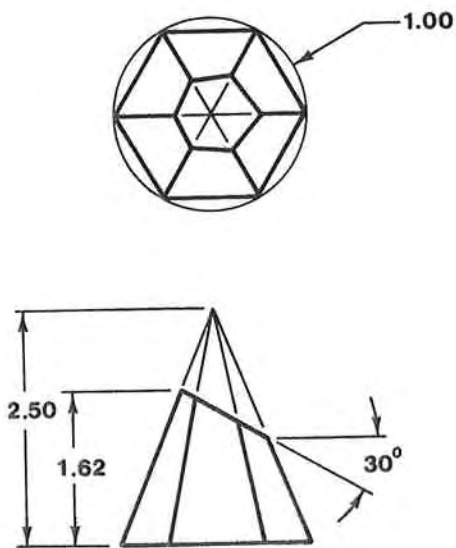
17-10



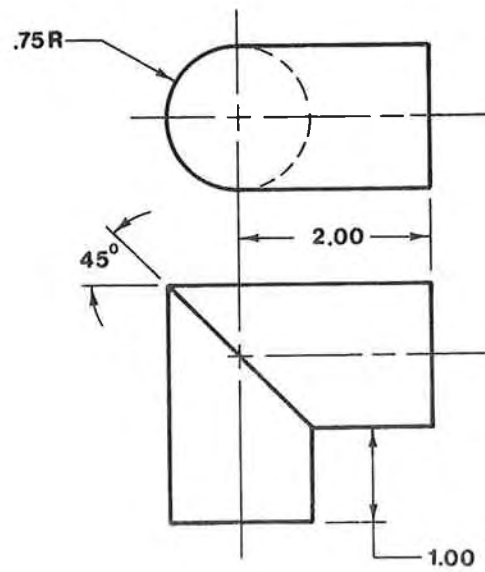
17-11



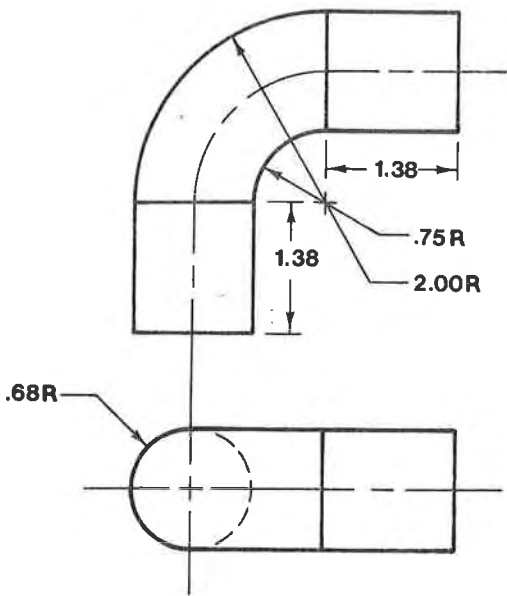
17-12



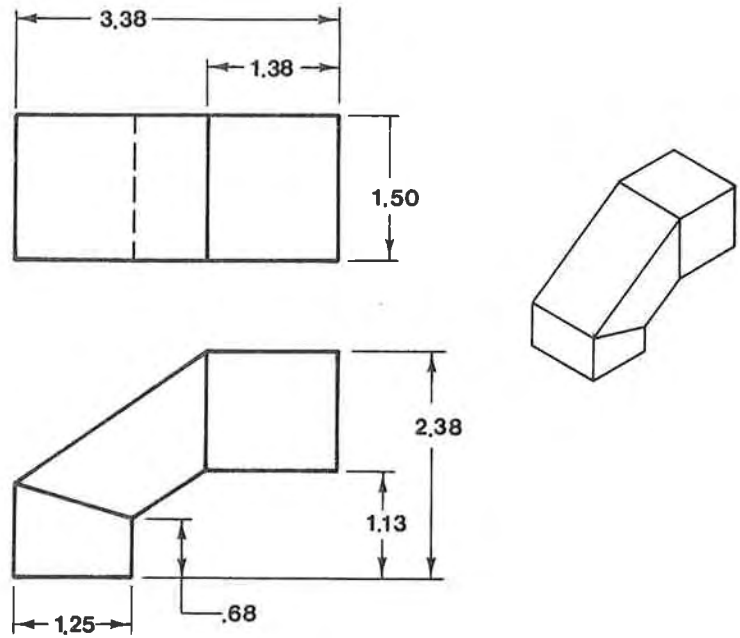
17-13



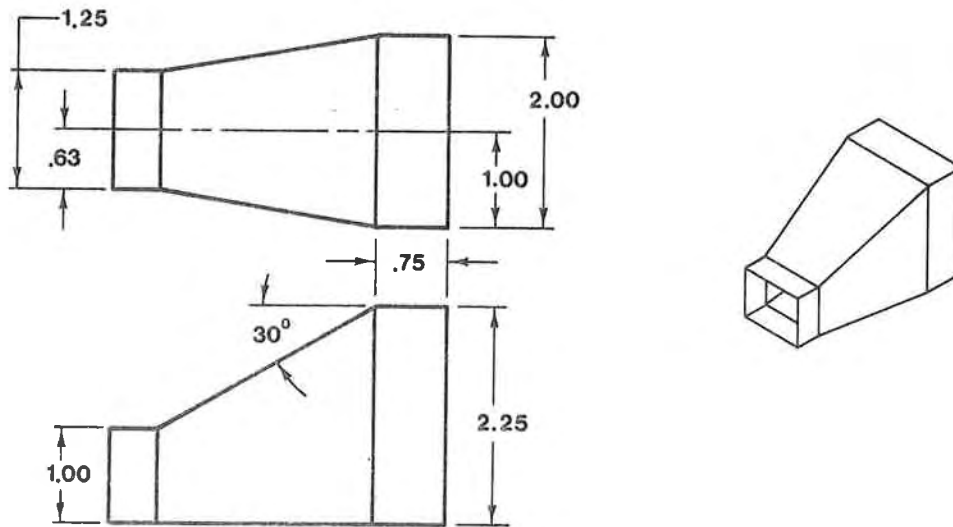
17-14



17-15



17-16



FINDING THE TRUE LENGTH OF A LINE BY USING THE REVOLUTION METHOD

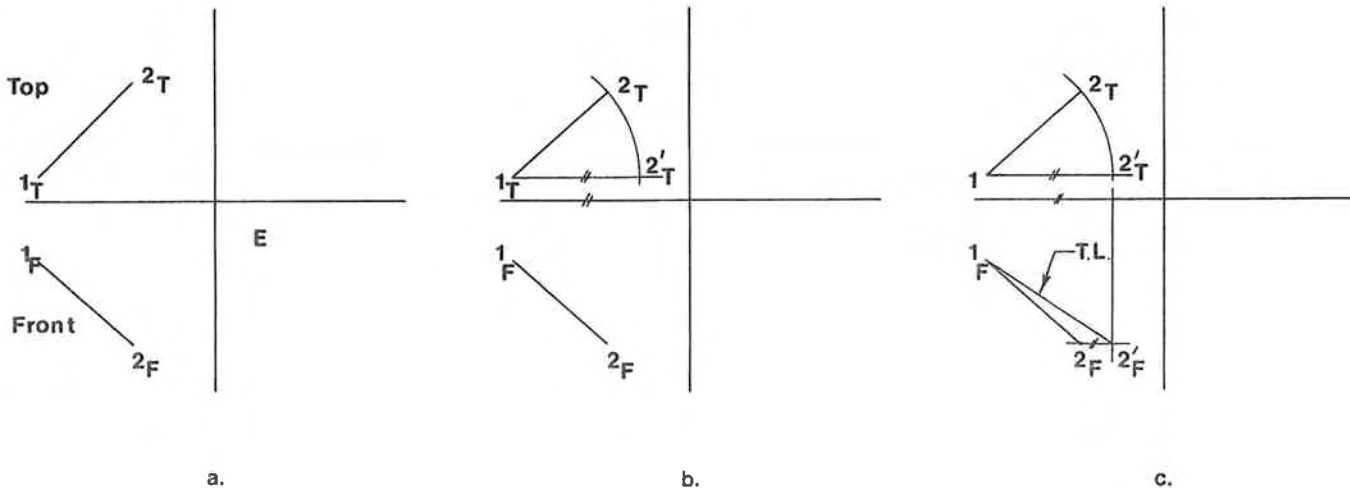
A

1. Define the line in at least two different orthographic views [Figure A-1(a)]. In any one of the views revolve the line so that it becomes parallel to one of the principal plane lines [Figure A-1(b)].

In the accompanying illustration a line was drawn in the top view parallel to the horizontal principal plane line through point 1_T and then point 2_T was rotated about point 1_T until it intersected this line. The intersection of the line parallel to the principal plane line and the rotation of point 2_T was labeled point $2'_T$.

2. Project the point rotated in step 1 into the other orthographic view so that it intersects a line drawn parallel to the principal plane line through the other view of the point. A line drawn from this point to the nonrotated point is the true length of the line [Figure A-1(c)].

In the accompanying illustration a line was drawn parallel to the principal plane line through point 2_F and point $2'_T$ was projected into the front view so that it intersected the parallel line as shown. This intersection was labeled $2'_F$. Line $1_F-2'_F$ is the true length of the line.



// Indicates parallel lines

Figure A-1

Figures A-2 and A-3 are further examples of the revolution method used to find the true length of a line.

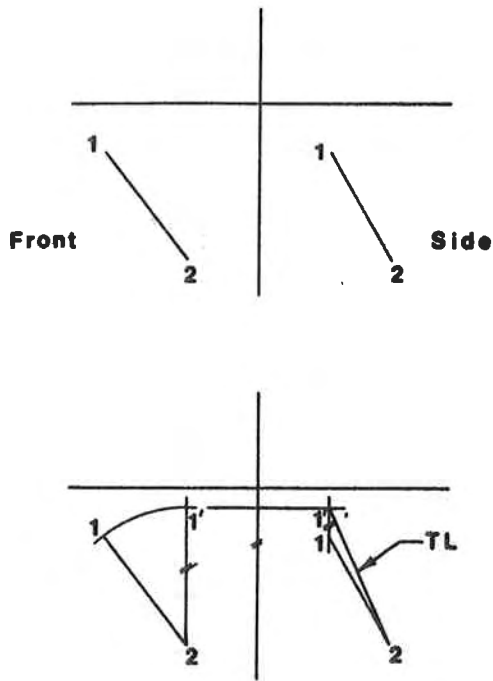


Figure A-2

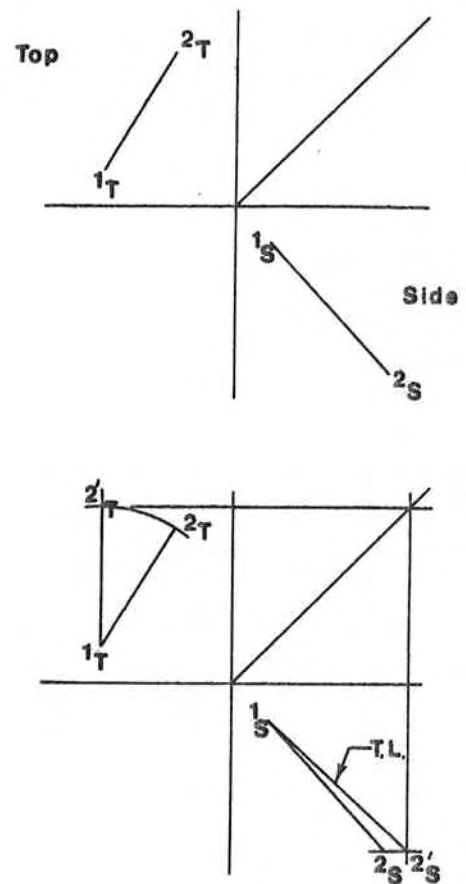
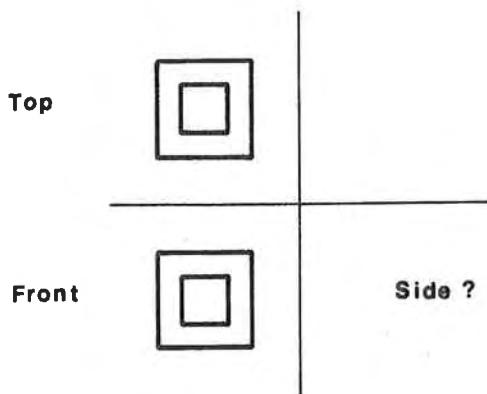


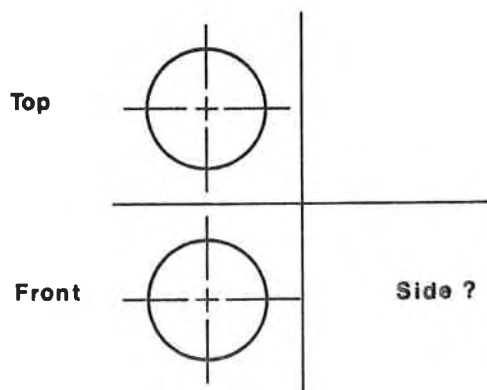
Figure A-3

GAME PROBLEMS **B**

This section has been included just for the fun of it. Like most skilled people, draftsmen enjoy games and puzzles that test and challenge their expertise; thus, they often try to stump one another with game problems. Three have been included here for you to test your skill. Try them and if you get stuck, write me and I'll send you the answers. Have fun!



Both are solid objects



Hollow object

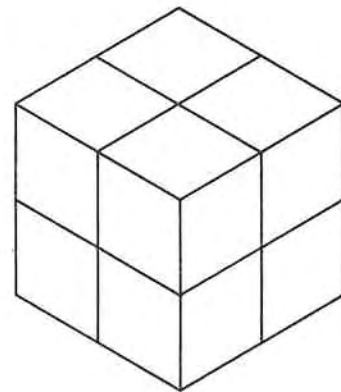


Figure B-1 The two problems on the left side of the page are missing view problems. The problem on the right side requires you to draw 8 hollow objects stacked as shown. Remember all the objects are hollow.

DRAFTING ART

C

This section presents samples of drafting art. Draftsmen may use their skill in geometric construction, line technique, and depth visualization to create anything from geometric design to illustration. They are limited only by their own imaginations and aggressiveness. Look over the examples presented here and try copying a few. Then make up your own creations.

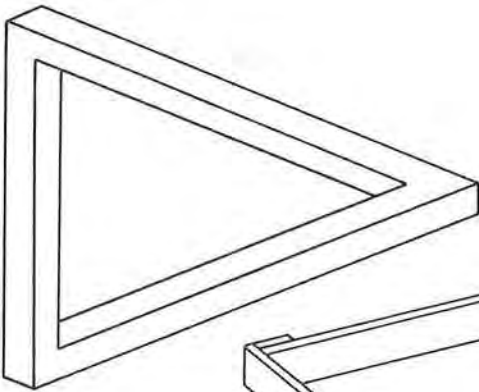


Figure C-1

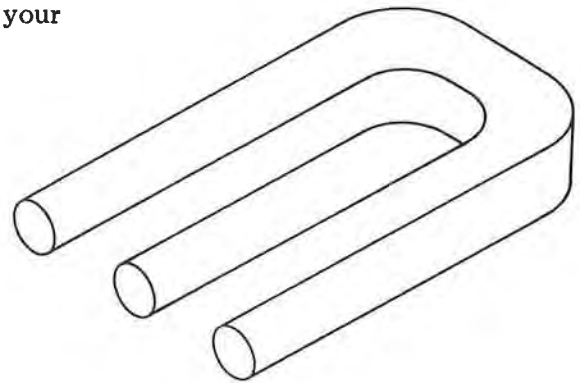


Figure C-2

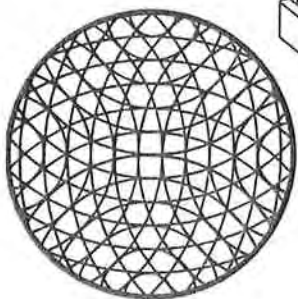


Figure C-4

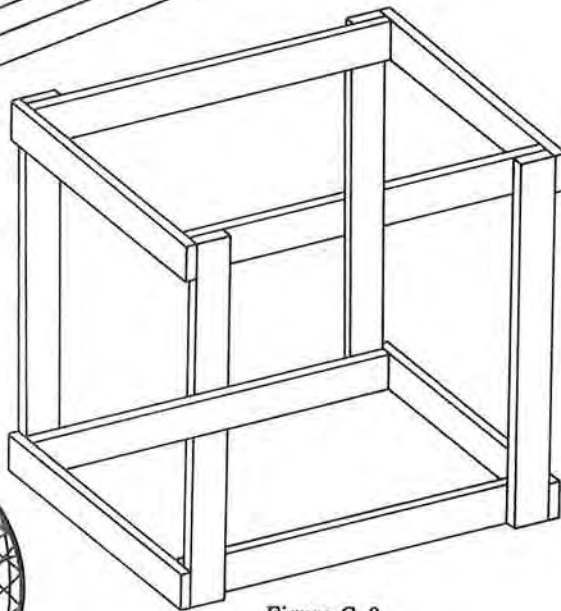


Figure C-3

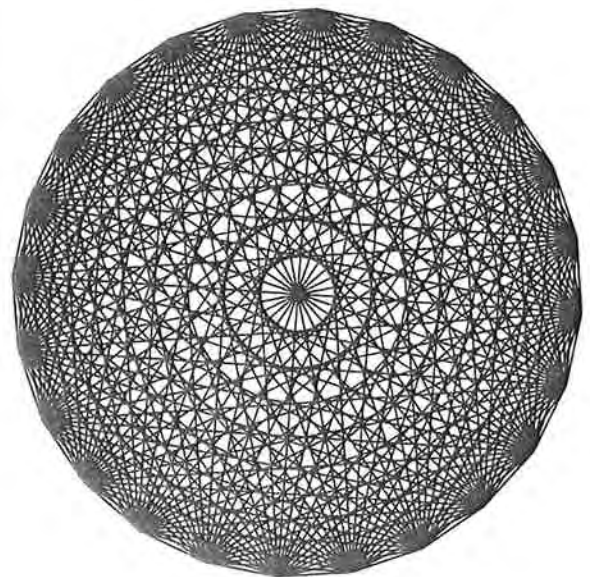


Figure C-5 (All straight lines.)

STANDARD THREAD SIZES

D

Whenever possible, a draftsman should call for standard thread sizes in his designs. Standard threads may be purchased from many different manufacturers, are completely interchangeable, and are relatively inexpensive when compared to "special" thread sizes.

Tables D-1 and D-2 are the UNC and UNF standards. To find the standard size for a given diameter, look up the diameter under the desired thread (UNC or UNF) and read the standard thread size adjacent to it. For example, a $\frac{1}{4}$ -diameter thread UNC has 20 threads per inch. The drawing call out would be

$$\frac{1}{4}\text{-}20 \text{ UNC}$$

A $1\frac{1}{4}$ UNF has 12 threads per inch and would be called out on a drawing as

$$1\frac{1}{4}\text{-}12 \text{ UNF}$$

The size numbers at the top of the tables are for small diameter threads. For example a #4 UNF has a diameter of 0.112 and 48 threads per inch. The drawing call out would be

$$\#4(0.112)\text{-}48 \text{ UNF}$$

Tables D-3 and D-4 define the 8 and 12 National (N) series thread. In each case, all diameters in the series are made with the same number of threads. All 8 series threads have 8 threads per inch. All 12 series threads have 12 threads per inch. For example, a $1\frac{7}{8}$ diameter series 8 thread would have a drawing call out

$$1\frac{7}{8}\text{-}8 \text{ UN}$$

TABLE D-1-UNC

Diameter	Threads Per inch (P)
1 (0.073)	64
2 (0.086)	56
3 (0.099)	48
4 (0.112)	40
5 (0.125)	40
6 (0.138)	32
8 (0.164)	32
10 (0.190)	24
12 (0.216)	24
1/4	20
5/16	18
3/8	16
7/16	14
1/2	13
1/2	12
9/16	12
5/8	11
3/4	10
7/8	9
1	8
1 1/8	7
1 1/4	7
1 3/8	6
1 1/2	6
1 3/4	5
2	4 1/2
2 1/4	4 1/2
2 1/2	4
2 3/4	4
3	4
3 1/4	4
3 1/2	4
3 3/4	4
4	4

TABLE D-2-UNF

Diameter	Threads Per inch (P)
0 (0.060)	80
1 (0.073)	72
2 (0.086)	64
3 (0.099)	56
4 (0.112)	48
5 (0.125)	44
6 (0.138)	40
8 (0.164)	36
10 (0.190)	32
12 (0.216)	28
1/4	28
5/16	24
3/8	24
7/16	20
1/2	20
9/16	18
5/8	18
3/4	16
7/8	14
1	12
1 1/8	12
1 1/4	12
1 3/8	12
1 1/2	12

TABLE D-3-Series 8

Diameter	Threads Per inch (P)
1 1/8	8
1 1/4	8
1 3/8	8
1 1/2	8
1 5/8	8
1 3/4	8
1 7/8	8
2	8
2 1/8	8
2 1/4	8
2 1/2	8
2 3/4	8
3	8
3 1/4	8
3 1/2	8
3 3/4	8
4	8
4 1/4	8
4 1/2	8
4 3/4	8
5	8
5 1/4	8
5 1/2	8
5 3/4	8
6	8

TABLE D-4-Series 12

Diameter	Threads Per inch (P)
1/2	12
5/8	12
1 1/16	12
3/4	12
1 3/16	12
7/8	12
15/16	12
1 1/16	12
1 3/16	12
1 5/16	12
1 7/16	12
1 5/8	12
1 3/4	12
1 7/8	12
2	12
2 1/8	12
2 1/4	12
2 3/8	12
2 1/2	12
2 5/8	12
2 3/4	12
2 7/8	12
3	12
3 1/8	12
3 1/4	12
3 3/8	12
3 1/2	12
3 5/8	12
3 3/4	12
3 7/8	12
4	12
4 1/4	12
4 1/2	12
4 3/4	12
5	12
5 1/4	12
5 1/2	12
5 3/4	12
6	12

Pilot Drill Sizes for Coarse and Fine Threads*

Nominal Thread Diameter		Coarse (UNC, NC)		Fine (UNF, NF)	
		Threads Per Inch	Pilot Drill Diameter	Threads Per Inch	Pilot Drill Diameter
.073	1	64	No. 53	72	No. 53
.086	2	56	No. 50	64	No. 50
.099	3	48	No. 47	56	No. 45
.112	4	40	No. 43	48	No. 42
.125	5	40	No. 38	44	No. 37
.138	6	32	No. 36	40	No. 33
.164	8	32	No. 29	36	No. 29
.190	10	24	No. 25	32	No. 21
.216	12	24	No. 16	28	No. 14
.250	1/4	20	No. 7	28	No. 3
.3125	5/16	18	F	24	I
.375	3/8	16	5/16	24	Q
.4375	7/16	14	U	20	25/64
.500	1/2	13	27/64	20	29/64
.5625	9/16	12	31/64	18	33/64
.625	5/8	11	17/32	18	37/64
.750	3/4	10	21/32	16	11/16
.875	7/8	9	49/64	14	13/16
1.000	1	8	7/8	12	59/64
1.125	1 1/8	7	63/64	12	1 3/64
1.250	1 1/4	7	1 7/64	12	1 11/64
1.375	1 3/8	6	1 13/64	12	1 19/64
1.500	1 1/2	6	1 21/64	12	1 27/64

*from ANS B1.1-1960

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