SHOP MATHEMATICS

CHAPTER 14

Hull Maintenance Technician

NAVEDTRA 14119

DEPARTMENT OF THE NAVY

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Preface

The intent of this document is to help potential welding inspectors with shop mathematics The intent is to help Welding inspectors get a brush up on their math skills as well as helping them understand the fundamentals of the four branches of mathematics as well as being able describe the metric system, and convert the English system to the metric and vice versa

With all that being said- this document is cut from Hull Maintenance Technician

NAVEDTRA 14119 DEPARTMENT OF THE NAVY written by the DEPARTMENT OF THE NAVY. What I did is go through the aforementioned document and "weed out" things that I deemed are not so relevant to what the average weld inspector needs to know about basic metallurgy

Bottom line- this document was written by the US Navy and I did some cutting to whittle it down to what is needed.

NONRESIDENT
TRAINING
COURSE

Hull Maintenance Technician

NAVEDTRA 14119

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

COURSE OVERVIEW: In completing this nonresident training course, you will demonstrate an understanding of course materials by correctly answering questions on the following: safety; ship repair; woodworking cuts and joints; small boat repair and deck coverings; tools and equipment; metallurgy; introduction to cutting and welding; oxyacetylene cutting and welding; brazing and braze welding; metal-are welding and cutting; nondestructive tests and inspection of welds; sheet metal layout and fabrication; structural steel fabrication; shop mathematics; piping systems; piping system repairs; and sewage systems.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

1995 Edition Prepared by
HTC Michael Smart
HTC Arnold L. Steber

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CHAPTER 14

SHOP MATHEMATICS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Identify the fundamentals of the four branches of mathematics, and describe how they are related to the Hull Technician rating.*
- *Describe the method of geometric construction.*
- *Describe the methods of construction for several plane figures.*
- *Determine the areas and volumes of geometric shapes and figures.*
- *Describe the metric system, and convert the English system to the metric system.*

INTRODUCTION

Mathematics is as important a tool for you to use as a Hull Technician as are manual skills and good tools. It is a universal language that lets you understand measurements and values written in any language. HTs are constantly working with measurements and calculating weights and quantities of materials. HTs develop geometric outlines. This chapter is not a complete text in ship mathematics. Instead, it is a review of the basic mathematical knowledge you will need as a Hull Technician.

Tables of weights, measures, and equivalents are useful references when you are solving mathematical problems. This chapter contains a number of tables that you will use frequently.

If you desire further study of mathematics, you should request the following manuals through your educational services office:

Mathematics, Volume 1, NAVEDTRA 10069-D1

Mathematics, Volume 2-A, NAVEDTRA 10062-B

Mathematics, Volume 2-B, NAVEDTRA 10063

Mathematics, Volume 3, NAVEDTRA 10073-A1

FUNDAMENTALS OF MATHEMATICS

The basics of mathematics remain the same no matter what the field. Mathematics is divided into several different branches. You will be concerned with arithmetic, algebra, geometry, and trigonometry.

Arithmetic deals with the manipulation of numbers, using addition, subtraction, multiplication, and division.

Algebra uses letters and symbols in place of numbers and values. These letters and symbols construct equations that follow established mathematic rules.

Geometry investigates the relationships, properties, and measurements of solids, plane surfaces, lines, angles, graphs, and other geometric characteristics.

Trigonometry investigates the properties of triangles and of trigonometric functions and their applications.

COMMON FRACTIONS

Common fractions are often used in sheet metal layout, woodworking, piping repairs, and structural repairs. Most of your measuring devices, such as the shrink rule, are divided into common fractional increments.

The common fraction is a simple method of expressing the division of a whole number or object. Fractions show one or more parts divided into any number of equal parts. Examples are dividing 1 inch into four equal parts or dividing a line into four equal parts. These equal parts are expressed as increments of one—fourth. You know that four increments equal the whole number or object. You can write any part less than the whole as a common fraction, such as l/4 or 3/4.

The common fraction contains two parts—the denominator and the numerator. The denominator shows how many equal parts the whole divides into. The numerator shows the number of equal parts being considered.

Example: $\dfrac{5 \text{ (Numerator)}}{8 \text{ (Denominator)}}$

DECIMAL FRACTION

A decimal fraction is a fraction whose denominator is 10 or some multiple of 10, such as 100, 1,000, or 10,000. *Decimal fractions differ from common fractions in that the denominators are not written but are expressed by place value.* Figure 14-1, views A and B, shows a place value chart. As we proceed from left to right in place value, the value of each place is one-tenth the value of the preceding place. Notice in views A and B that the units place is the center of the system and that the place values proceed to the right or left by powers of ten. Ten on the left is replaced by tenths on the right, hundreds by hundredths, thousands by thousandths, and so on. Notice that each decimal fraction begins with a period. This period is called a decimal point. To call attention to the decimal point, we usually begin the decimal fraction with a zero.

Examples of decimal fractions, their equivalent common fractions, and how you read them are as follows:

$0.3 = \dfrac{3}{10}$ = three tenths

$0.07 = \dfrac{7}{100}$ = seven hundredths

$0.023 = \dfrac{23}{1000}$ = twenty–three thousandths

$0.1276 = \dfrac{1276}{10000}$ = one thousand two hundred seventy–six ten–thousandths

A mixed decimal is an integer and a decimal fraction combined. We use a decimal point to separate the integer portion from the decimal fraction portion.

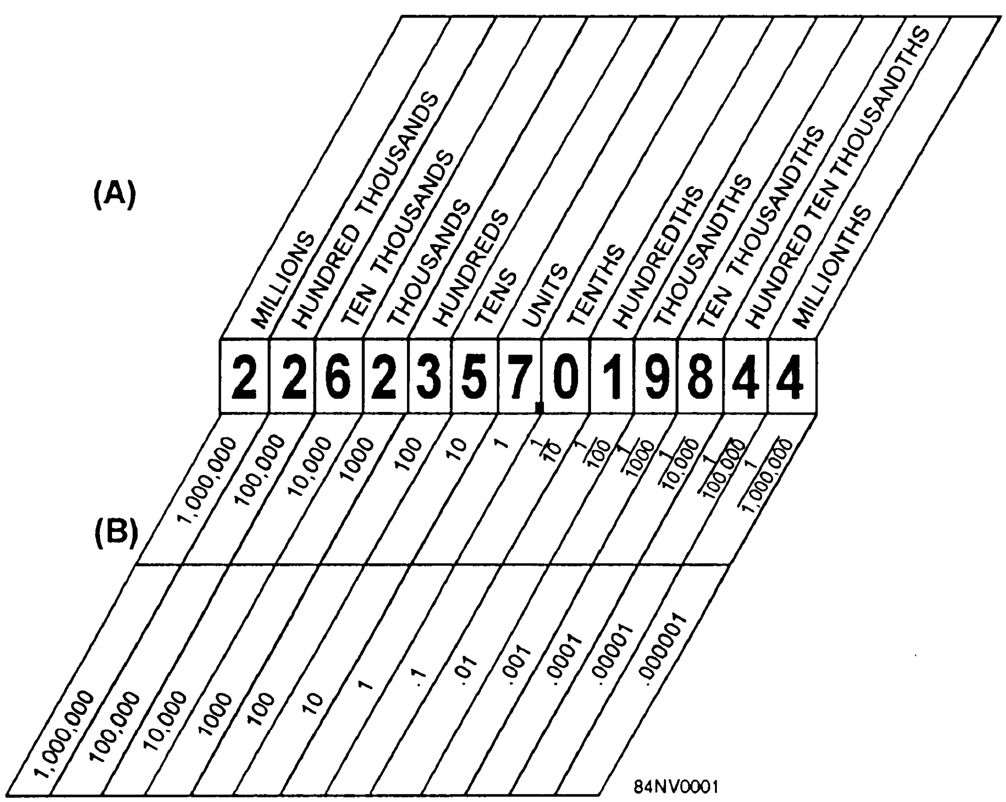


Figure 14-1.—Place value chart.

The following are examples of mixed decimals, their equivalent mixed numbers, and how they are read:

$160.32 = 160\frac{32}{100} =$ one hundred sixty and thirty–two hundredths

$21.005 = 21\frac{5}{1000} =$ twenty–one and five thousandths

A decimal is any number written with a decimal point, which includes decimal fractions and mixed decimals. For the rest of the manual, we will refer to decimal fractions and mixed decimals as decimals.

Equivalent Decimals

From our study of fractions, it should be clear that

$$\frac{5}{10} = \frac{50}{100} = \frac{500}{1000}$$

Writing the same values as decimals would be equivalent to

0.5 = 0.50 = 0.500

In other words, the value of a decimal is not changed by attaching zeros to the right of any decimal point after the last digit.

Converting Fractions to Decimals

One way to convert a fraction to a decimal is to divide the numerator by the denominator. To obtain our answer, we will attach as many zeros after the understood decimal point in the numerator as needed, since we have determined this will not change the value of our numerator.

Example: Convert 3/5 to a decimal.

Solution:

```
  0.6
5)3.0
  0
  30
  30
   0
```

So the answer is 3/5 = 0.6. Notice that the decimal point in the quotient was placed directly above the decimal point of the number we are dividing into.

Example: Convert -7/32 to a decimal

Solution:

```
      -0.21875
32 )(-)7.00000
       0
       70
       64
        60
        32
        280
        256
         240
         224
          160
          160
            0
```

Therefore, -7/32 = -0.21875.

Example: Convert 51/8 to a decimal.

Solution:

```
  6.375
8)51.000
  48
   30
   24
    60
    56
     40
     40
      0
```

Hence, 51/8 = 6.375.

The answers in the examples just covered were all considered terminating decimals since each quotient terminated or ended. A repeating decimal will have a repeating pattern and never terminate.

Example: Convert l/3 to a decimal.

Solution:

```
  0.333...
3)1.000
   9
   10
    9
    10
     9
     1
```

As you can see, there is a repeating pattern of 3. We will represent the repeating digits with a bar over the repeating pattern. Therefore, l/3 = $0.\overline{3}$.

Example: Convert -25/11 to a decimal.

Solution:

$$
\begin{array}{r}
-2.2727\ldots \\
11\overline{)(-)25.0000} \\
\underline{22} \\
3\,0 \\
\underline{2\,2} \\
80 \\
\underline{77} \\
30 \\
\underline{22} \\
80 \\
\underline{77} \\
3
\end{array}
$$

Hence, -25/11 =2.$\overline{27}$.

You may find it of interest to know that if the denominator of a common fraction reduced to lowest terms is made up of prime factors of just 2s or just 5s or both, the fraction can be converted to an exact or terminating decimal.

Another way to convert a fraction to a decimal is to express the fraction as an equivalent fraction whose denominator is a multiple of 10, such as 10, 100, 1000. Then, change the fraction to adecimal. You will always get a terminating decimal with this method.

Example: Convert 3/4 to a decimal.

Solution:

$$\frac{3}{4}=\frac{3\times 25}{4\times 25}=\frac{75}{100}=0.75$$

Example: Convert -47/200 to a decimal.

Solution:

$$\frac{-47}{200}=\frac{-47\times 5}{200\times 5}=\frac{-235}{1000}=-0.235$$

Example: Convert -11/8 to a decimal.

Solution:

$$\frac{-11}{8}=\frac{-11\times 125}{8\times 125}=\frac{-1375}{1000}-1\frac{375}{1000}=-1.375$$

Example: Convert 102/25 to a decimal.

Solution:

$$\frac{102}{25}=\frac{102\times 4}{25\times 4}=\frac{408}{100}=4\frac{8}{100}=4.08$$

In the two previous examples, the fractions could have been expressed as mixed numbers and then converted to decimals. To convert a mixed number to a decimal, leave the integer portion as it is and convert the fractional portion to a decimal.

Example: Convert -15 2/5 to a decimal.

Solution:

$$-15\frac{2}{5}=\left[15+\left(\frac{2\times 2}{5\times 2}\right)\right]=-15\frac{4}{10}=-15.4$$

Example: Convert 2 5/16 to a decimal.

Solution:

$$2\frac{5}{16}=2+\left(\frac{5\times 625}{10\times 1000}\right)=2+\left(\frac{3125}{10000}\right)=2.3125$$

Example: Convert 3 5/6 to a decimal.

Solution: Since the denominator 6 is not made up of just 2s or just 5s or both, we will have to divide 6 into 5 to obtain a repeating decimal and then add 3 to our answer.

$$
\begin{array}{r}
0.83333\ldots \\
6\overline{)5.0000} \\
\underline{4\,8} \\
20 \\
\underline{18} \\
20 \\
\underline{18} \\
20 \\
\underline{18} \\
2
\end{array}
$$

Therefore, 3 5/6 = 3.$\overline{83}$.

Example: Convert -61 13/15 to a decimal.

Solution:

$$
\begin{array}{r}
0.8666\ldots \\
15\overline{)13.0000} \\
\underline{12\,0} \\
1\,00 \\
\underline{90} \\
100 \\
\underline{90} \\
100 \\
\underline{90} \\
100 \\
\underline{90} \\
10
\end{array}
$$

Therefore, -61 13/15 = -61.$\overline{86}$.

We could also convert a fraction to a decimal to a particular decimal place.

Example: Convert 25/16 to a decimal to the nearest tenth.

Solution:

$$\frac{25}{16}=\frac{25\times 625}{16\times 625}=\frac{15625}{10000}=1.5625$$

So, 25/16 = 1.6 to the nearest tenth.

Example: Convert -72 5/11 to a decimal to the nearest hundredth.

Solution: In this case, you would divide 5 by 11 to one place past the desired place value of hundredths and then round.

$$\begin{array}{r} 0.454 \\ 11\overline{)5.000} \\ \underline{4\,4} \\ 60 \\ \underline{55} \\ 50 \\ \underline{44} \\ 6 \end{array}$$

So, -72 5/11 = -72.45 to the nearest hundredth.

Converting Terminating Decimals to Fractions

To convert a terminating decimal to a fraction, count the number of digits to the right of the decimal point. Move the decimal point that many places to the right, and write the answer you get over a denominator beginning with 1 followed by as many zeros as places moved to the right. Reduce to lowest terms, if possible.

Example: Convert 0.77 to a fraction.

Solution: The number of digits to the right of the decimal point is 2. Therefore, we will move the decimal point 2 places to the right and place 77 over 100. So

$$0.77 = \frac{77}{100}$$

Example: Convert -0.045 to a fraction and reduce to lowest terms.

Solution:

$$-0.045 = \frac{-45}{1000}$$

$$= \frac{-9}{200}$$

When converting mixed decimals to fractions, you will usually find it is easier to keep the integer portion as an integer and change the decimal fraction to a common fraction.

Example: Convert 12.625 to a fraction and reduce to lowest terms.

Solution:

$$12.625 = 12\frac{625}{1000}$$

$$= 12\frac{5}{8}$$

Example: Convert -200.4 to a fraction and reduce to lowest terms.

Solution:

$$-200.4 = -200\frac{4}{10}$$

$$= -200\frac{2}{5}$$

Converting Repeating Decimals to Fractions

Converting a repeating decimal to a fraction is a little more confusing than the conversions we have previously performed. A repeating decimal can be converted to a fraction by the following steps:

1. Form an equation letting n equal the repeating decimal.
2. Multiply both sides of the equation by a multiple of 10 in order to shift a set of the repeating pattern.
3. Subtract the original equation from the new equation (in step 2).
4. Solve for *n* and reduce to lowest terms.

Example: Convert $0.\overline{2}$ to a fraction.

Solution: First, let n equal the repeating decimal, or

$n = 0.222...$

Second, multiply both sides of the equation by 10 since there is only one digit in the repeating pattern. Hence,

$10n = 2.222...$

Third, subtract the original equation from the new equation. That is,

$$\begin{array}{r} 10n = 2.222... \\ -\quad n = 0.222... \\ \hline 9n = 2.000... \end{array}$$

Fourth, solve for *n.*

$9n = 2$

$$\frac{9n}{9} = \frac{2}{9}$$

$$n = \frac{2}{9}$$

Therefore, $0.\overline{2} = 2/9$.

Example: Convert $5.\overline{63}$ to a fraction and reduce to lowest terms.

Solution: Let

$n = 5.636363...$

Multiply both sides by 100, since there are two repeating digits.

$100n = 563.636363...$

Subtract the original equation from the new equation.

$$\begin{array}{r} 100n = 563.636363... \\ -\quad n = \quad 5.636363... \\ \hline 99n = 558 \end{array}$$

Solve for n and reduce to lowest terms.

$$99n = 558$$

$$\frac{99n}{99} = \frac{558}{99}$$

$$n = \frac{558}{99} = \frac{62}{11} \text{ or } 5\frac{7}{11}$$

Hence, $5.\overline{63} = 57/11$.

For the previous problem we could have kept the integer portion as an integer and converted the repeating decimal to a fraction.

Example: Convert $-38.\overline{054}$ to a fraction and reduce to lowest terms.

Solution: We will retain -38 and work with .

$$\begin{array}{r} 1000n = 54.054054... \\ -\quad n = \quad 0.054054... \\ \hline 999n = 54 \end{array}$$

$$n = \frac{54}{999} = \frac{2}{37}$$

Therefore, $-38.\overline{054} = -38\ 2/37$.

Example: Convert $-12.\overline{637}$ to a fraction.

Solution:

$$\begin{array}{r} 100n = 63.73737... \\ -\quad n = \quad 0.63737... \\ \hline 99n = 63.1 \end{array}$$

$$n = \frac{63.1}{99} = \frac{631}{990}$$

Hence, $-12.\overline{637} = -12\ 631/990$.

PERCENTAGE

Percentage is the expression of numbers in hundredths. The percent sign (%) is used to show percentage. Three terms apply to percentage problems—*base*, *rate*, and *percentage*. The base is the number upon which a percent is calculated. The rate is the amount of the percent. The percentage is the result of the calculations made with the base and rate. For example, 2% of $125.00 equals $2.50. The rate is 2%. The base is $125.00. The percentage is $2.50.

Percentage is calculated as a decimal fraction. Therefore, the rate must be a decimal fraction. For example, 2% and 25% are equal to 2/100 and 25/100, respectively. Convert these to 0.02 and 0.25, respectively. Write a rate of 100% as 1.00, 225% as 2.25, and so on.

RATIO AND PROPORTION

You can use ratio and proportion to solve problems quickly and reduce the chances of error.

Ratio

A ratio is a method of comparing two numbers or values in fractional form. For example, a fast frigate has a top speed of 30 knots and a cargo ship has a top speed of 15 knots. You can easily compare their speeds. This comparison can be written as 30:15 and 30/15. This makes the fractional form easier to calculate. To simplify the comparison, you reduce the fraction 30/15 to its simplest form of 2/l. Now, you can use this fraction form of a comparison very easily when calculating.

Comparison by a ratio is limited to quantities of the same kind. To express the ratio between 6 feet and 3 yards, both quantities must be in like terms. The proper forms of this ratio would be either 2 yards:3 yards or 6 feet:9 feet. Mathematically, like terms cancel each other. The yards or feet would cancel each other and the resulting ratio would read 2:3 or 6:9.

Proportion

Closely related to the study of ratio is the subject of proportion. The term *proportion* is defined as a relation of equality. A proportion is nothing more than an equation of two ratios that are equal to each other. Proportion can be written in three different ways, as shown in the following examples:

Example 1: 15:20::3:4

Example 2: 15:20 = 3:4

Example 3: $\frac{15}{20} = \frac{3}{4}$

As shown in the examples, a proportion is nothing more than an equation of common fractions. The value of proportion is that if any three of the terms are given, the fourth or unknown term can be found. This is done by solving a simple problem of common fractions.

GEOMETRIC CONSTRUCTION

Patterns are geometric shapes that conform to a draftsman's plan (blueprint) and contain allowances for draft, shrinkage, and machine finish. To construct a pattern, you must solve graphics problems of geometric construction. Graphics problems can be solved by trial and error or by measuring with a scale. However, neither method is accurate; therefore, they cannot be used in patternmaking. Because of its accuracy, only the geometric method of construction should be used in patternmaking. No other method is acceptable.

NOTE: You will need specific tools to USC during geometric construction. Sonic of these tools include a pencil divider, a 12-inch scale, a flexible straightedge, a 30- to 60-degree triangle, and a T-square.

As you read about geometric construction, the discussion will contain some geometric terms that you should know. These terms arc defined as follows:

Angle—A figure formed by two lines converging on a common point .

Apex—The highest point of a triangle.

Arc—A portion of a circle or curve.

Bisect—To divide into two equal parts.

Circumference—The distance around a circle, ellipse, or closed curve.

Curve—Any geometric line or shape that is not straight, contains no angles, and does not form a closed figure.

Diameter—The distance from a point on the circumference of a circle, through the center, to the opposite point on a circle.

Hypotenuse—The side of a right triangle that is opposite the right angle.

Intersect—To meet and cross at a point or series of points. Two lines intersect at one point. Two plants intersect at a series of adjacent points (which is the definition of a line).

Parallel—Maintaining an equal distance at all points on two or more lines or plants.

Perpendicular—Right angles (90°) to a line or plane.

Plane—A two—dimensional geometric figure.

Point—The intersection of two lines. A point has no dimensions.

Polygon—Any closed figure having three or more sides.

Radius—The distance from the center of a circle to the circumferece of that circle (one-half of the diameter).

Tangent—A curved or straight lint that touches but does not cross another curved or straight line at a point other than its ends.

Vertex—The point of intersection of two lines forming an angle.

BISECTING A LINE

As you read this section, refer to figure 14-2. You arc going to learn how to bisect a line by using the following steps:

1. USC your dividers and adjust them with a spread that is visually greater than one-half the length of the line.
2. Insert one point of the dividers at one end of the line (point A, view A) and draw an arc. Be careful not to change the adjustment on the dividers.
3. Insert one point at the other end of the line (point B, view B) and draw an arc from that end intersecting the first arc.
4. Draw a straight line connecting the two intersection points of the arcs to bisect the line (view C).

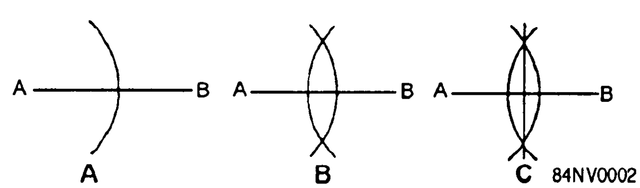


Figure 14-2.—Bisecting a line.

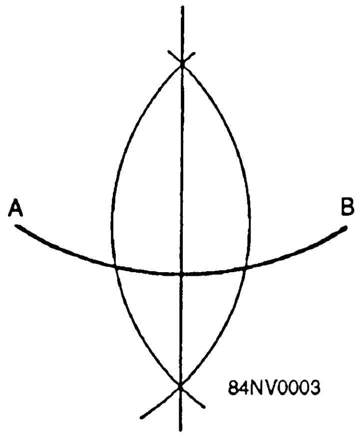


Figure 14-3.—Bisecting an arc.

BISECTING AN ARC

To bisect an arc, you should follow the same steps as those given for bisecting a line. Use the ends of the arc (points A and B in fig. 14-3) as centers for the arcs that intersect.

BISECTING AN ANGLE

Look at figure 14-4 as you read about bisecting an angle. Use the following steps to bisect an angle:

1. Use the vertex of the angle as the center for one point of the dividers. Draw arcs cutting the legs of the angle (view A).
2. Use the intersections of the arcs and the legs as centers to draw arcs that intersect each other inside the angle (view B).
3. Connect the intersection point of these last two arcs with the vertex of the angle to bisect the angle (view C).

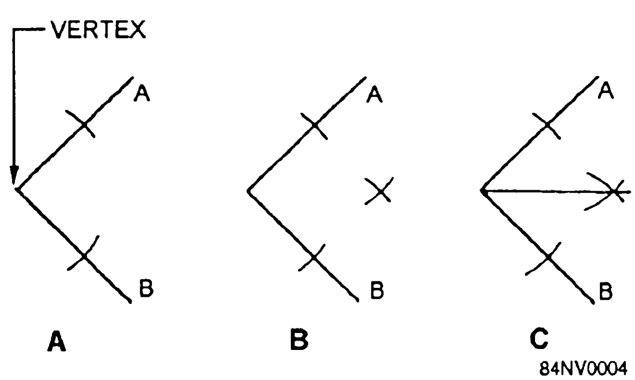


Figure 14-4.—Bisecting an angle.

COPYING OR TRANSFERRING AN ANGLE

A simple geometrical method can be used to copy or transfer an angle. Figure 14-5 shows you how to do this. To use this method, use the following steps to copy angle AOB onto base line B´O´:

1. Insert one point of the dividers at point 0 (view A). Adjust the other leg to intersect line A´O´ at a distance that is convenient to work with.
2. Draw an arc that intersects both legs of the angle (view A).
3. Look at view B. Without changing the adjustment on the dividers, place the point on point O´ and draw an arc intersecting the base line.
4. Look at view C. Use the dividers to measure between the legs of the angle where the arc cuts the legs. Transfer this measurement to line O´B´ by placing one point of the dividers at the intersection of line O´B´ and the transferred arc. Draw a short arc that intersects the transferred are (view C).
5. Connect the intersection point of the two arcs to point O´ to draw leg A´O´ and form A´O´B´ (view D).

DIVIDING A LINE INTO FIVE EQUAL PARTS

You may wonder, why not just measure and divide into the required number of parts? This is not a very

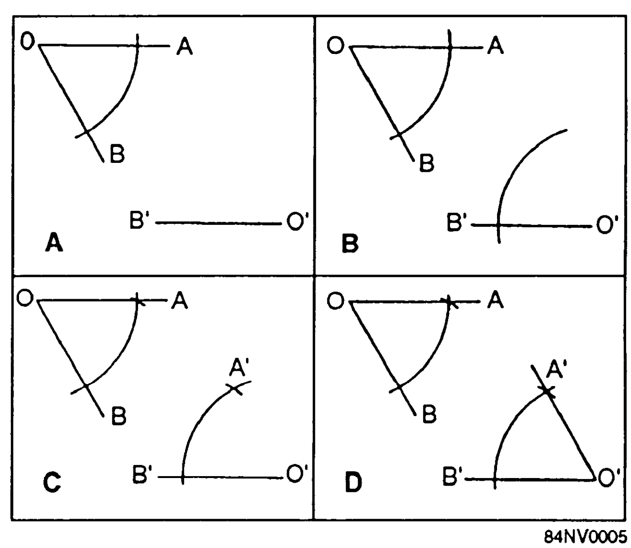


Figure 14-5.—Copying an angle.

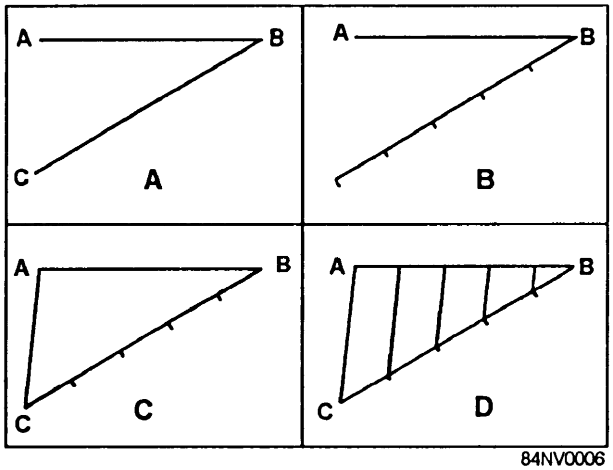


Figure 14-6.—Dividing a line geometrically.

accurate way to divide a line. A more accurate division can be made by using dividers. You may divide a line into any number of equal parts by using the following procedure (fig. 14-6):

1. Draw a line at an angle from one end of line AB (view A).
2. On this line mark off five equal points with dividers (view B).
3. Draw a line from the last point at the widest part of the angle (point C in view C) to the end of the original line (point A). This line is shown as AC in view C.
4. From each of the other marked-off points, draw lines parallel with line AC (view D).

DRAWING A CIRCLE OR AN ARC THROUGH THREE GIVEN POINTS

The steps used in drawing a circle through three given points are given in the following list and are shown in figure 14-7, which you should refer to as you read this section.

1. Draw lines between points A, B, and C, and bisect these lines (view A).
2. The point where the bisecting lines intersect each other (point D) is the center of the circle. Place one point of the dividers at this point and the other point at one of the other three lettered points.
3. Draw the circle as shown in view B. The circle will now pass through all three lettered points.

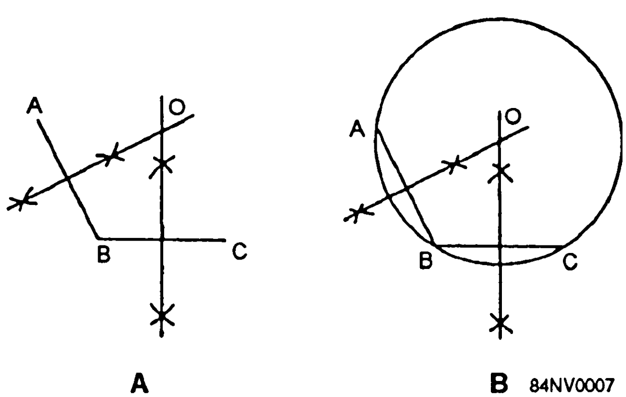


Figure 14-7.—Drawing a circle through three given points.

DRAWING A PERPENDICULAR FROM THE END OF A LINE

Figure 14-8 shows the steps you will follow to draw a perpendicular from the end of a line.

1. Pick any point, such as C, above base line AY.
2. With the dividers set at a radius of CA, place the point at point C. Draw an arc so the arc intersects line AY at point B. It must extend an equal distance on the other side of A.
3. Draw a line intersecting the arc through points B and C. Label this point D.
4. Then, draw line DA perpendicular to line AY.

DRAWING A PERPENDICULAR TO A GIVEN LINE FROM A GIVEN POINT

At times, you will need to draw a perpendicular to a given line from a given point. The steps for drawing

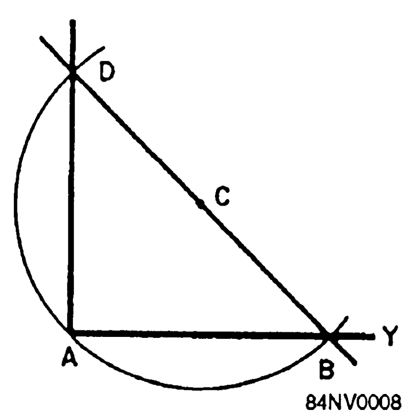


Figure 14-8.—Drawing a perpendicular from the end of the line.

a perpendicular to a given line from a given point are shown in figure 14-9.

1. From point A above line XY, pick any two points on line XY, such as C and B. Points C and B can either be on opposite sides of A or both on the same side of A.
2. With B as a center, and with a radius of BA, draw short arcs above and below line XY.
3. With C as a center, and a radius of CA, draw short arcs intersecting the arcs drawn in step 2.
4. Draw line DA through the intersecting arcs. Line DA is perpendicular to line XY.

BLENDING ARCS AND TANGENTS

Laying out circles or arcs, and straight lines tangent to them, is difficult. It is difficult because there is an element of optical illusion involved. Drawing a straight line to a curved one is easier than drawing a curved line to a straight one. Because of this, major circles or arcs are drawn first on layouts.

Even when you draw a straight line to a curve, an optical illusion may make it difficult for you to blend the curve and the line perfectly. This section discusses a few simple methods that should help you to blend lines and arcs.

The Draftsman's Method of Drawing a Tangent to a Circle at a Given Point

The draftsman's method of drawing a tangent to a circle is described in the following steps. It is shown in figure 14-10, and you should refer to this figure as you read this section. You will need your triangle and straightedge to draw a tangent to a circle.

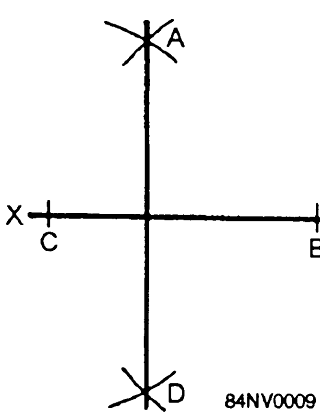


Figure 14-9.—Drawing a perpendicular to a given line from a given point.

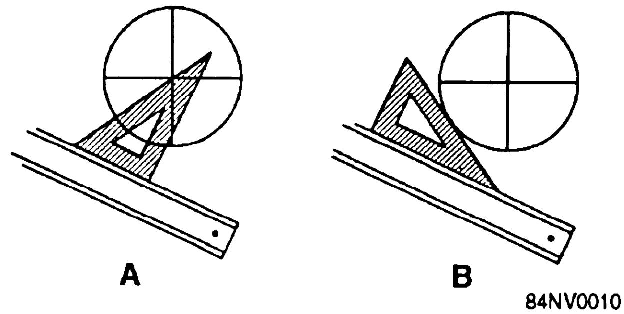


Figure 14-10.—Drawing a tangent to a circle at a given point.

1. Place a triangle against a straightedge, as shown in view A. The hypotenuse of the triangle should pass through the center of the circle and the point where the line is to be tangent to the circle.
2. Hold the straightedge firmly in place, and turn the triangle over.
3. Move the triangle until the hypotenuse passes through the point of tangency, and then draw the tangent, as shown in view B.

Drawing an Arc to a Line

You may find that when you draw an arc that ends in a straight line, you have a tendency to overdraw the arc (fig. 14-11). Use the following procedure and the steps shown in figure 14-12 to avoid this.

1. Use any given radius as the distance to set your dividers.
2. Set one point of the dividers at point A and strike tangent points at B and C (view A).
3. Without changing the dividers, place one point at B and strike an arc at D.

Figure 14-11.—Errors in drawing a line to the end of an arc.

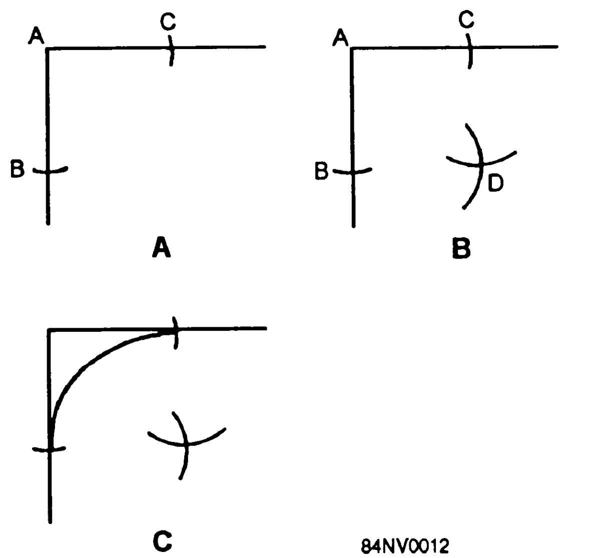


Figure 14-12.—Precaution to avoid overdrawing an arc that ends in a straight line.

4. Next, place the point at C and strike another arc intersecting the arc at D (view B).
5. Place one divider point where these two arcs intersect and strike an arc to the points of tangency (view C).

Drawing Arcs Tangent to Two Lines (Fillets and Rounds)

Small arcs tangent to two lines forming an inside comer are fillets. They must often be drawn after the straight lines have been drawn. Small arcs tangent to two lines forming an outside comer are rounds.

Use the following steps to draw a fillet or round when two lines form a right angle. Remember, look at figure 14-13 as you read these steps.

1. Adjust the dividers to the required radius.
2. Place one point of the dividers at the comer of the angle, and draw a short arc intersecting each straight line (view A). Intersection points of the arcs and the lines are the point of tangency.

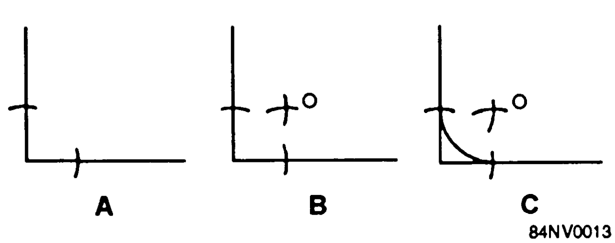


Figure 14-13.—Drawing a fillet or round to a right angle.

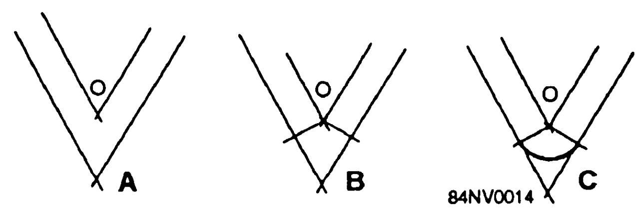


Figure 14-14.—Drawing a fillet or round to two lines that do not form a right angle.

3. Use the intersection points as alternate centers for the point of the dividers. Draw intersecting arcs inside the angle (view B).
4. Use this point of intersection (O) as the center for the point when you draw the fillet, as shown in view C.

Use the following steps to draw a fillet or round when the lines form an angle that is not a right angle. Look at figure 14-14 as you read these steps.

1. Draw lines inside the angle that are parallel to the first two lines. Draw them a distance of a given radius from the first two lines (view A). The intersection of these parallel lines will be the center of the fillet's arc.
2. Find the exact points of tangency, as shown in view B.
3. Now draw the fillet, using the intersection of the inside lines (point 0) as the center of the circle. Start at one point of tangency and stop when the arc touches the other point of tangency (view C).

Drawing Large Arcs Tangent to Smaller Arcs

Any of the methods of drawing fillets apply in laying out large circles or arcs tangent to other arcs. The trial-and-error method is shown in figure 14-15. In this figure, the arc of a large circle is tangent to two small circles or arcs. Points T and T´ are estimated as the points of tangency. Use them to find the intersecting arcs at point O. Point 0 is used as the center in drawing the arc from T to T´.

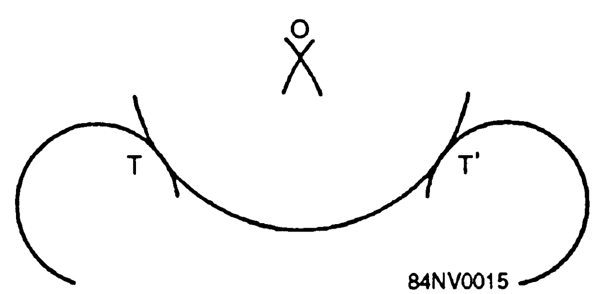


Figure 14-15.—Trial-and-error method of drawing a large arc tangent to two smaller arcs.

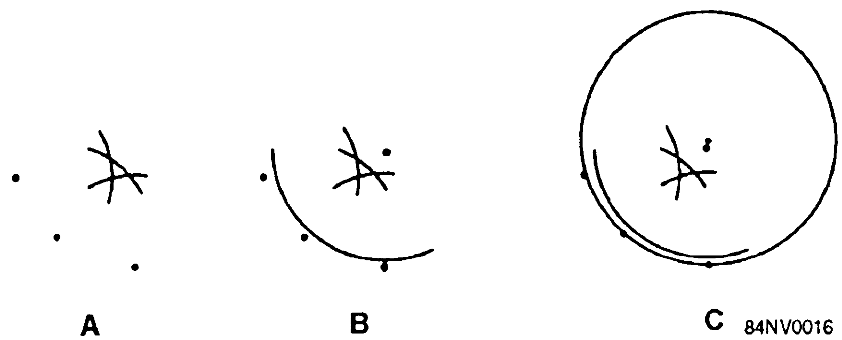


Figure 14-16.—Trial-and-error method of finding the center of a circle that passes through three given points.

The trial-and-error method also can be used in drawing a circle through three given points. In figure 14-16, view A, arcs with an equal radius have been drawn from each of the three points. You can see that they fail to have a common point of intersection and are, therefore, not at the proper center.

If the arcs from the two outer points intersect below the center point arc (view B), you know that the radius of the circle is larger. If the two outer points intersect above the center point arc, then the radius of the circle is smaller.

From this trial you can judge where the center will probably fall. Select a point (O) to use as the center in drawing your first trial arc. If this trial arc fails to pass through the three points perfectly (view B), move the center, as shown in view C.

This time you can judge the position of the center so accurately that the circle may be drawn through the points (view C).

Drawing a Reverse or Ogee Curve Tangent to Two Lines

The following steps tell you how to draw a reverse or ogee curve. Refer to figure 14-17 as you read this section.

1. Erect a perpendicular at point A and drop one at point B (view A).
2. Connect points A and B with a line (view B).
3. Assume a point (C) on this line through which the curve will pass. This point may be the midpoint of the line if equal arcs are desired.
4. Bisect AC and CB, as shown in view C. The intersection of these lines with the perpendiculars from points A and B are the centers of the required arcs. Complete the curve, as shown in view D.

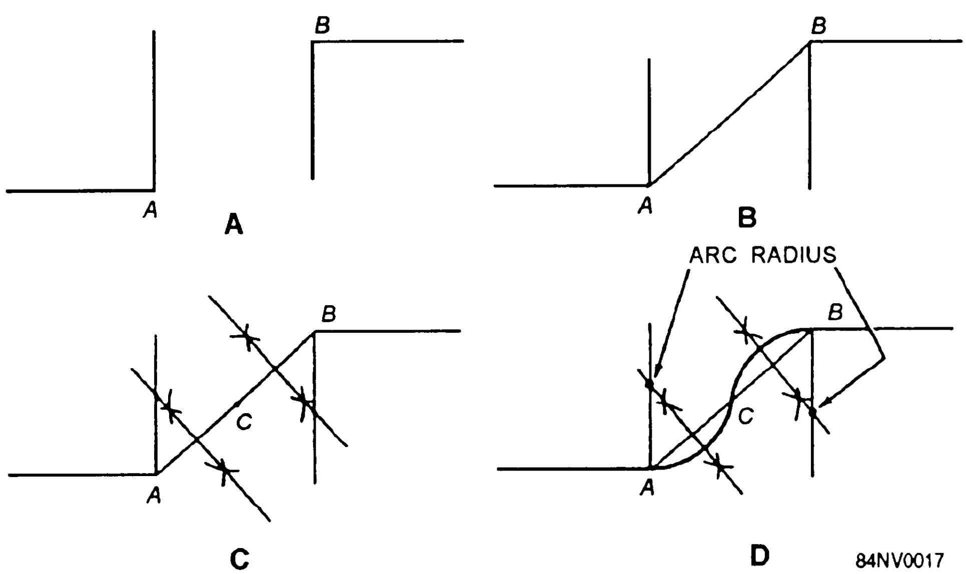


Figure 14-17.—Reverse or ogee curve.

DRAWING PLANE FIGURES

A plane has only two dimensions. Your layout is a plane. This section gives methods of construction for several plane figures.

DRAWING TRIANGLES WITH GIVEN LENGTH SIDES

Figure 14-18 shows the steps in drawing a triangle with given lengths for its sides. The lengths for the sides are shown in view A.

1. Draw one side of the triangle in the desired position as the base line (view B).
2. Adjust the dividers to the length of a second side. Using one end of the base line as a center for the point of the dividers, draw an arc (view B).
3. Adjust the dividers to the length of the third side. From the other end of the base line, draw another arc that intersects the first arc (view B).
4. Draw lines from the intersection point of these arcs to the ends of the base line. They are for the sides of the triangle (view C).

DRAWING EQUILATERAL, ISOSCELES, AND RIGHT TRIANGLES

An equilateral triangle has three equal sides. To draw this type of triangle, first draw one side as the base line. Then, use the length of that side as the radius to draw intersecting arcs from each end of the base line (fig. 14-19, view A).

An isosceles triangle has two equal sides. To draw an isosceles triangle, first draw the base. Then, draw intersecting arcs from each end of the base line. Use the length of one of the equal sides as the radius (fig. 14-19, view B).

A right triangle has a 90-degree angle. You can draw a right triangle by using the method for bisecting a line (refer to fig. 14-2). Draw a perpendicular from the end of a line (refer to fig. 14-8), or draw a perpendicular to a given line from a given point (refer to fig. 14-9).

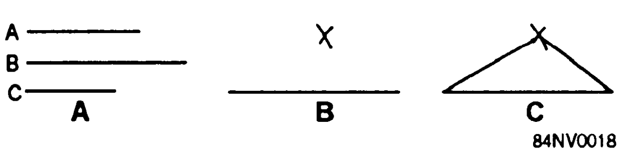


Figure 14-18.—Drawing a triangle with three given sides.

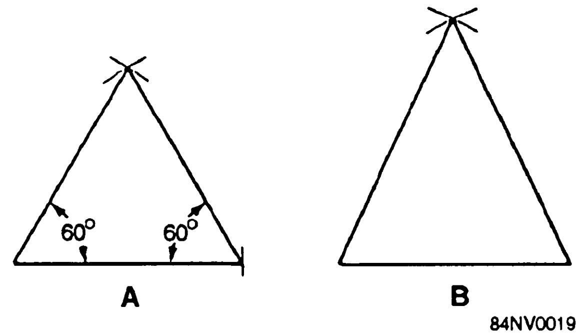


Figure 14-19.—Drawing triangular plane figures. A. An equilateral triangle. B. An isosceles triangle.

CONSTRUCTING A REGULAR PENTAGON WITHIN A CIRCLE

Look at figure 14-20. Here, you can see how to draw a pentagon. Refer to figure 14-20 as you read the following section.

1. Draw the diameter of the circle, shown as line AOB (view A).
2. Bisect radius OB of the circle (view B).
3. With D as a center and a radius equal to DC, strike arc CE (view C).
4. With C as a center, strike arc FG passing through point E (view D).
5. Distance CF or CG is equal to the length of one side of the pentagon. Mark off the other sides with the dividers (view E).

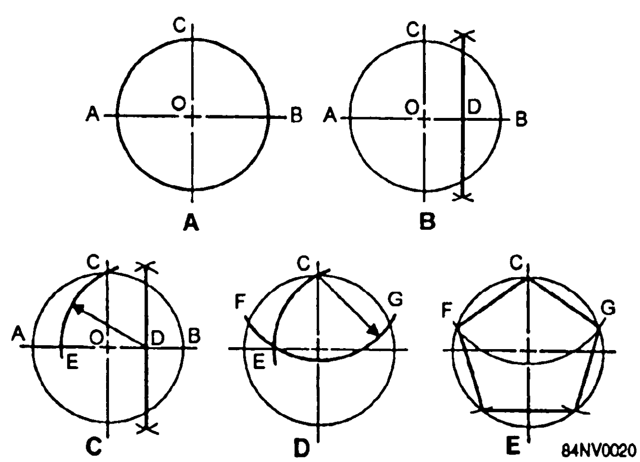


Figure 14-20.—Drawing a regular pentagon in a circle.

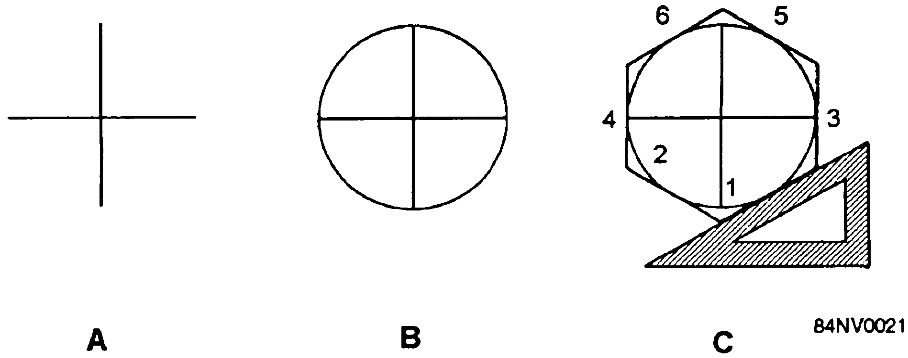


Figure 14-21.—Drawing a regular hexagon when the distance across flats is given.

DRAWING A REGULAR HEXAGON

Bolt heads and nuts are hexagonal forms (six sided) and are common figures in mechanical drawings. You can draw a regular hexagon if you are given the distance between opposite sides of a hexagon. The opposite sides are the *short distance* or *distance across the flats.* To draw the hexagon, use the following steps. Refer to figure 14-21 as you read this section.

1. Draw a horizontal line and a vertical line. Draw each as long as a given distance. They intersect at right angles to each other (view A).
2. With these lines as diameters and their intersection as the center for the point of the dividers, draw a circle as shown in view B.
3. Using the 30- to 60-degree triangle resting on a T-square or straightedge base, draw lines tangent to the circle in the order shown in view C.

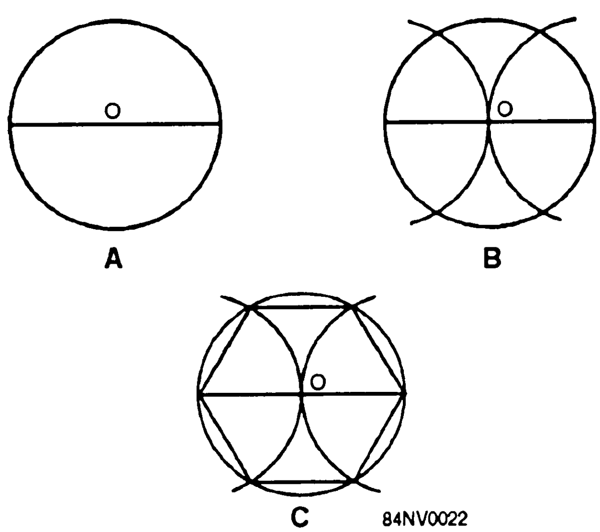


Figure 14-22.—Drawing a regular hexagon when the distance across corners is given.

If you are given the distance between opposite comers of a hexagon, called the *distance across comers* or the long *diameter,* use the method shown in figure 14-22.

1. Draw a circle with the long diameter as the circle diameter (view A).
2. Using the same radius as you used to draw the circle, draw arcs with the ends of the diameter as centers (view B).
3. Draw lines from the points where the arcs intersect the circle to those where the diameter touches the circle (view C).

DRAWING A REGULAR OCTAGON (AN EIGHT-SIDED FIGURE)

As you read this section, refer to figure 14-23. If you are given the distance between opposite sides of an octagon, you can use the following method to draw a regular octagon.

1. Use the given distance as the side dimension in drawing a square (view A).
2. Draw the diagonals of the square.
3. Adjust the dividers to a radius equal to one-half the length of a diagonal.

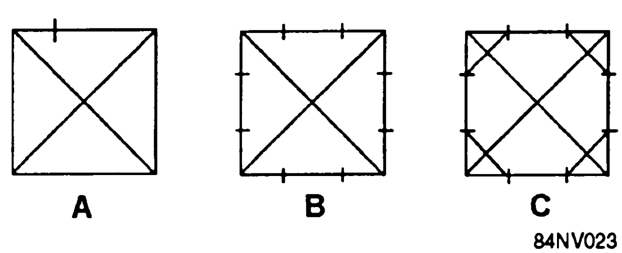


Figure 14-23.—Drawing a regular octagon when the distance between sides is given.

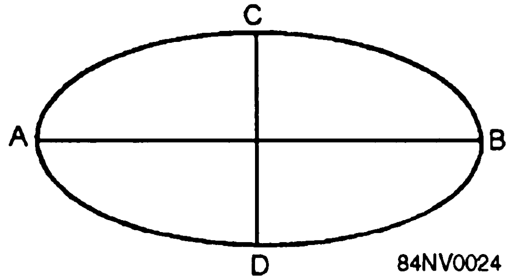


Figure 14-24.—An ellipse with major axis AB and minor axis CD.

4. Place the point of the dividers on each comer and draw arcs intersecting the sides of the square (view B).

5. Draw lines connecting the intersecting points and form a regular octagon (view C).

DRAWING AN ELLIPSE

The ellipse is a difficult figure to draw. There are several ways you can use to draw it. Normally, you are given the length of the major and minor axes of the ellipse (fig. 14-24).

Using a Compass to Draw an Ellipse

As you read this section, refer to figure 14-25. An ellipse that is not accurate but gives a good visual effect may be drawn, using a compass, as follows:

1. Draw the major and minor axes.

2. Draw a line connecting one end of the major axis and one end of the minor axis (view A).

3. Using a radius equal to half the major axis and with C as the center, lay off OE on OB (view B).

4. Using a radius equal to EB, lay off CF on CB (view C).

5. Bisect line FB as shown in view D. Extend the bisecting line to intersect AB at X and CD at Y.

6. Using a radius equal to XB, lay off AX´. Using a radius equal to DY, lay off CY´ (view D).

7. Using radii XB and X´A, draw the arcs, as shown in view E.

8. Using radii YC and Y´D, draw the side arcs, as shown in view F.

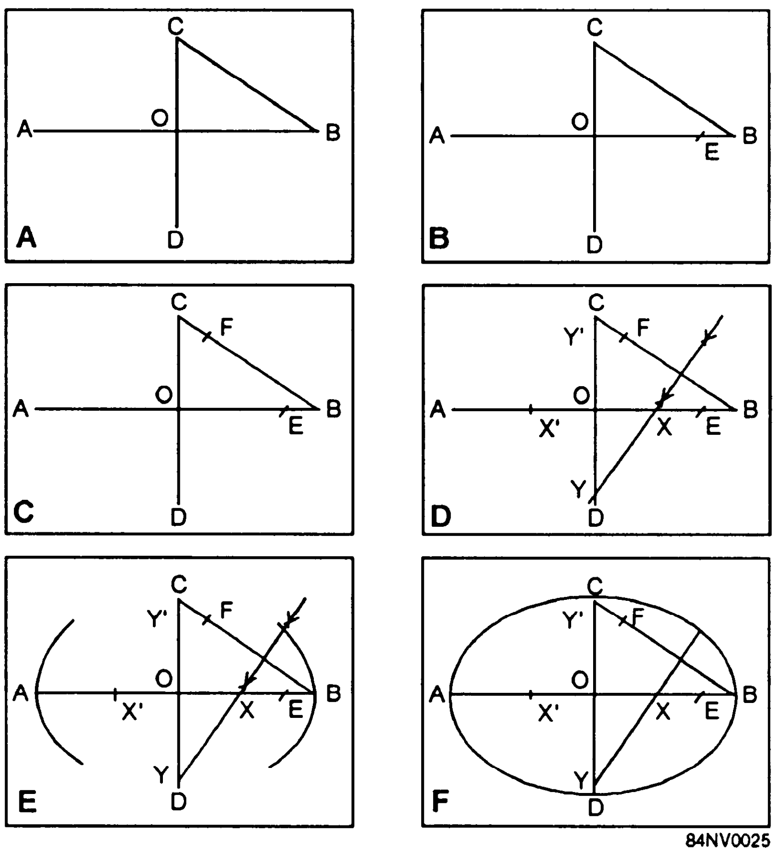


Figure 14-25.—Drawing an ellipse.

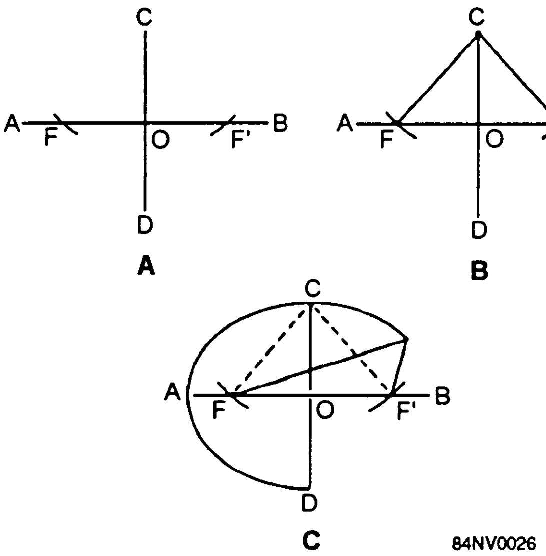


Figure 14-26.—Drawing an ellipse using a pin and string.

Pin-and-String Method

The easiest method of drawing a large ellipse is the pin-and-string method. To use this method, refer to figure 14-26 and use the following steps:

1. Draw the major and minor axes.
2. Set the dividers to one-half the length of the major axis. Using one end of the minor axis as a center, draw arcs intersecting the major axis. Points F and F´ are the foci of the ellipse (view 4 .
3. Drive pins at the foci and at one end of the minor axis. Tie a cord around the three pins, as shown in view B.
4. Remove the pin at the end of the minor axis, and place a pencil or pen inside the loop. Keep the string taut and draw the line of the ellipse.

Trammel Method

An ellipse may also be drawn by the trammel method. You will need your straightedge. On the straight edge of a strip of material, mark half the distance of the major axis, AO (fig. 14-27, view A). Then, mark half the distance of the minor axis, CO. Draw the major and minor axes on the drawing sheet. Move the straightedge, keeping point A on the minor axis and point C on the major axis. Using point 0 as the guide, draw the ellipse as shown in view B.

Concentric-Circle Method

The concentriccircle method of drawing an ellipse is the most accurate of the methods discussed in this section. However, you must be able to handle your instruments accurately. As you read this section, refer to figure 14-28.

1. Draw the major and minor axes.
2. With the intersection as a center, draw a circle that has the major axis as a diameter. Then, draw another circle with the minor axis as the diameter (view A).
3. Draw several radii from the center to the arc of the larger circle (view B).
4. Wherever these lines cut the smaller circle, draw short horizontal lines outward from the arc of that circle.
5. Wherever the radii touch the larger circle, draw short vertical lines to intersect the short horizontal lines (view C). The points where these short horizontal and vertical lines intersect define the ellipse.
6. Use the French curve and draw the ellipse from these plotted points (view D). The French curve

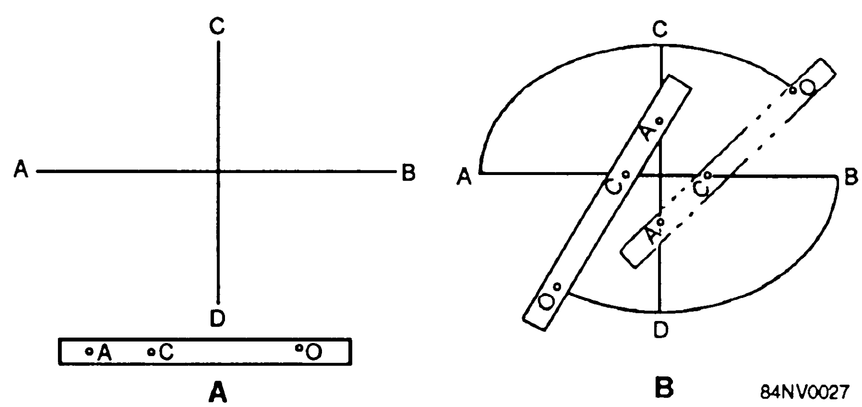


Figure 14-27.—Drawing an ellipse using the trammel method.

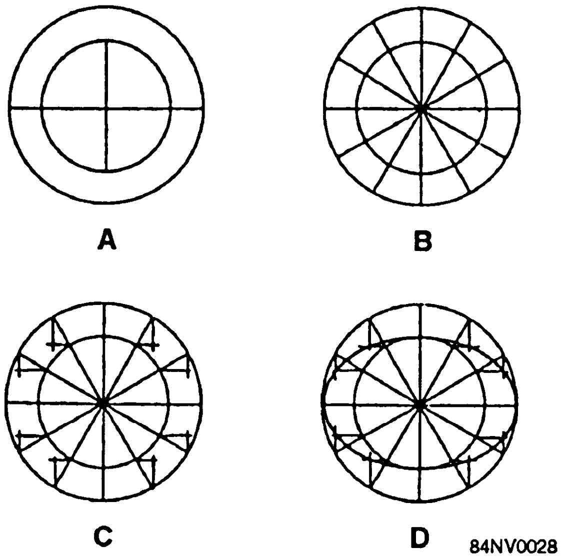


Figure 14-28.—Drawing an ellipse using the two-circle method.

is an instrument used to draw smooth irregular curves.

DRAWING SPIRALS AND INVOLUTES

A spiral or involute is a constantly changing curve that winds, coils, or circles around a center point. For a practical example, the main spring in your watch is a spiral. This section gives methods of construction for common spirals.

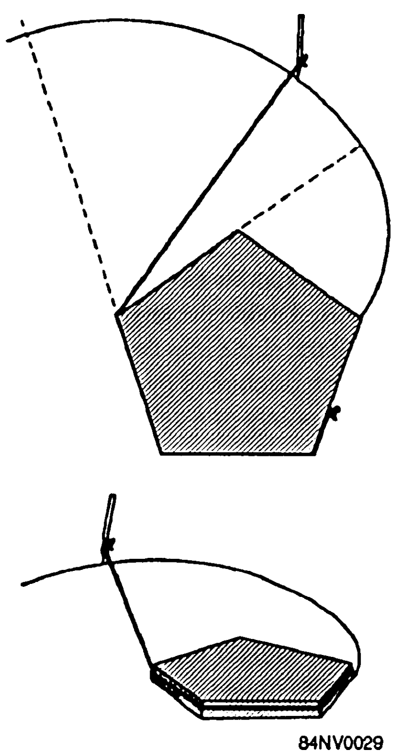


Figure 14-29.—Drawing the involute of a pentagon using pin and string.

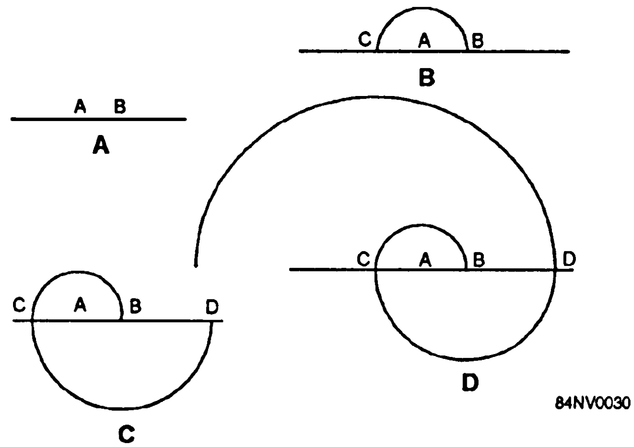


Figure 14-30.—Drawing the involute of a line.

An involute is the curve that might be traced by a point on a cord that is being unwound from a line, a triangle, a square, or other geometric figure. Figure 14-29 shows the pin-and-string method of drawing the involute of a pentagon.

Drawing the Involute of a Line

Look at figure 1430. To draw the involute of a line, extend line AB (view A). Using length AB as a radius and A as a center, draw a semicircle (view B). Then, using BC as the radius and B as the center, draw a second semicircle, continuing the curve as shown in view C. Then, with CD as the radius and C as the center, draw the next arc as shown in view D. Proceed until the curve is the desired size.

Drawing the Involute of a Triangle

As you draw the involute of a triangle, refer to figure 14-3 1. Extend the sides of the triangle (view A).

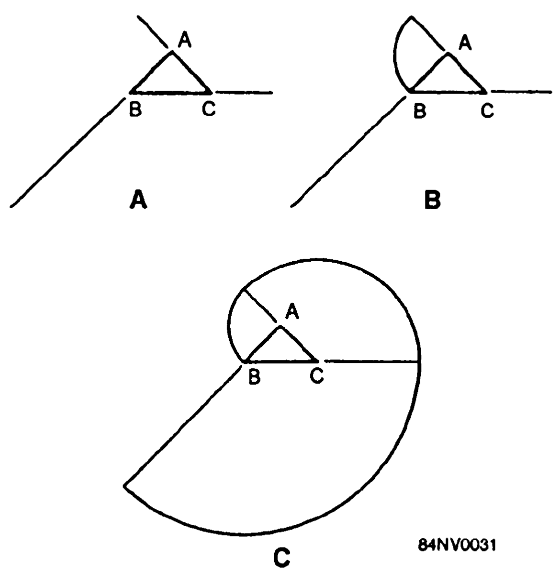


Figure 14-31.—Drawing the involute of a triangle.

Use one side of AB as a radius and A as the center. Draw an arc from B to the extension of side AC, as shown in view B. Next, measure a radius the length of AC plus its extension. With C as the center, draw an arc to the extension of side BC. With BC plus its extension as the radius and B as the center, draw an arc to the extension of side AB, as shown in view C. Continue in this manner until the figure is the desired size.

Drawing the Involute of a Circle

Consider the circle as a polygon with many sides. Divide the circumference of the circle into several equal segments (fig. 14-32, view A). Then, draw tangents from each segment (view B). With the cord of a segment as a radius, draw an arc from one segment to intersect the tangent of the next segment, as shown in view B. With the intersection point on this tangent to the point of tangency as a radius, draw an arc to intersect the next tangent (view C). Continue until the figure is the required size.

Drawing a Spiral of Archimedes

The spiral is generated by a point moving around a fixed point, its distance increasing uniformly with the angle. To draw a spiral that makes one turn in a given circle, divide the circle into several equal segments (fig. 14-33, view A). Then, divide the radius of a circle into the same number of parts, and number them from the center outward (view A). Using the center of the circle as a center, draw an arc from each of the numbered segments that intersect the corresponding numbered divisions on the radius (view B). These intersections are the points of the curve (view C).

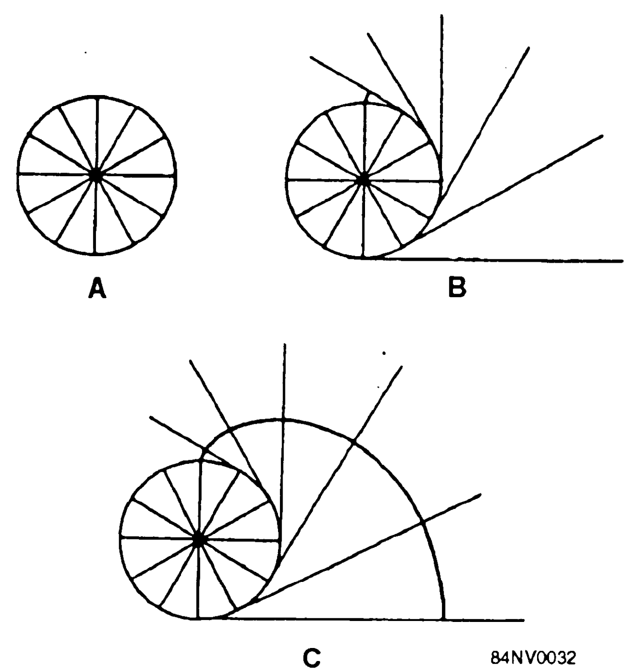


Figure 14-32.—Drawing the involute of a circle.

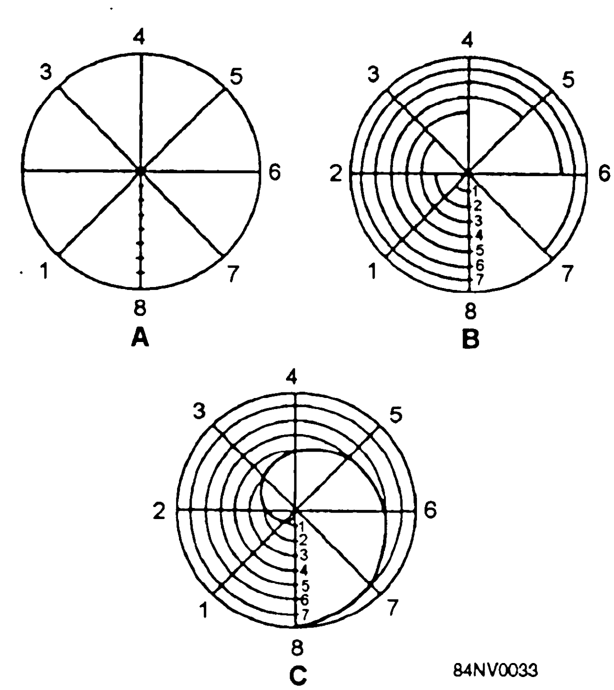


Figure 14-33.—Drawing the spiral of Archimedes.

Drawing the Helix

Consider the helix (fig. 14-34), a curve that is generated by a point moving uniformly along a straight line that revolves around an axis. If the line moves parallel to the axis, it will generate a cylindrical helix. If it moves at an angle to the. axis, it will generate a conical helix. The lead of a helix is the distance along the axis to which the point advances in one revolution.

To draw a helix, draw two views of the cylinder, as shown in view A. Divide the lead into an equal number of parts. Divide the circle into the same number of parts (view B). The intersection of the lines from these points (view C) are the points of a cylindrical helix.

AREAS AND VOLUMES

You must be able to calculate the amount of material needed to manufacture or repair many different items used throughout the Navy. You must also be able to determine the weight of the finished product to calculate the approximate weight of an object. To do this, you must have a knowledge of geometry and be able to determine areas and volumes of geometric shapes and figures.

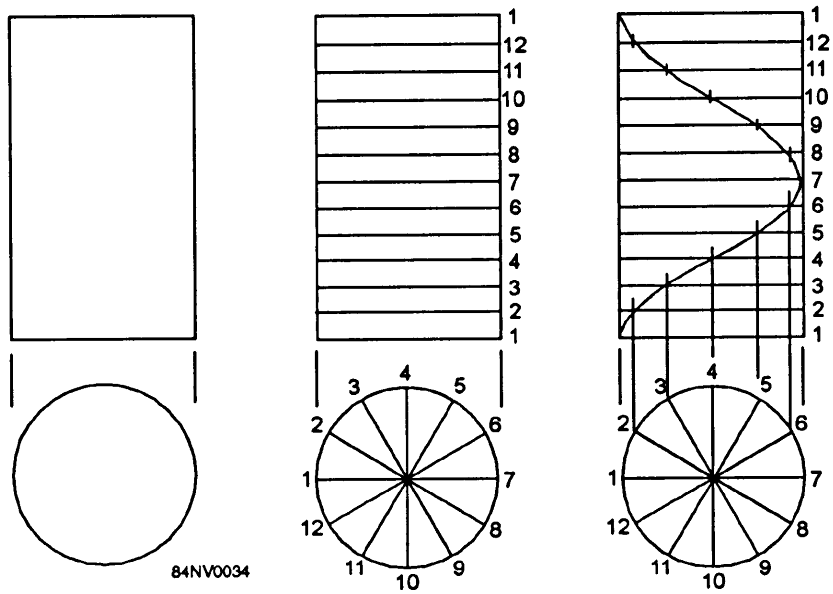


Figure 14-34.—Drawing a helix.

Area is the extent of a surface bounded by two dimensions, such as length and width. The unit of measure showing area is the square, such as square inches, square feet, and square yards.

Volume is the extent of an object bounded by three dimensions, such as length, width, and height. The unit of measure showing volume is the cube, such as cubic inches or cubic feet.

To find the area (A) of the rectangle shown in figure 14-35, you must multiply the length (L) by the width (W) or A = LW. Since L = 8 inches and W = 5 inches, A = 8 x 5 = 40 square inches.

To find the volume (V) of the cube shown in figure 14-36, you must multiply length (L) times width (W) times height (H), or V = LWH. Since L = 8 inches, W = 5 inches, and H = 7 inches, $V = 8 \times 5 \times 7 = 280$ cubic inches.

Many of the geometric figures you will be concerned with are shown in figure 14-37. With each figure is the formula and some examples of problems for calculating area and volume for that particular figure.

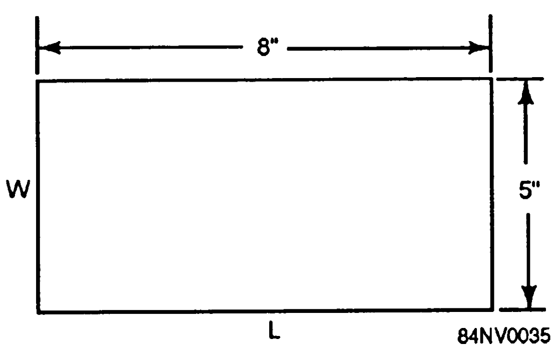


Figure 14-35.—Two-dimensional view.

When values are enclosed in parentheses ( ), brackets [ ], or braces { }, they are grouped. Some equations contain a group within a group. An example of this is the formula for finding the area of a trapezium where

$A = 1/2[a(e + d) + bd + ce]$.

In this formula you have parentheses and brackets. Parentheses can be enclosed in braces, and braces can

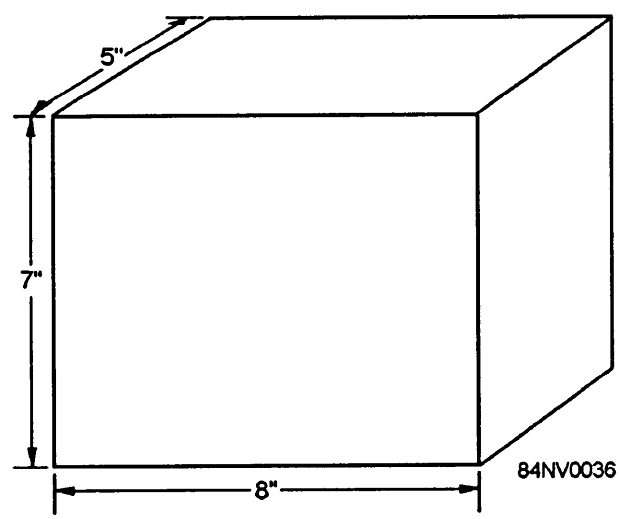
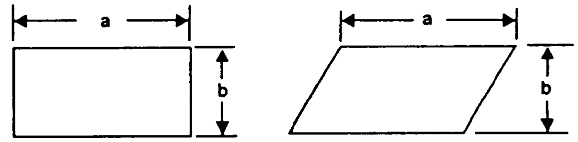


Figure 14-36.—Three-dimensional view.

Rectangle and Parallelogram

Area = ab



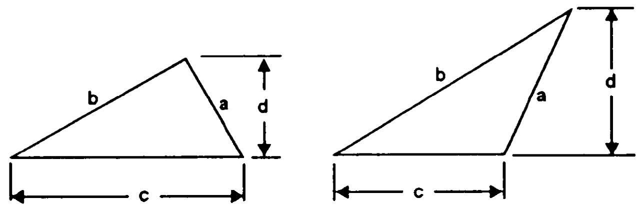
Triangle

Area = ½ cd.

Example: d = 5"

c = 6"

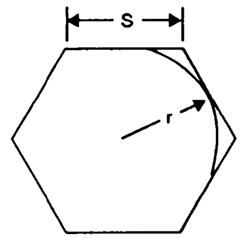
Then, ½ × 5" × 6" = 15 sq. in.



Regular Polygons

n = Number of sides, s = Length of one side, r = Inside radius

Area = ½ nsr



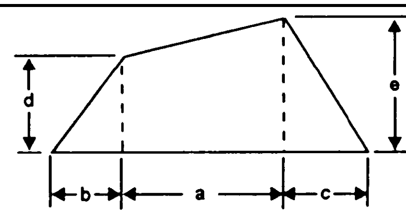
Number of Sides	Area
5	1.72047 s^2 = 3.63273 r^2
6	2.59809 s^2 = 3.46408 r^2
7	3.63395 s^2 = 3.37099 r^2
8	4.82847 s^2 = 3.31368 r^2
9	6.18181 s^2 = 3.27574 r^2
10	7.69416 s^2 = 3.24922 r^2
11	9.36570 s^2 = 3.22987 r^2
12	11.19616 s^2 = 3.21539 r^2

Trapezium

Area = ½ [a (e + d) + bd + ce]

Example: a = 10", b = 3", c = 5", d = 6", e = 8"

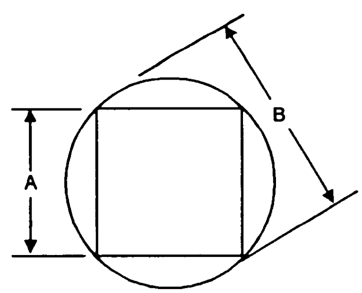
Area = ½ [10 (8 + 6) + (3 × 6) + (5 × 8)] = 99 sq. in.



Square

The diagonal of a square = A X 1.414

The side of a square inscribed in a given circle is B X 0.707.



84NV0037

Figure 14-37.—Areas and volumes for calculating weights of castings.

be enclosed in brackets. The reverse is not true. The values enclosed by parentheses must be calculated before the values within brackets. As an example, find the area of a trapezium using the formula and values shown in figure 14-37.

A= 1/2[a(e + d) + bd + ce]

A= 1/2[10(8 + 6) + 3 x 6 + 5 × 8]

A= 1/2[10(14) + 18 + 40]

A= 1/2[140+18 + 40]

Circle

θ (the Greek letter Theta) = angle included between radii

π (pi) = 3.1416, D = Diameter, R = Radius, C = Chord.

h = Height of Arc, L = Length of Arc.

Circumference $= \pi D = 2\pi R = 2\sqrt{\pi \times \text{Area}}$

Diameter $= 2R = \text{Circumference} \div \pi = 2\sqrt{\dfrac{\text{Area}}{\pi}}$

Radius $= \frac{1}{2}D = \text{Circumference} \div 2\pi = \sqrt{\dfrac{\text{Area}}{\pi}}$

Radius $= \dfrac{\left(\frac{C}{2}\right)^2 + h^2}{2h}$

Area $= \frac{1}{4}\pi D^2 = 0.7854\ D^2 = \pi R^2$

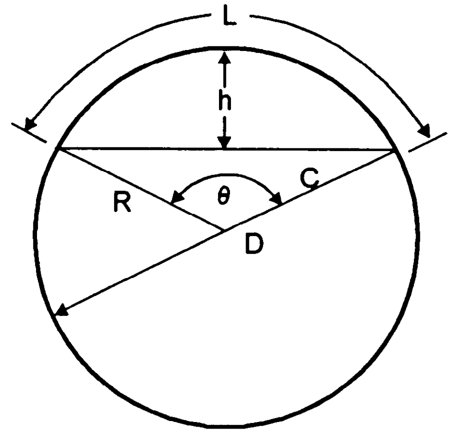
Chord $= 2\sqrt{h\ (D-h)} = 2R \times \text{sine}\ \frac{1}{2}\theta$

Height of Arc, $h = R - \sqrt{R^2 - \left(\frac{C}{2}\right)^2}$

Length of Arc, $L = \dfrac{\theta}{360} \times 2\pi R = 0.0174533\ R\theta$

$\frac{1}{2}\theta$ (in degrees) $= 28.6479 \dfrac{L}{R}$

Sine $\frac{1}{2}\ \theta = \dfrac{C}{2} \div R$



Sector of a Circle

Area $= \frac{1}{2}$ LR

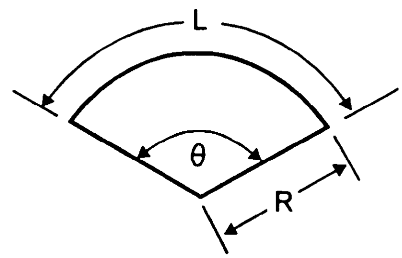
Example: L = 10.472", R = 5"

Area $= \dfrac{10.472}{2} \times 5 = 26.180$ sq. in.

or Area $= \pi R^2 \times \dfrac{\theta}{360} = 0.0087266\ R^2\theta$

Example: R = 5", $\theta = 120°$

Area $= 3.1416 \times 5^2 \times \dfrac{120}{360} = 26.180$ sq. in.



Segment of a Circle

Area $= \pi R^2 \times \dfrac{\theta}{360} - \dfrac{C\ (R-h)}{2}$

Example: R = 5", θ = 120°, C = 8.66", h = 2.5"

Area $= 3.1416 \times 5^2 \times \dfrac{120}{360} - \dfrac{8.66\ (5-2.5)}{2} = 15.355$ sq. in.

Length of arc $L = 0.0174533\ R\theta$

Area $= \frac{1}{2}\left[LR - C(R-h)\right]$

Example: R = 5", C = 8.66", h =- 2.5", θ = 120°

$L = 0.0174533 \times 5 \times 120 = 10.472"$

Area $= \frac{1}{2}\left[(10.472 \times 5) - 8.66\,(5-2.5)\right] = 15.355$ sq. in.

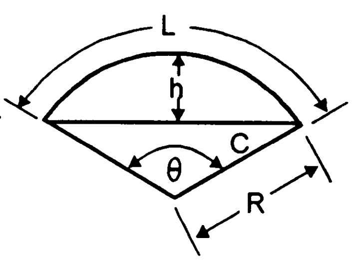


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Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

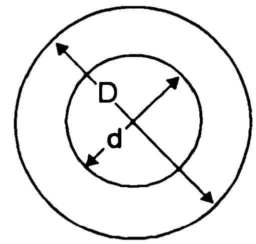
A = 1/2[198]

A= [99]

After substituting numerical values for the letter symbols, add *e* + *d*, since they are enclosed within parentheses. There are no symbols between a and the first parenthesis. This means that a must be multiplied by the sum of *e* + *d*, which results in a product of 140. Next multiply *bd* and *ce*. This results in products of 18 and 40. When these products are added to 140, you

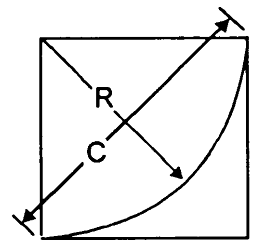
Circular Ring

Area = $0.7854 (D^2 - d^2)$. or $0.7854 (D - d) (D + d)$
Example: D = 10", d = 3"
Area = $0.7854 (10^2 - 3^2) = 71.4714$ sq. in.



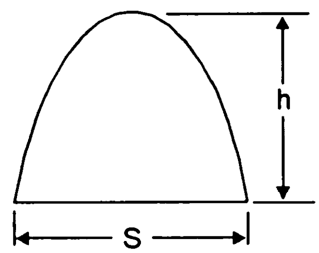
Spandrel

Area = $0.2146 R^2 = 0.1073 C^2$
Example: R = 3
Area = $0.2146 \times 3^2 = 1.9314$



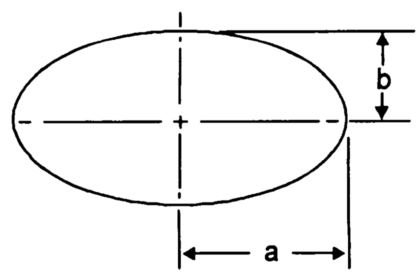
Parabolic Segment

Area = $\frac{2}{3}sh$
Example: s = 3, h = 4
Area = $\frac{2}{3} \times 3 \times 4 = 8$



Ellipse

Area = $\pi ab = 3.1416\, ab$
Example: a = 3, b = 4
Area = $3.1416 \times 3 \times 4 = 37.6992$



Irregular Figures

Area may be found as follows:
Divide the figure into equal spaces as shown by the lines in the figure.

(1) Add lengths of dotted lines.
(2) Divide sum by number of spaces.
(3) Multiply result by A.

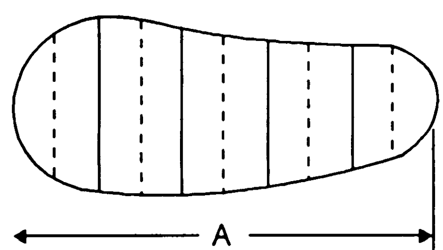


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Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

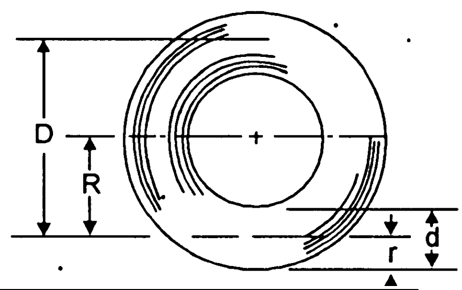
have a value of 198. This value is now multiplied by 1/2, resulting in a product of 99. Since all values are in inches, the area is 99 square inches.

PRINCIPLES OF SURFACE DEVELOPMENT

A surface has two dimensions—length and width. It is bounded by lines that are either straight or curved.

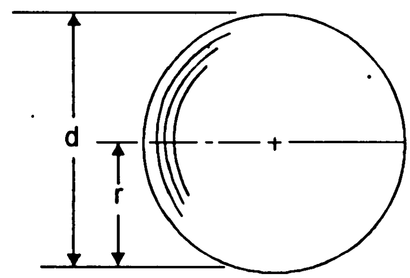
Ring of Circular Cross Section

Area of surface $= 4\pi^2 Rr = 39.4784\ Rr$
Area of surface $= \pi^2 Dd = 9.8696\ Dd$
Volume $= 2\pi^2 Rr^2 = 19.7392\ Rr^2$
Volume $= \frac{1}{4}\pi^2 Dd^2 = 2.4674\ Dd^2$



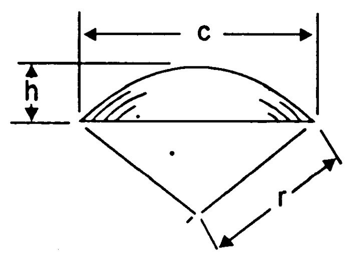
Sphere

Surface $= 4\pi r^2 = 12.5664\ r^2 = \pi d^2$
Volume $= \frac{4}{3}\pi r^3 = 4.1888\ r^3$
Volume $= \frac{1}{6}\pi d^3 = 0.5236\ d^3$



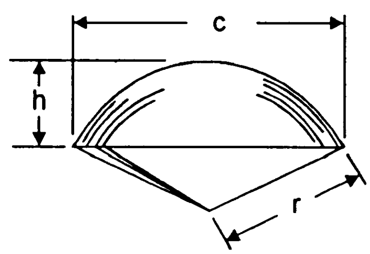
Segment of a Sphere

Spherical surface $= 2\pi rh = \frac{1}{4}(c^2 + 4h^2) = 0.7854\ (c^2 + 4h^2)$
Total surface $= \frac{1}{4}\pi(c^2 + 8rh) = 0.7854\ (c^2 + 8rh)$
Volume $= \frac{1}{3}\pi h^2(3r - h) = 1.0472\ h^2\ (3r - h)$
or
Volume $= \frac{1}{24}\pi h\ (3c^2 + 4h^2) = 0.1309\ h\ (3c^2 + 4h^2)$



Sector of a Sphere

Total surface $= \frac{1}{2}\pi r\ (4h + c) = 1.5708\ r\ (4h + c)$
Volume $= \frac{2}{3}\pi r^2 h = 2.0944\ r^2 h$



Cylinder

Cylindrical surface $= \pi dh = 2\pi rh = 6.2832\ rh$
Total surface $= 2\pi r\ (r + h) = 6.2832\ r\ (r + h)$
Volume $= \pi r^2 h = \frac{1}{4}\pi d^2 h = 0.7854\ d^2 h$

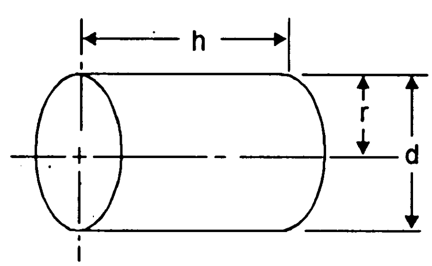


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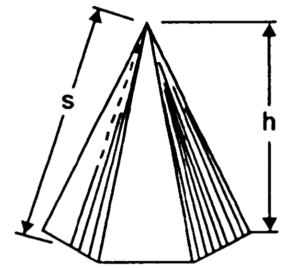
Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

The surface itself may be plane or flat. It could be plane-curved, such as the peripheral surface of a cylinder; warped, like the surface of a screw thread; or double-curved, like the surface of a sphere. A plane-curved surface can be unrolled and laid out flat. This is called developing the surface, A warped surface or double-curved surface can only be developed approximately.

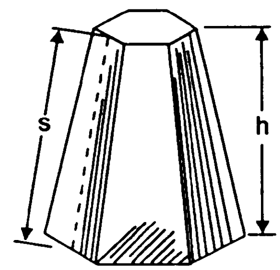
Pyramid

A = Area of base
P = Perimeter of base
Lateral area = $\frac{1}{2}$ Ps
Volume = $\frac{1}{3}$Ah



Frustum of a Pyramid

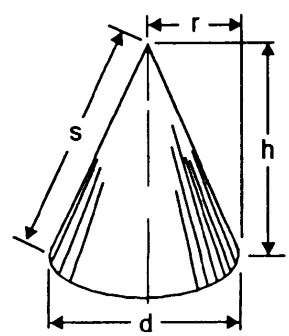
A = Area of base
a = Area of top
m = Area of midsection
P = Perimeter of base
p = Perimeter of top
Lateral area = $\frac{1}{2}s\ (P + p)$
Volume = $\frac{1}{3}h\ (a + A + \sqrt{aA})$
Volume = $\frac{1}{6}h\ (A + a + 4\,m)$



Cone

Conical area + $\pi rs = \pi r\ \sqrt{r^2 + h^2}$

Volume = $\frac{1}{3}\pi r^2 h = 1.0472\ r^2 h = 0.2618\ d^2 h$



Frustum of a Cone

A = Area of base
a = Area of top
m = Arca of midscction
R = D ÷ 2; r = d ÷ 2
Arca of conical surfacc = $\frac{1}{2}\pi s\ (D + d) = 1.5708\ s\ (D + d)$
Volume = $\frac{1}{3}h\ (R^2 + Rr + r^2) = 1.0472\ h\ (R^2 + Rr + Rr + r^2)$
Volume = $\frac{1}{12}h\ (D^2 + Dd + d^2) = 0.2618\ h\ (D^2 + Dd + d^2)$
Volume = $\frac{1}{3}h\ (a + A + \sqrt{aA}) = \frac{1}{6}h\ (a + A + 4\,m)$

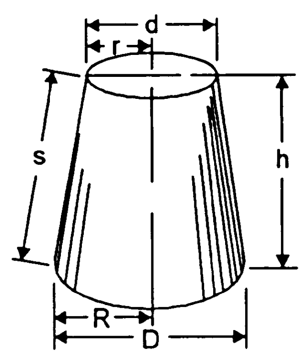


Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

In figure 14-38, several three-dimensional figures are shown. Try to form a mental picture of how these figures would look if they were unfolded or unrolled and laid out in a flat plane. The polyhedrons, of course, would be merely a system of connected squares, triangles, or other polygons. A cylinder with parallel ends would unroll into a parallelogram. A cone would unroll into a section of a circle. However, warped surfaces cannot lie flat. Double-curved surfaces present a similar problem.

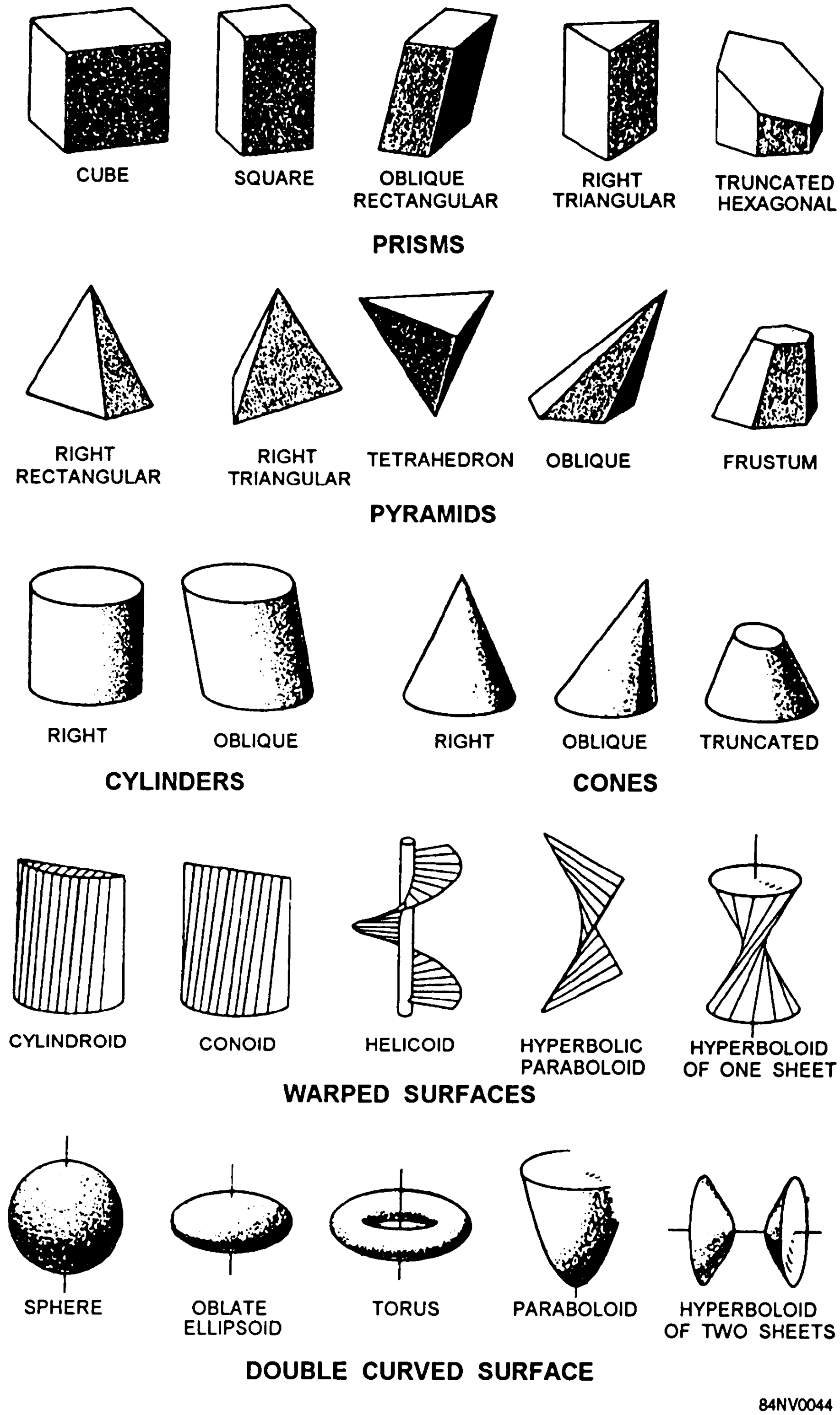


Figure 14-38.—Three-dimensional shapes.

The three principal methods of developing the surface of three-dimensional objects are parallel development, radial development, and triangulation. Parallel development is for surfaces such as prisms or

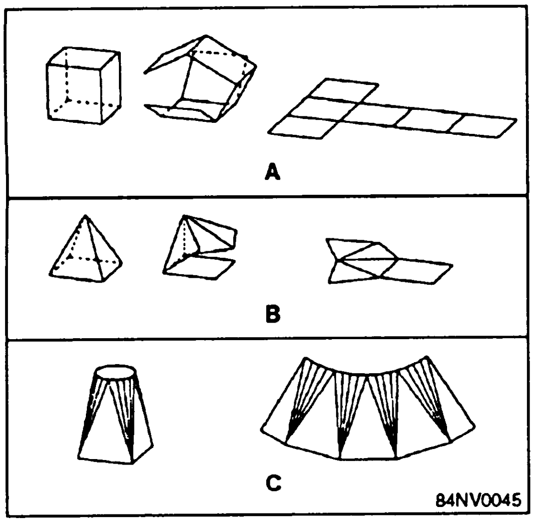


Figure 14-39.—Surface development. A. Parallel development. B. Radial development. C. Development by triangulation.

cylinders (fig. 14-39, view A). Radial development is for surfaces such as cones and pyramids (view B). Triangulation is for surfaces that do not lend themselves to either of the other two methods (view C).

Double-curved surfaces, such as a sphere, may be developed approximately by the same methods as those used for map projecting. A sphere can be cut into horizontal sections or zones that may be considered and developed as frustrums of cones (fig. 14-40, view A).

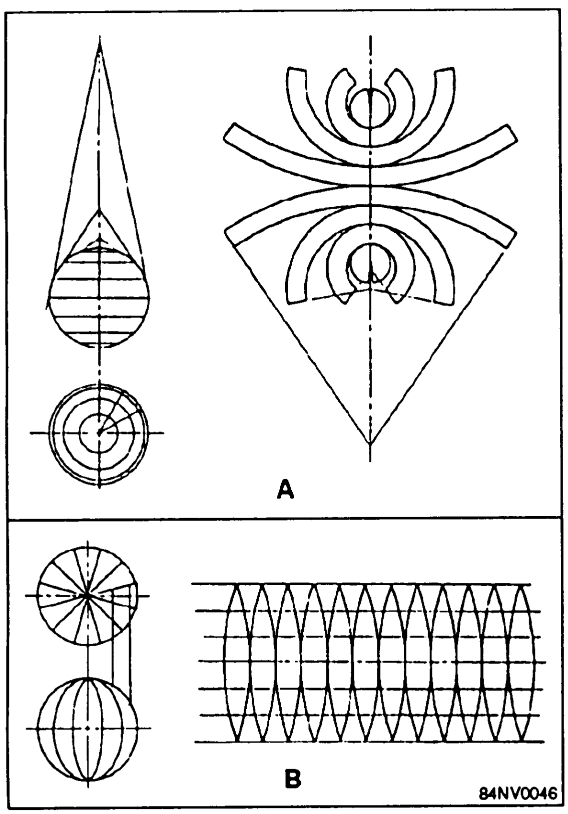


Figure 14-40.—Development of double-curved surfaces.

A sphere also can be cut into equal meridian sections called lunes, and these developed as if they were sections of cylinders (view B).

PARALLEL DEVELOPMENT

The surfaces of prisms and cylinders are parallel elements or elements that can be treated as parallel elements. Figure 14-41 shows the steps in developing a rectangular prism. You should refer to it as you read the following section.

1. To determine the length of all the edges of the prism, draw the front and top views in orthographic projection (view A).
2. Draw the development to one side of the front view so dimensions of vertical elements on that view can be projected to the development (view B).
3. Transfer the dimensions of other elements from the top view (view C). Mark all bend lines with crosses near their ends to distinguish them from outlines.
4. To check the drawing, measure the edges that are to join (view D). Such edges must correspond exactly.

Figure 14-42 shows the following steps in the development of a truncated hexagonal prism:

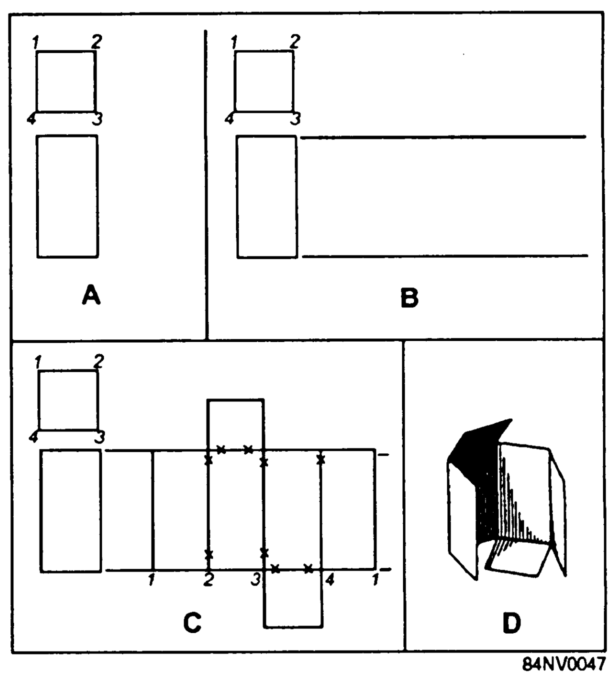


Figure 14-41.—Parallel development of a rectangular plane.

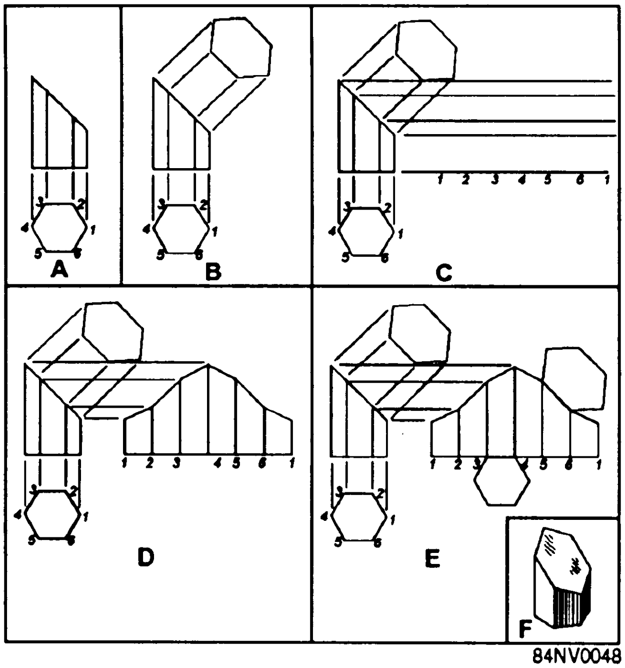


Figure 14-42.—Development of a truncated hexagonal prism.

1. Draw a front view and a bottom view of the prism in orthographic projection (view A).
2. Draw an auxiliary view (view B) since the true shape of the slanting plane and the length of the lines of its edges are not shown in these views. Note that drawing the entire prism in the auxiliary view is not necessary. Only the dimensions of the plane surface are required.
3. Project the lines of the front view horizontally as the first step in constructing the development (view C).
4. Number the points of intersection of planes on the bottom view. Mark off line segments of the same length on the base line of the development.
5. Erect vertical lines from these numbered points to intersect the lines projected from the front view of the prism (view D). These intersections mark the comers of the prism.
6. Connect the intersection points with straight lines.
7. Draw the bottom of the prism attached to one of the sides at the base line. Draw the slanting plane at the top of the prism (view E).
8. Check all edge measurements to be joined, as shown in the pictorial drawing (view F), to be sure they will coincide exactly.

The truncated cylinder is a prism with an infinite number of sides. The number of sides must be limited when developing a cylinder. However, the greater the number of sides, the more accurate the development. The following steps for the development of a truncated cylinder are shown in figure 14-43.

1. To develop one-half of a two-piece elbow, first draw a front and bottom view of that piece in orthographic projection (view A). Since the elbow does not require an end piece, you do not need to draw an auxiliary view showing the true shape of the ellipse formed by the cutting plane at the top of the cylinder.
2. Divide half the circumference of the circle into several equal parts. The parts should be small enough so a straight line drawn between division points will approximate the length of the arc. Project lines from these points to the front view (view B). The resulting parallel lines on the front view are called elements.

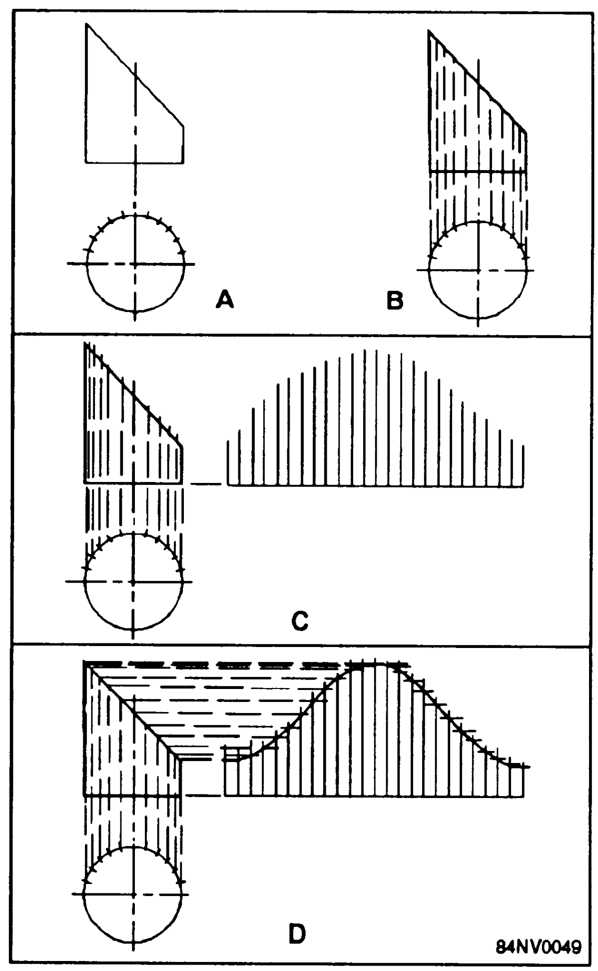


Figure 14-43.—Development of a truncated cylinder.

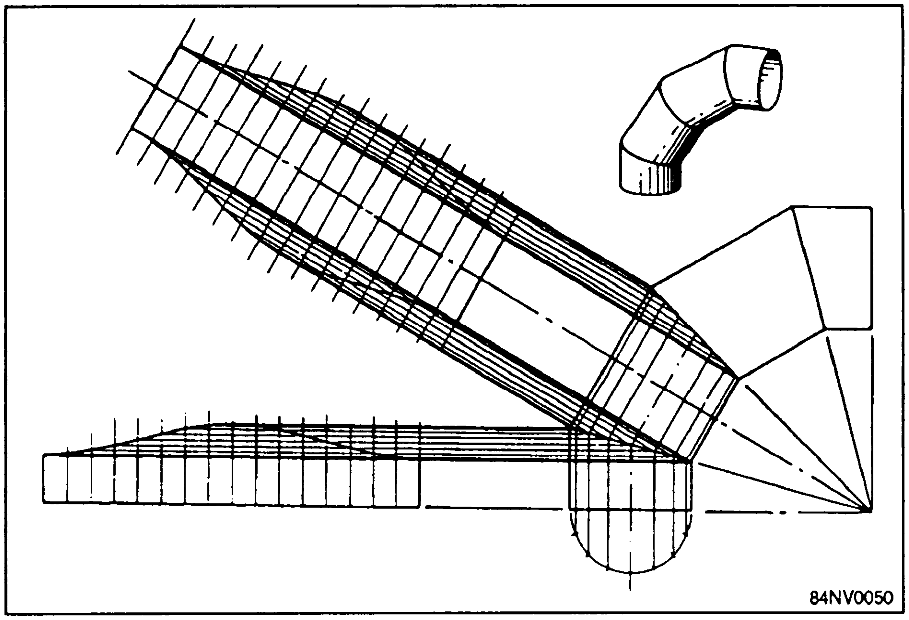


Figure 14-44.—Development for a four-piece elbow.

3. Lay off the base line, called the stretch-out line, of the development. The length of this line can be calculated as π times the diameter of the cylinder (3.14 × D).
4. Divide the stretch-out line into twice the number of equal parts as the number on the half circle of the orthographic view (view C).
5. Erect perpendiculars at each point, as shown in view C.
6. Using a T-square, project the lengths of the elements on the front view to the development (view D).
7. Using a French curve, join the resulting points of intersection in a smooth curve.

When the two pieces of the elbow are the same, you only need to make one drawing.

When a four-piece elbow is to be drawn, follow the same steps to produce as many developments as may be required. The orthographic view may be drawn of the whole elbow and the developments drawn beside each separate piece, as shown in figure 14-44. Here, only one end and one middle development are drawn. The other two pieces are the same as these.

You must determine the exact points of intersection when two pieces, such as two cylinders or a cylinder and a prism, intersect. This is so you can make developments, for the pieces, that will fit together without gaps or unnecessary overlaps. These intersections are determined by carefully drawing the elements intersecting on orthographic views and then projecting or transferring these intersection points to the developments. The following steps in making developments for a T-joint are shown in figure 14-45.

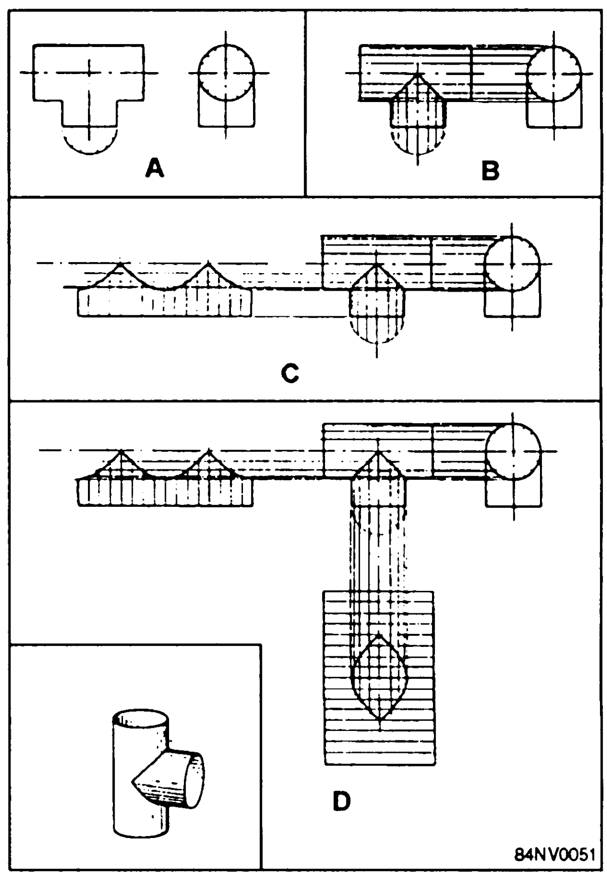


Figure 14-45.—Development of a T-joint with two cylindrical pipes of unequal diameters.

You should refer to this figure as you read the following section. The T-joint consists of two cylinders with equal diameters that intersect at right angles.

1. Draw a front view and a side view of the T-joint. A bottom view representing the open end of the other cylinder might also be drawn. Since this cylinder is perfectly round, a semicircle may be drawn attached to the front view. The division points for the elements can be located on it (view A).
2. Draw equally spaced divisions to locate the elements. Project these divisions to both cylinders. The points where the elements of one cylinder intersect those of the other define the intersection of the two cylinders (view B).
3. Draw the surface of the projecting pipe at one side of the orthographic view so the length of each element can be projected from the front view (view C).
4. Draw the surface of the cross pipe below the front view. Project lines down from the branch pipe to locate the opening for it (view D).

When making the T-joint of two cylindrical pipes of unequal diameter, the procedure differs slightly. Refer to figure 14-46 as you read the following section.

1. Draw the orthographic views.
2. Divide the smaller diameter branch pipe into equal parts. Draw the elements on this pipe in both views (view A). The length of each element is shown in the side view.
3. Project lines from the upper end of each element in the side view to the front view (view B). The intersections of these lines with the vertical lines drawn on the branch pipe define the intersection of the two pipes.
4. Draw the line of intersection on the front view.
5. Draw the surface of the branch pipe to the left, continuing the projection lines to locate the element ends (view C).
6. Draw the surface of the larger diameter main pipe beneath the front view. Project lines down from the branch pipe to locate the opening for it (view D).

Figure 14-47 shows the following steps in drawing a round pipe joint made up of two cylindrical pipes of unequal diameters that intersect at an angle other than 90°.

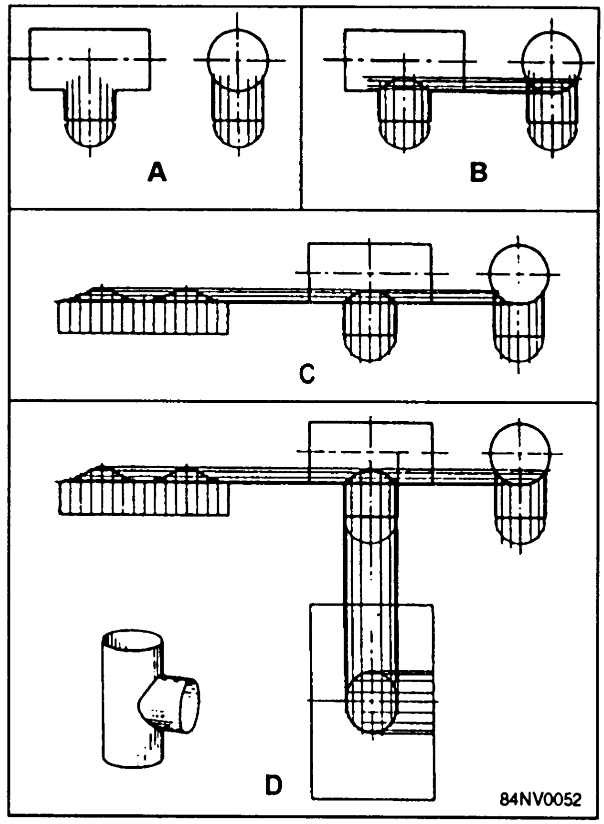


Figure 14-46.—Development of a T-joint with two cylindrical pipes of unequal diameters.

1. Draw the front and top orthographic views (view A). The ellipse formed by the top of the branch pipe may be omitted at this point and drawn later.
2. Draw the elements on the branch pipe in both views (view B).
3. Project lines down from the left end of each element in the top view to the corresponding element in the front view. Draw the line of intersection (view C).
4. Draw the ellipse formed by the end of the branch pipe in the top view. Do this by projecting lines up from the upper end of each element in the front view to the corresponding element in the top view (view D).
5. Draw the pattern of the branch pipe to the right and perpendicular to the pipe the same as in the front view (view E).
6. Draw the pattern for the main pipe to the left, with lines projecting from the intersection of the two pipes on the orthographic view to locate the opening for the branch pipe (view F).

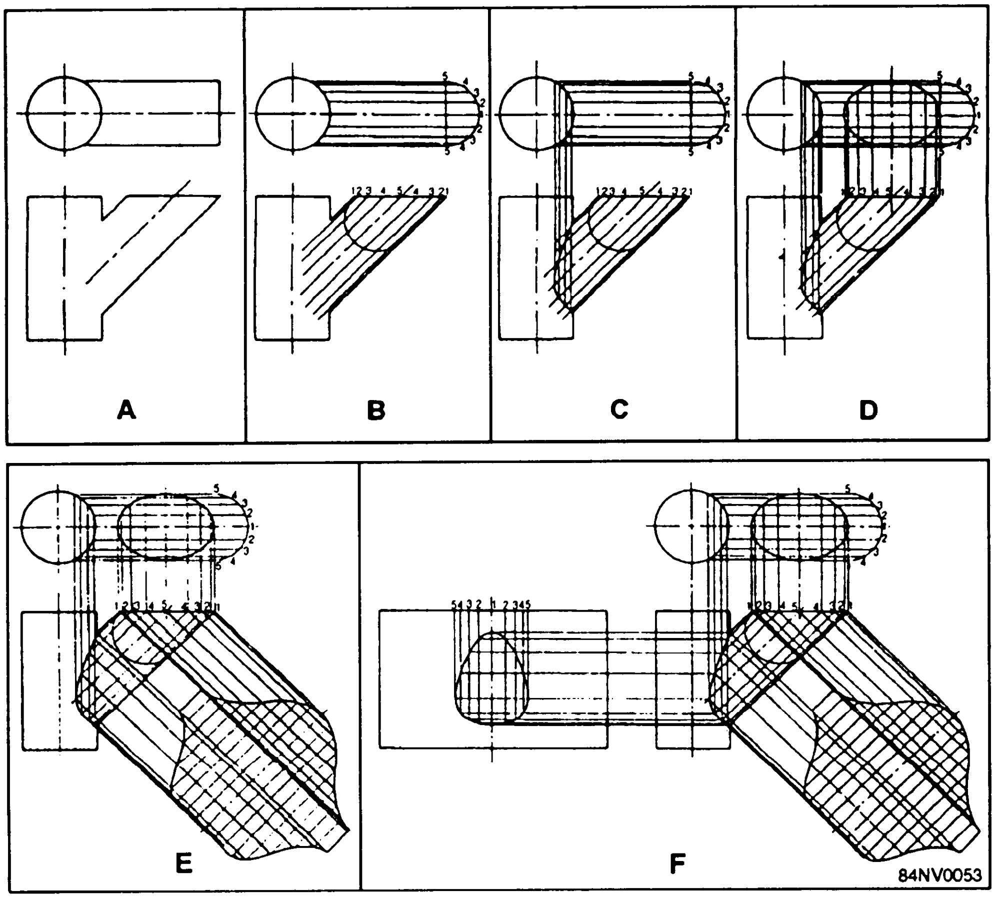


Figure 14-47.—Development of a round pipe joint made of two cylindrical pipes of unequal diameters, intersecting at an angle of other than 90°.

When a pipe joint consists of a rectangular pipe intersecting a round pipe at an angle other than 90°, the procedure is similar. This procedure is shown in figure 14-48 and is described in the following steps:

1. Draw the orthographic views, as shown in view A. Divide the upper surface of the rectangular pipe in the top view by equally spaced elements.
2. Project the points of intersection of these lines with the circle down to the upper and lower surfaces of the branch pipe in the front view (view B).
3. Develop the surface of the rectangular pipe perpendicular to it in the front view (view C).
4. Draw the surface of the round pipe with the opening for the rectangular pipe to the side of the front view (view D).

RADIAL DEVELOPMENT

The sides of a pyramid and the elements of a cone meet at a point called the vertex or apex. These same lines meet at a point in the development of a pyramid or cone and radiate from this point. Therefore, the method of developing pyramids or cones is radial development (fig. 14-49).

Follow the same general procedures in radial development as those used in parallel development. The only major exception is that since the slanting lines of pyramids and cones do not always appear in their true lengths on the orthographic views (fig. 14-49, view A), other procedures must be followed to determine these true lengths.

To find the true lengths of these edges, rotate the pyramid so some of the edges appear in their true lengths (view B). In this case, the lines that appear as horizontal lines in the top view are shown in outline and in their true length in the front view. In other words, when a line appears as horizontal or as a point in the top view, the corresponding line in the front view is its true length. Conversely, when a line appears as horizontal in the front view, the corresponding line in the top view is its true length.

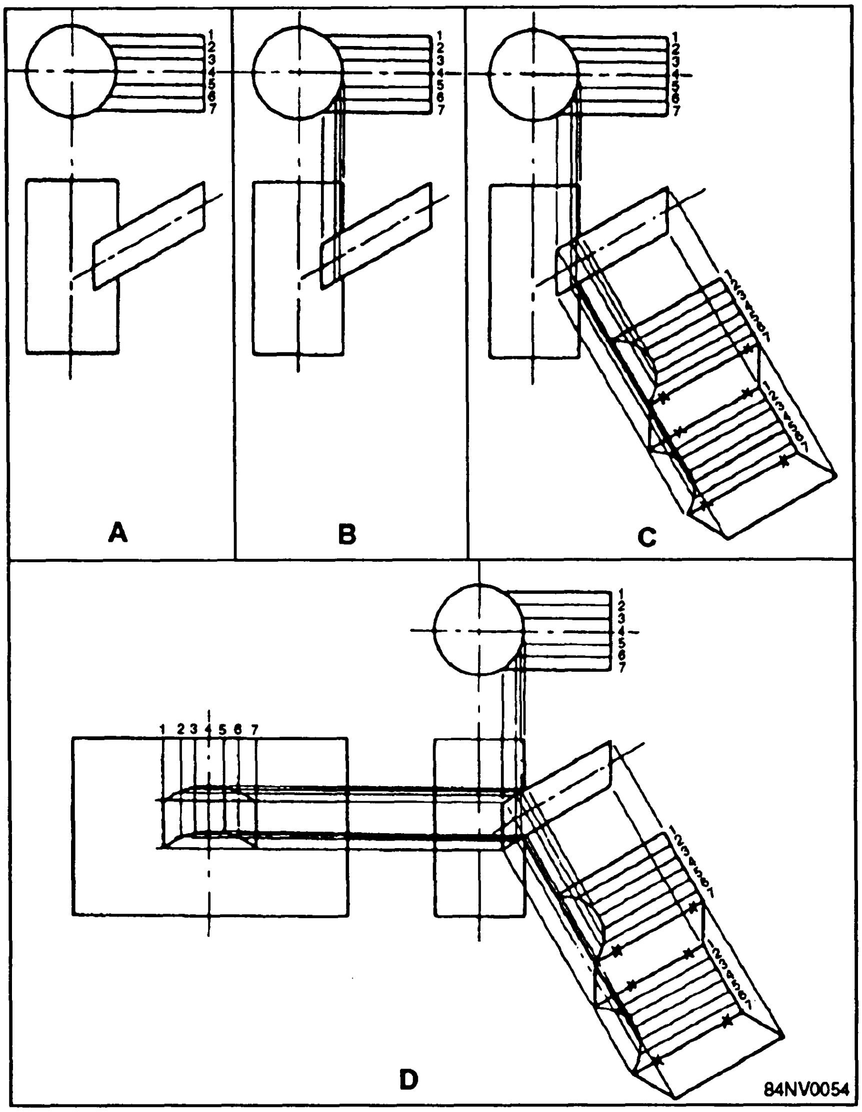


Figure 14-48.—Development of a pipe joint in which a rectangular pipe intersects a round pipe at an angle other than 90°.

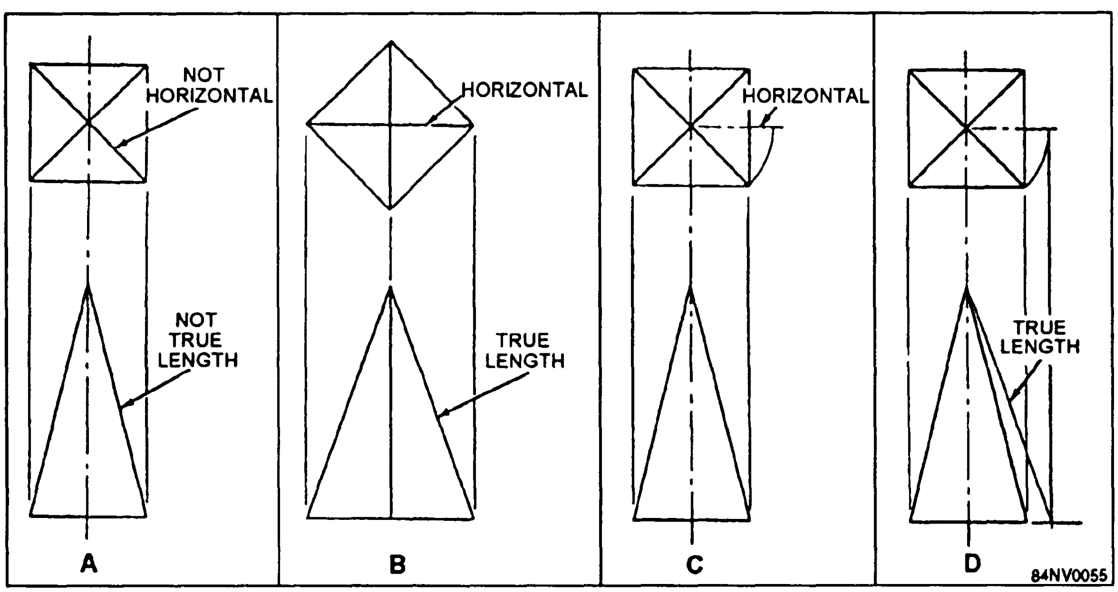


Figure 14-49.—Methods of finding the true length of a line in a radial development.

Instead of rotating the whole pyramid, simply rotate the line of the edge itself into the horizontal on a conventional orthographic view. For example, in view C, the line of an edge from apex to base, as it appears in the top view, is used as the radius for an arc to the horizontal The point of intersection of the arc with the horizontal is projected to the front view. A true-length line for that edge is drawn (view D).

The following steps for developing a truncated pyramid are shown in figure 14-50. This is a transition piece for connecting a large square pipe with a smaller one. Normally, the square ends would end in square collars, which also would be developed.

1. Draw the orthographic views, completing the lines of the sides to the apex (view A).
2. Rotate the line of one edge in the top view to the horizontal and project it to the front view (view W
3. Draw an arc with a radius equal to the length of this true-length line, plus its extension to the apex of the pyramid. Draw a second arc defining the upper limit of the true-length line (view C).
4. Step off lengths along these arcs equal to the sides of the pyramid (view D).
5. Connect these points with the vertex, as shown in view D.

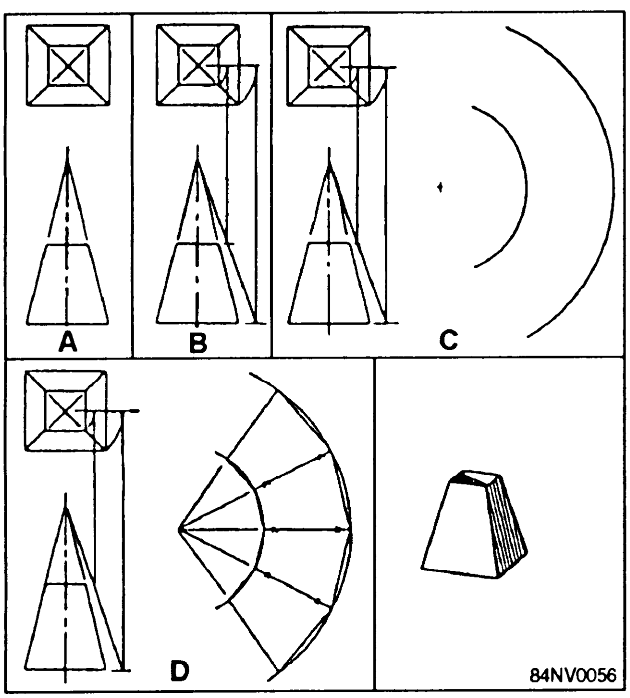


Figure 14-50.—Development of a truncated pyramid.

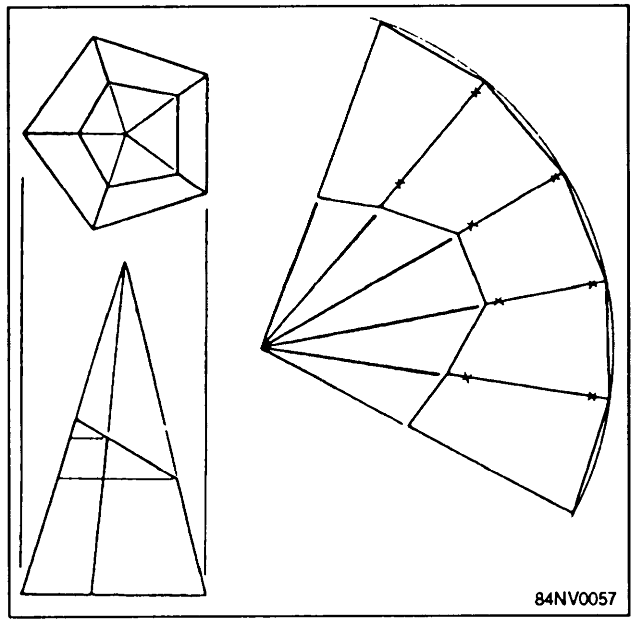


Figure 14-51.—Development of a truncated pentagonal pyramid with the upper corners cut by a slanting plane.

To develop a truncated pentagonal pyramid, like that shown in figure 14-51, follow the same general steps. However, since one lateral edge appears in its true length in the front view, the limits of the other edges can be projected onto the line of this edge to determine the true lengths. Measure the length of each edge. Transfer this measurement to the development.

Figure 14-52 shows the following steps in the development of an offset transition piece. It is offset

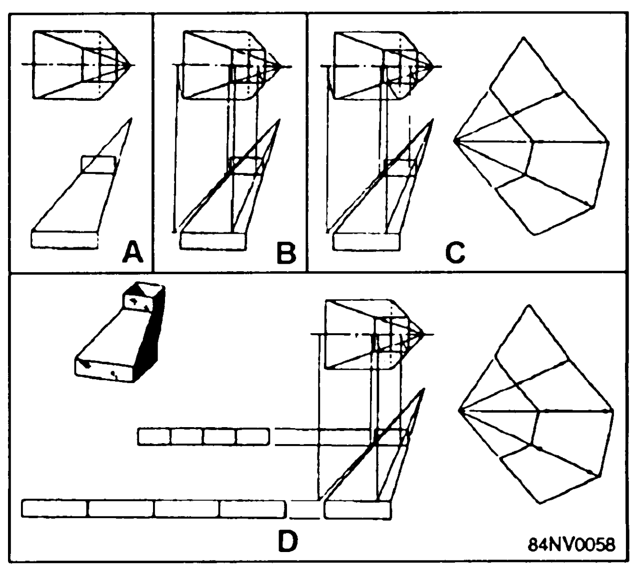


Figure 14-52.—Development of an offset transition piece.

because the center of one end is not in line with the center of the other end. The three parts consist of an upper and a lower section that are truncated rectangular prisms. The third section is a truncated oblique pyramid.

1. Draw the orthographic views, extending the lines of the sides of the pyramid to its apex in both views (view A).
2. Rotate the lines of the sides to the horizontal in the top view. Project the points located on the front view and draw the true-length lines (view W
3. At one side of the views, develop the surface of the oblique square pyramid. Construct one triangle at a time, and take the length of the three sides of each triangle from the views (view C). Draw the upper edges to complete the drawing.
4. Draw the surface patterns of the upper and lower prisms (view D).

The development of a cone is similar to the development of a pyramid. Consider it a pyramid with an infinite number of sides. In actual practice, of course, the number of sides are drawn on the orthographic views and projected to the development. The steps in developing a truncated right cone are shown in figure 14-53.

The truncated right cone has a center line that is perpendicular to its base. The elements on a right cone are all the same length. The true length of these elements is shown by those that fall to the extreme right and left in a front view. These elements are horizontal lines in a top view. A slanting plane cuts the cone in figure 14-53. The end points of the elements between the two outside elements must project to one of the outside lines to determine their true lengths.

To develop a truncated right cone, use the following steps:

1. Draw the orthographic views. Include either a side view (view A) or an auxiliary view of the ellipse formed by the slanting plane. Note that the center of the ellipse must be determined since it does not fall on the center line of the cone. This center point is projected to the side view and defines the length of the minor axis of the ellipse. The length of the major axis is defined by the length of the slanting line in the front view.

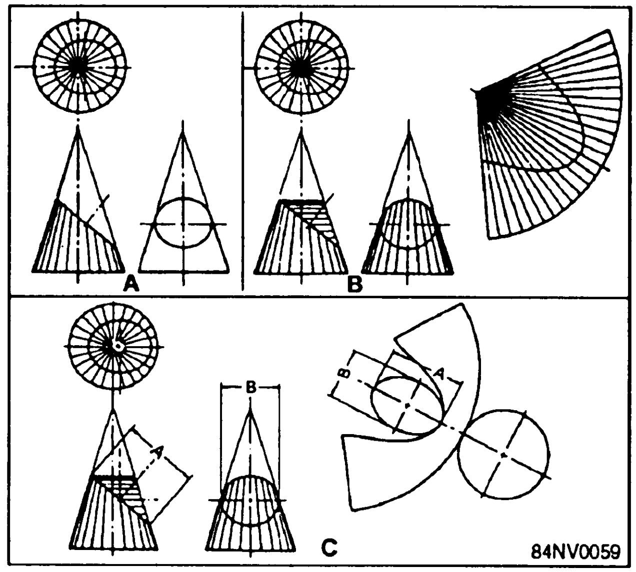


Figure 14-53.—Development of a truncated right cone.

2. Develop the surface pattern of the cone using the length from the apex to the base as a radius for drawing the arc. Step off on this line the equally spaced division of the base. Then, measure each element individually and transfer this measurement to the development. The ends of each of these elements define the curve of the upper edge of the peripheral surface (view B).
3. Draw the base surface circle and the top surface ellipse attached to the peripheral surface (view C).

TRIANGULATION DEVELOPMENT

Triangulation is slower and more difficult than parallel line or radial development, but it is more practical for many types of figures. It is the only method with which the development of warped surfaces may be approximated. In development of triangulation, the piece is divided into a series of triangles, as in radial development. However, there is no single apex for the triangles. The problem becomes one of finding the true lengths of the varying oblique lines. This is usually done by drawing a true-length diagram.

Figure 14-54 shows the following steps in the triangulation of a warped transition piece joining a large square pipe and a smaller round pipe:

1. Draw the top and front orthographic views (view A).
2. Divide the circle in the top view into several equal spaces and connect the division points with the comers of the square (view B).
3. Transfer the division points to the front view and draw the elements. Some of the triangles curve slightly, but they can be considered flat.
4. Now the true length of each of these elements may be found. Draw a right triangle with a base equal to the length of an element on the top view. Draw it with an altitude equal to the altitude of the corresponding element on the front view. The hypotenuse of the triangle is the true length of the element. In view C, the true-length diagram consists of only three right triangles. Since the piece is symmetrical, several elements are the same length.
5. Draw the surface pattern by constructing one triangle at a time.

Figure 14-55 shows the following steps in developing a rectangular transition piece that is not a true pyramid because the extended lateral edges would not meet at a common vertex. The best way to develop

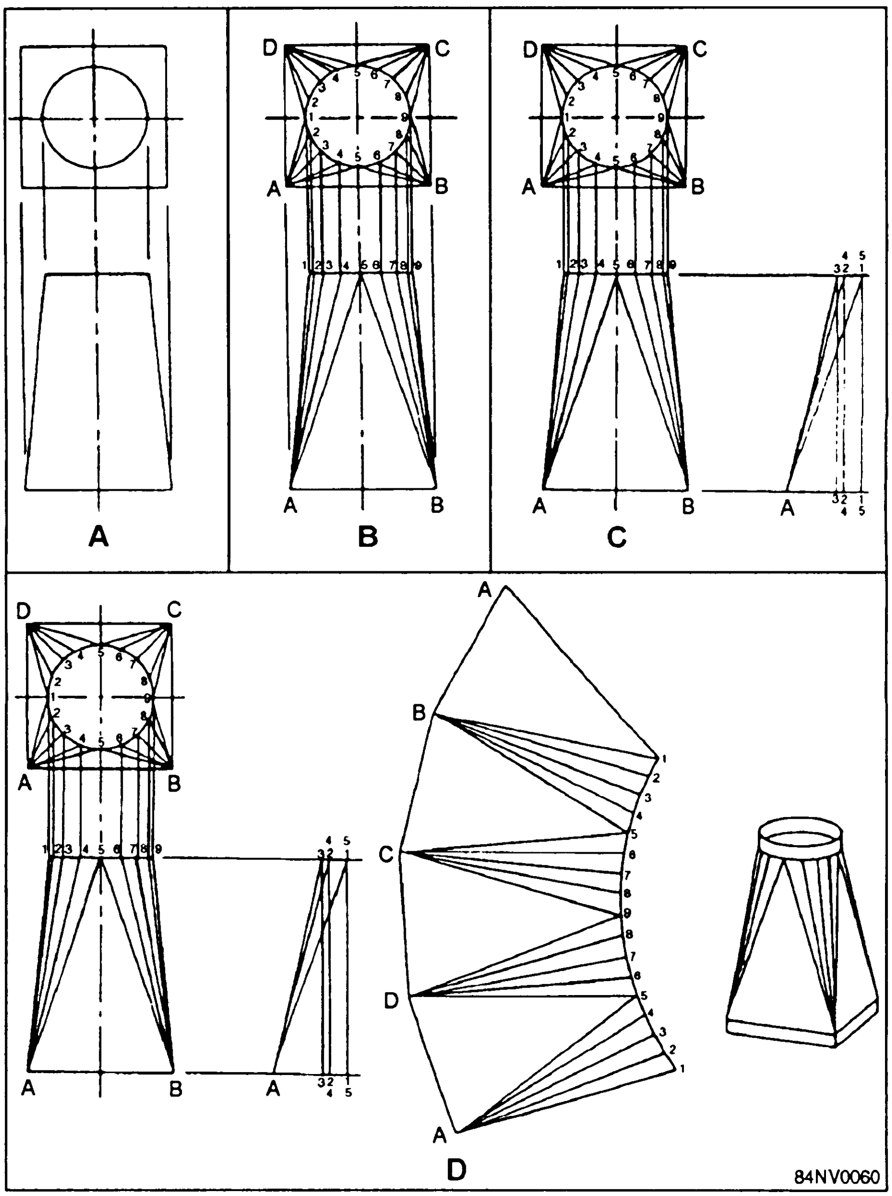


Figure 14-54.—Development by triangulation of a transition piece.

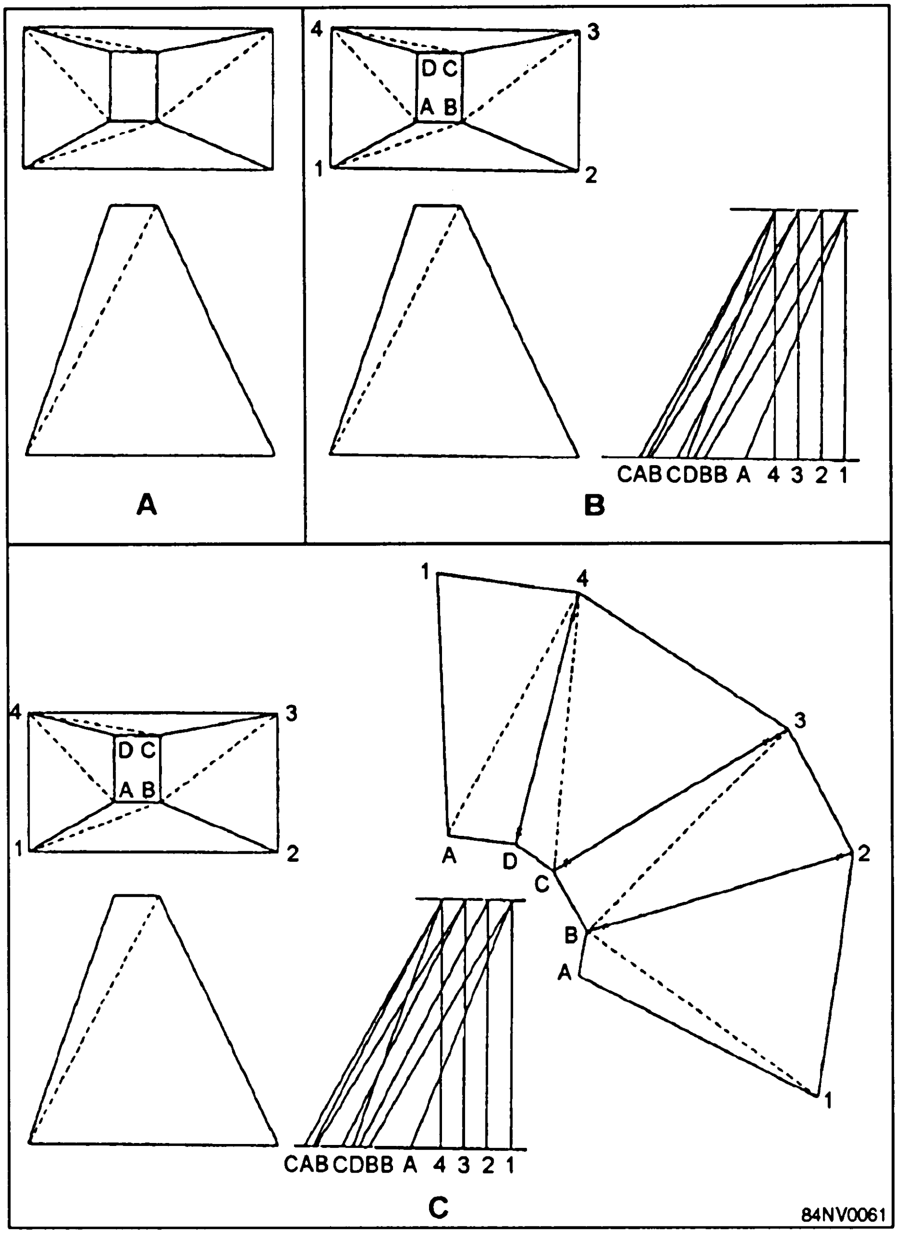


Figure 14-55.—Development of a rectangular transition piece, which is not a true pyramid.

this is by drawing diagonals that split the sides into two triangles. These diagonals are usually drawn as dotted lines to separate them from other elements. Then, the true length of each element is found, and the surface pattern developed by constructing each triangle in turn. To find the true-length lines, draw a true-length diagram.

1. Draw the orthographic views with the bend lines and the diagonals (view A).
2. Draw a true-length diagram of these elements (view B).
3. Draw the surface pattern by constructing one triangle at a time (view C).

The fitting in figure 14-56 has a warped surface. Its base is round and its top is oblong. The following method for development consists of dividing the surface into quadrilaterals of about the same size. A quadrilateral is a plane figure having four sides and four angles. A diagonal is then drawn across each of these to produce two triangles. When the true lengths of these elements have been found, the surface pattern may be drawn triangle by triangle.

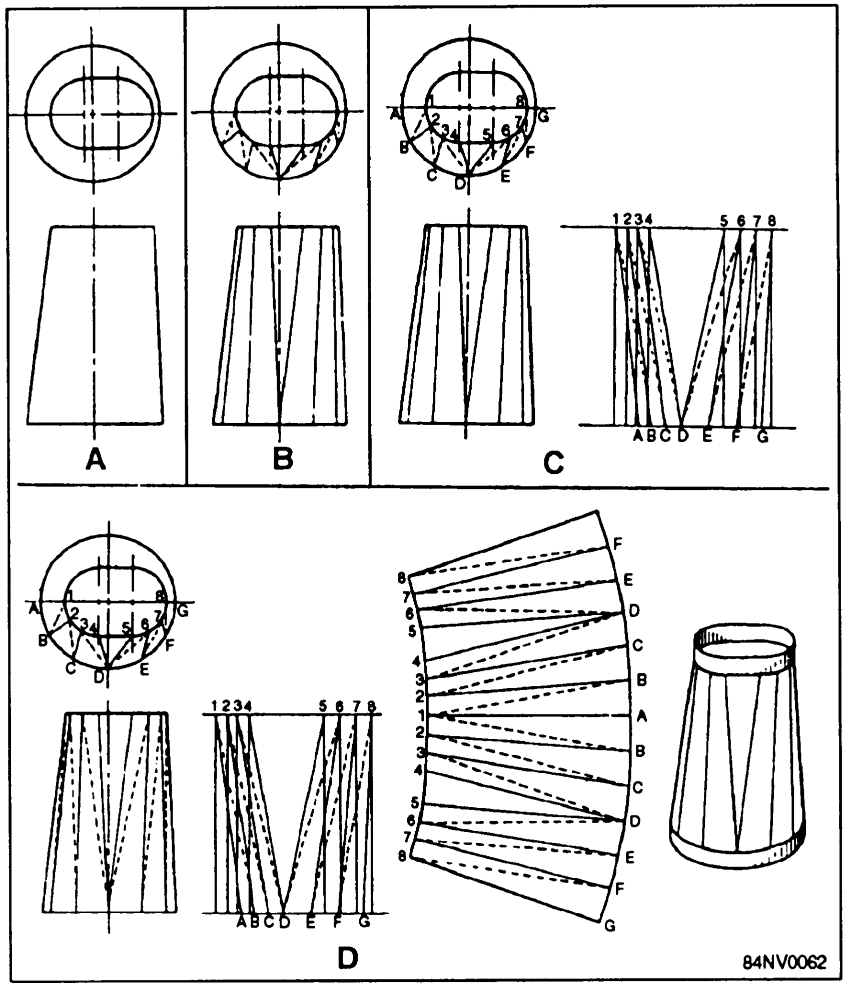


Figure 14-56.—Development of a warped transition piece.

1. Draw the top and front orthographic view (view A).
2. Divide the circle of the base into several equal spaces. Divide the arcs at the ends of the oblong into half as many spaces. Since the transition piece is symmetrical on a central axis, this may be done on only half of the top view. Connect these division points (view B). Use dotted lines for the diagonals to differentiate them.
3. Project the division points to the front view and draw the elements there.
4. Draw the true-length diagram for the elements (view C).
5. Draw an approximation of the surface pattern of the warped surface by constructing one triangle after another (view D).

METRIC SYSTEM

The metric system is an extremely accurate universal system of weights and measures. It is based on a unit called a meter.

NOTE: 1 meter was originally 1/10,000,000 the distance from the earth's equator to its pole. It is a system based on units of ten, making it a very uncomplicated system with which to work. A meter is 39.37 inches long or slightly longer than a yard.

Adding prefixes to the name of the primary unit of measure, such as micrometer or millimeter, form the names of metric denominations

Table 14-1 explains the metric system by showing nomenclature and giving the English measure equivalents.

Tables 14-1, 14-2, 14-3, 14-4, 14-5, and 14-6 are given as a quick reference when solving math-related problems.

Table 14-1.—Metric System and English Conversion

The gram, which is the primary unit of weights, is the weight of one cubic centimeter of pure distilled water at a temperature of 39.2° F., the kilogram is the weight of 1 liter of water; the ton is the weight of 1 cubic meter of water. The gram is used in weighing gold, jewels, and small quantities of things. The kilogram, commonly called kilo for brevity, is used by grocers; the ton is used for weighing heavy articles.

Measures of Pressure

1 pound per square inch	=	144 pounds per square foot 0.068 atmosphere 2.042 inches of mercury at 62° F. 27.7 inches of water at 62° F. 2.31 feet of water at 62° F.
1 atmosphere	=	30 inches of mercury at 62° F. 14.7 pounds per square inch 2116.3 pounds per square foot 33.95 feet of water at 62° F.
1 foot of water at 62° F.	=	62.355 pounds per square foot 0.433 pound per square inch
1 inch of mercury at 62° F.	=	1.132 foot of water 13.58 inches of water 0.491 pound per square inch

Metric and English Conversion Table

Measures of Length

1 millimeter	=	0.03937 inch
1 centimeter	=	0.3937 inch
1 meter	=	39.37 inches 3.2808 feet 1.0936 yards
1 kilometer	=	0.6214 mile
1 inch	=	25.4 millimeters 2.54 centimeters
1 foot	=	304.8 millimeters 0.3048 meter
1 yard	=	0.9144 meter
1 mile	=	1.609 kilometer

Square Measure—Measures of Surface

1 square millimeter	=	0.00155 square inch
1 square centimeter	=	0.155 square inch
1 square meter	=	10.764 square feet 1.196 square yard
1 are	=	0.0247 acre 1076.4 square feet
1 hectare	=	2.471 acres 107,640 square feet
1 square kilometer	=	0.3861 square mile 247.1 acres
1 square inch	=	6.542 square centimeters 654.2 square millimeters
1 square foot	=	0.0929 square meter 9.290 square centimeters
1 square yard	=	0.836 square meter
1 acre	=	0.4047 hectare 40.47 acres
1 square mile	=	2.5899 square kilometers

Cubic Measure—Measures of Volume and Capacity

1 cubic centimeter	=	0.061 cubic inch
1 cubic decimeter	=	61.023 cubic inches 0.0353 cubic foot

Micro, a millionth	$= \frac{1}{1,000,000}$
Milli, a thousandth	$= \frac{1}{1000}$
Centi, a hundredth	$= \frac{1}{100}$
Deci, a tenth	$= \frac{1}{10}$
Deca, ten	= 10
Hecto, one hundred	= 100
Kilo, one hundred	= 1000
Myria, ten thousand	= 10,000
Mega, one million	= 1,000,000

Principal Units of Metric System

The meter for lengths

The square meter for surfaces

The cubic meter for large volumes

The liter for small volumes

The gram for weights

Measures of Length

10 millimeters (mm.)	= 1 centimeter (cm.)
10 centimeters	= 1 decimeter (dm.)
10 decimeters	= 1 meter (m.)
10 meters	= 1 decameter (Dm.)
10 decameters	= 1 hectometer (Hm.)
10 hectometers	= 1 kilometer (Km.)
10 kilometers	= 1 myriameter

A meter is used in ordinary measurements; the centimeter or millimeter in calculating very small distances; and the kilometer for long distances.

Square Measure—Measures of Surface

100 square millimeters ($mm.^2$)	= 1 square centimeter ($cm.^2$)
100 square centimeters	= 1 square decimeter ($dm.^2$)
100 square decimeters	= 1 square meter ($m.^2$)
100 centiares, or square meters	= 1 are (a.)
100 ares	= 1 hectare (ha.)

The square meter is used for ordinary surfaces; the are, a square, each of whose sides is 10 meters, is the unit of land measure.

Cubic Measure—Measures of Volume

1000 cubic millimeters ($mm.^3$)	= 1 cubic centimeter ($cm.^3$ or cc.)
1000 cubic centimeters	= 1 cubic decimeter ($dm.^3$)
1000 cubic decimeters	= 1 cubic meter ($m.^3$)

The term stere is used to designate the cubic meter in measuring wood and timber. A tenth of a stere is a decistere, and ten steres and a decastere.

Liquid and Dry Measures—Measures of Capacity

10 milliliters (ml.)	= 1 centiliter (cl.)
10 centiliters	= 1 deciliter (dl.)
10 deciliters	= 1 liter (l.)
10 liters	= 1 decaliter (Dl.)
10 decaliters	= 1 hectoliter (Hl.)
10 hectoliters	= 1 kiloliter (Kl.)

The liter, which is a cube each of whose edges is $\frac{1}{10}$ of a meter in length, is the principal unit of measures of capacity. The hectoliter is the unit that is used in measuring large quantities of grain, fruits, roots, and liquids.

Measures of Weight

10 milligrams (mg.)	= 1 centigram (cg.)
10 centigrams	= 1 decigram (dg.)
10 decigrams	= 1 gram (g.)
10 grams	= 1 decagram (Dg.)
10 decagrams	= 1 hectogram (Hg.)
10 hectograms	= 1 kilogram (Kg.)
1000 kilograms	= 1 (metric) ton (T.)

1 cubic meter = 35.314 cubic feet; 1.308 cubic yards; 264.2 U.S. gallons

1 liter = 1 cubic decimeter; 61.023 cubic inches; 0.0353 cubic foot; 1.0567 U.S. quarts; 0.2642 U.S. gallons; 2.202 lbs. of water at 62° F.

Table 14-1.—Metric System and English Conversion-Continued

1 cubic inch = 16.383 cubic centimeters

1 cubic foot = { 0.02832 cubic meter
28.317 cubic decimeters
28.317 liters }

1 cubic yard = 0.7645 cubic meter

1 gallon U.S. = 3.785 liters

1 gallon British = 4.543 liters

Measures of Weight

1 gram = { 0.03216 ounce troy
0.03527 ounce avoirdupois
15.432 grains }

1 kilogram = { 2.2046 pounds aviordupois
35.274 ounces avoirdupois }

1 metric ton = { 0.9843 ton of 2,240 pounds
19.68 hundredweight
2204.6 pounds
1.1023 tons of 2,000 pounds }

1 grain = 0.0648 gram

1 ounce troy = 31.103 grams

1 ounce avoirdupois = 28.35 grams

1 pound = { 0.4536 kilogram
453.6 grams }

1 ton of 2240 pounds = { 1.016 metric tons
1016 kilograms }

Inches and Equivalents in Millimeters

Inches	MM	Inches	MM	Inches	MM
1/64	.397	45/64	17.859	26	660.4
1/32	.794	23/32	18.256	27	685.8
3/64	1.191	47/64	18.653	28	711.2
1/16	1.588	3/4	19.050	29	637.6
5/64	1.984	49/64	19.447	30	762.0
3/32	2.381	25/32	19.844	31	787.4
7/64	2.778	51/64	20.241	32	812.8
1/8	3.175	13/16	20.638	33	838.2
9/64	3.572	53/64	21.034	34	863.6
5/32	3.969	27/32	21.431	35	889.0
11/64	4.366	55/64	21.828	36	914.4
3/16	4.763	7/8	22.225	37	939.8
13/64	5.159	57/64	22.622	38	965.2
7/32	5.556	29/32	23.019	39	990.6
15/64	5.953	59/64	23.416	40	1016.0
1/4	6.350	15/16	23.813	41	1041.4
17/64	6.747	61/64	24.209	42	1066.8
9/32	7.144	31/32	24.606	43	1092.2
19/64	7.540	63/64	25.003	44	1117.6
5/16	7.938	1	25.400	45	1143.0
21/64	8.334	2	50.8	46	1168.4
11/32	8.731	3	76.2	47	1193.8
23/64	9.128	4	101.6	48	1219.2
3/8	9.525	5	127.0	49	1244.6
25/64	9.922	6	152.4	50	1270.0
13/32	10.319	7	177.8	51	1295.4
27/64	10.716	8	203.2	52	1320.8
7/16	11.113	9	228.6	53	1346.2
29/64	11.509	10	254.0	54	1371.6
15/32	11.906	11	279.4	55	1397.0
31/64	12.303	12	304.8	56	1422.4
1/2	12.700	13	330.2	57	1447.8
33/64	13.097	14	355.6	58	1473.2
17/32	13.494	15	381.0	59	1498.6
35/64	13.891	16	406.4	60	1524.0
9/16	14.288	17	431.8	61	1549.4
37/64	14.684	18	457.2	62	1574.8
19/32	15.081	19	482.6	63	1600.2
39/64	15.478	20	508.0	64	1625.6
5/8	15.875	21	533.4	65	1651.0
41/64	16.272	22	558.8	66	1676.4
21/32	16.669	23	584.2	67	1701.8
43/64	17.066	24	609.6	68	1727.2
11/16	17.463	25	635.0	69	1752.6

Table 14-1.—Metric System and English Conversion—Continued

Inches and Equivalents in Millimeters—*Continued*

Inches	MM	Inches	MM	Inches	MM
70	1778.0	114	2895.6	158	4013.2
71	1803.4	115	2921.0	159	4038.6
72	1828.8	116	2946.4	160	4064.0
73	1854.2	117	2971.8	161	4089.4
74	1879.6	118	2997.2	162	4114.8
75	1905.0	119	3022.6	163	4140.2
76	1930.4	120	3048.0	164	4165.6
77	1955.8	121	3073.4	165	4191.0
78	1981.2	122	3098.8	166	4216.4
79	2006.6	123	3124.2	167	4241.8
80	2032.0	124	3149.6	168	4267.2
81	2057.4	125	3175.0	169	4292.6
82	2082.8	126	3200.4	170	4318.0
83	2108.2	127	3225.8	171	4343.4
84	2133.6	128	3251.2	172	4368.8
85	2159.0	129	3276.6	173	4394.2
86	2184.4	130	3302.0	174	4419.2
87	2209.8	131	3327.4	175	4445.0
88	2235.2	132	3352.8	176	4470.4
89	2260.6	133	3378.2	177	4495.8
90	2286.0	134	3403.6	178	4521.2
91	2311.4	135	3429.0	179	4546.6
92	2336.8	136	3454.4	180	4572.0
93	2362.2	137	3479.8	181	4597.4
94	2387.6	138	3505.2	182	4622.8
95	2413.0	139	3530.6	183	4648.2
96	2438.4	140	3556.0	184	4673.6
97	2463.8	141	3581.4	185	4699.0
98	2489.2	142	3606.8	186	4724.4
99	2514.6	143	3632.2	187	4749.8
100	2540.0	144	3657.6	188	4775.2
101	2565.4	145	3683.0	189	4800.6
102	2590.8	146	3708.4	190	4826.0
103	2616.2	147	3733.8	191	4851.4
104	2641.6	148	3759.2	192	4876.8
105	2667.0	149	3784.6	193	4902.2
106	2692.4	150	3810.0	194	4927.6
107	2717.8	151	3835.4	195	4953.0
108	2743.2	152	3860.8	196	4978.4
109	2768.6	153	3886.2	197	5003.8
110	2794.0	154	3911.6	198	5029.2
111	2819.4	155	3937.0	199	5054.6
112	2844.8	156	3962.4	200	5080.0
113	2870.2	157	3987.8		

Millimeters and Equivalents in Inches

MM	Inches	MM	Inches	MM	Inches
1/100	.0004	45/100	.0177	89/100	.0350
2/100	.0008	46/100	.0181	90/100	.0354
3/100	.0012	47/100	.0185	91/100	.0358
4/100	.0016	48/100	.0189	92/100	.0362
5/100	.0020	49/100	.0193	93/100	.0366
6/100	.0024	50/100	.0197	94/100	.0370
7/100	.0028	51/100	.0201	95/100	.0374
8/100	.0031	52/100	.0205	96/100	.0378
9/100	.0035	53/100	.0209	97/100	.0382
10/100	.0039	54/100	.0213	98/100	.0386
11/100	.0043	55/100	.0217	99/100	.0390
12/100	.0047	56/100	.0221	1	.0394
13/100	.0051	57/100	.0224	2	.0787
14/100	.0055	58/100	.0228	3	.1181
15/100	.0059	59/100	.0232	4	.1575
16/100	.0063	60/100	.0236	5	.1969
17/100	.0067	61/100	.0240	6	.2362
18/100	.0071	62/100	.0244	7	.2756
19/100	.0075	63/100	.0248	8	.3150
20/100	.0079	64/100	.0252	9	.3543
21/100	.0083	65/100	.0256	10	.3937
22/100	.0087	66/100	.0260	11	.4331
23/100	.0091	67/100	.0264	12	.4724
24/100	.0094	68/100	.0268	13	.5118
25/100	.0098	69/100	.0272	14	.5512
26/100	.0102	70/100	.0276	15	.5906
27/100	.0106	71/100	.0280	16	.6299
28/100	.0110	72/100	.0284	17	.6693
29/100	.0114	73/100	.0287	18	.7087
30/100	.0118	74/100	.0291	19	.7480
31/100	.0122	75/100	.0295	20	.7874
32/100	.0126	76/100	.0299	21	.8268
33/100	.0130	77/100	.0303	22	.8661
34/100	.0134	78/100	.0307	23	.9055
35/100	.0138	79/100	.0311	24	.9449
36/100	.0142	80/100	.0315	25	.9843
37/100	.0146	81/100	.0319	26	1.0236
38/100	.0150	82/100	.0323	27	1.0630
39/100	.0154	83/100	.0327	28	1.1024
40/100	.0158	84/100	.0331	29	1.1417
41/100	.0161	85/100	.0335	30	1.1811
42/100	.0165	86/100	.0339	31	1.2205
43/100	.0169	87/100	.0343	32	1.2598
44/100	.0173	88/100	.0347	33	1.2992

Table 14-1.—Metric System and English Conversion-Continued

Millimeters and Equivalents in Inches—*Continued*

MM	Inches	MM	Inches	MM	Inches
34	1.3386	78	3.0709	122	4.8031
35	1.3780	79	3.1102	123	4.8425
36	1.4173	80	3.1496	124	4.8819
37	1.4567	81	3.1890	125	4.9213
38	1.4961	82	3.2283	126	4.9606
39	1.5354	83	3.2677	127	5.0000
40	1.5748	84	3.3071	128	5.0394
41	1.6142	85	3.3465	129	5.0787
42	1.6535	86	3.3858	130	5.1181
43	1.6929	87	3.4252	131	5.1575
44	1.7323	88	3.4646	132	5.1968
45	1.7717	89	3.5039	133	5.2362
46	1.8110	90	3.5433	134	5.2756
47	1.8504	91	3.5827	135	5.3150
48	1.8898	92	3.6220	136	5.3543
49	1.9291	93	3.6614	137	5.3937
50	1.9685	94	3.7008	138	5.4331
51	2.0079	95	3.7402	139	5.4724
52	2.0472	96	3.7795	140	5.5118
53	2.0866	97	3.8189	141	5.5512
54	2.1260	98	3.8583	142	5.5905
55	2.1654	99	3.8976	143	5.6299
56	2.2047	100	3.9370	144	5.6693
57	2.2441	101	3.9764	145	5.7087
58	2.2835	102	4.0157	146	5.7480
59	2.3228	103	4.0551	147	5.7874
60	2.3622	104	4.0945	148	5.8268
61	2.4016	105	4.1339	149	5.8661
62	2.4409	106	4.1732	150	5.9055
63	2.4803	107	4.2126	151	5.9449
64	2.5197	108	4.2520	152	5.9842
65	2.5591	109	4.2913	153	6.0236
66	2.5984	110	4.3307	154	6.0630
67	2.6378	111	4.3701	155	6.1024
68	2.6772	112	4.4094	156	6.1417
69	2.7165	113	4.4488	157	6.1811
70	2.7559	114	4.4882	158	6.2205
71	2.7953	115	4.5276	159	6.2598
72	2.8346	116	4.5669	160	6.2992
73	2.8740	117	4.6063	161	6.3386
74	2.9134	118	4.6457	162	6.3779
75	2.9528	119	4.6850	163	6.4173
76	2.9921	120	4.7244	164	6.4567
77	3.0315	121	4.7638	165	6.4961

Millimeters and Equivalents in Inches—*Concluded*

MM	Inches	MM	Inches	MM	Inches
166	6.5354	211	8.3071	256	10.079
167	6.5748	212	8.3464	257	10.118
168	6.6142	213	8.3858	258	10.157
169	6.6535	214	8.4252	259	10.197
170	6.6929	215	8.4646	260	10.236
171	6.7323	216	8.5039	261	10.276
172	6.7716	217	8.5433	262	10.315
173	6.8110	218	8.5827	263	10.354
174	6.8504	219	8.6220	264	10.394
175	6.8898	220	8.6614	265	10.433
176	6.9291	221	8.7008	266	10.472
177	6.9685	222	8.7401	267	10.512
178	7.0079	223	8.7795	268	10.551
179	7.0472	224	8.8189	269	10.591
180	7.0866	225	8.8583	270	10.630
181	7.1260	226	8.8976	271	10.669
182	7.1653	227	8.9370	272	10.709
183	7.2047	228	8.9764	273	10.748
184	7.2441	229	9.0157	274	10.787
185	7.2835	230	9.0551	275	10.827
186	7.3228	231	9.0945	276	10.866
187	7.3622	232	9.1338	277	10.905
188	7.4016	233	9.1732	278	10.945
189	7.4409	234	9.2126	279	10.984
190	7.4803	235	9.2520	280	11.024
191	7.5197	236	9.2913	281	11.063
192	7.5590	237	9.3307	282	11.102
193	7.5984	238	9.3701	283	11.142
194	7.6378	239	9.4094	284	11.181
195	7.6772	240	9.4488	285	11.220
196	7.7165	241	9.4882	286	11.260
197	7.7559	242	9.5275	287	11.299
198	7.7953	243	9.5669	288	11.339
199	7.8346	244	9.6063	289	11.378
200	7.8740	245	9.6457	290	11.417
201	7.9134	246	9.6850	291	11.457
202	7.9527	247	9.7244	292	11.496
203	7.9921	248	9.7638	293	11.535
204	8.0315	249	9.8031	294	11.575
205	8.0709	250	9.8425	295	11.614
206	8.1102	251	9.8819	296	11.654
207	8.1496	252	9.9212	297	11.693
208	8.1890	253	9.9606	298	11.732
209	8.2283	254	10.000	299	11.772
210	8.2677	255	10.039		

Useful Factors, English Measures

Inches	×	0.08333	= feet
"	×	0.02778	= yards
"	×	0.00001578	= miles
Square inches	×	0.00695	= square feet
" "	×	0.0007716	= square yards
Cubic inches	×	0.00058	= cubic feet
" "	×	0.0000214	= cubic yards
" "	×	0.004329	= U.S. gallons
Feet	×	0.3334	= yards
"	×	0.00019	= miles
Square feet	×	144.0	= square inches
" "	×	0.1112	= square yards
Cubic feet	×	1,728	= cubic inches
" "	×	0.03704	= cubic yards
" "	×	7.48	= U.S. gallons
Yards	×	36	= inches
"	×	3	= feet
"	×	0.0005681	= miles
Square yards	×	1,296	= square inches
" "	×	9	= square feet
Cubic yards	×	46,656	= cubic inches
" "	×	27	= cubic feet
Miles	×	63,360	= inches
"	×	5,280	= feet
"	×	1,760	= yards
Avoirdupois ounces .	×	0.0625	= pounds
" " .	×	0.00003125	= tons
" pounds .	×	16	= ounces
" " .	×	.001	= hundredweight
" " .	×	.0005	= tons
" " .	×	27.681	= cubic inches of water at 39° F
" tons	×	32,000	= ounces
" "	×	2,000	= pounds
Watts	×	0.00134	= horse power
Horse power	×	746	= watts

Weight of round iron per foot = square of diameter in quarter inches ÷ 6.

Weight of flat iron per foot = width × thickness × 10/3.

Weight of flat plates per square foot = 5 pounds for each 1/8 inch thickness.

Useful Factors, Metric Measures

Millimeters × 0.03937	= inches
Millimeters ÷ 25.4	= inches
Centimeters × 0.3937	= inches
Centimeters ÷ 2.54	= inches
Meters × 39.37	= inches
Meters × 3.281	= feet
Meters × 1.094	= yards
Kilometers × 0.621	= miles
Kilometers ÷ 1.6093	= miles
Kilometers × 3280.7	= feet
Square millimeters × 0.0155	= square inches
Square millimeters ÷ 645.1	= square inches
Square centimeters × 0.155	= square inches
Square centimeters ÷ 6.451	= square inches
Square meters × 10.764	= square feet
Square kilometers × 247.1	= acres
Hectares × 2.471	= acres
Cubic centimeters ÷ 16.385	= cubic inches
Cubic centimeters ÷ 3.69	= fluid drachms, U.S. Pharmacopoeia
Cubic centimeters ÷ 29.57	= fluid ounce U.S. Pharmacopoeia
Cubic meters × 35.315	= cubic feet
Cubic meters × 1.038	= cubic yards
Cubic meters × 264.2	= gallons, United States
Liters × 61.022	= cubic inches
Liters × 33.84	= fluid ounces
Liters × 0.2642	= gallons, United States
Liters ÷ 3.78	= gallons, United States
Liters ÷ 28.316	= cubic feet
Hectoliters × 3.531	= cubic feet
Hectoliters × 2.84	= bushels, United States
Hectoliters × 0.131	= cubic yards
Hectoliters × 26.42	= gallons, United States
Grams × 15.432	= grains
Grams (water) ÷ 29.57	= fluid ounces
Grams ÷ 28.35	= ounces, avoirdupois
Kilograms × 2.2046	= pounds
Kilograms × 35.3	= ounces, avoirdupois
Kilograms ÷ 1102.3	= tons, 2000 pounds

Table 14-2.—Mathematics Symbols

SYMBOL	NAME OR MEANING	SYMBOL	NAME OR MEANING
$+$	Addition or positive value	$\sqrt{\ }$	Square root symbol
$-$	Subtraction or negative value	$\sqrt[n]{\ }$	Radical symbol. Letter n represents a number indicating which root is to be taken.
$\pm$	Positive or negative value		
$\cdot$	Multiplication dot (Centered; not to be mistaken for decimal point.)	i or j	Imaginary unit; operator j for electronics; represents $\sqrt{-1}$.
$\times$	Multiplication symbol	∞	Infinity symbol
( )	Parentheses	. . .	Ellipses. Used in series of numbers in which successive numbers are predictable by their conformance to a pattern; meaning is approximated by "etc."
[ ]	Brackets } Grouping symbols		
{ }	Braces		
%	Percent		
$+$	Division symbol	$\log_a N$	Logarithm of N to the base a.
:	Ratio symbol	log N	Logarithm of N to the base 10. (understood)
: :	Proportion symbol	1n N	Natural or Napierian logarithm of N. Base of the natural or Napierian logarithm system.
$=$	Equality symbol		
$\neq$	"Not equal" symbol	$\lvert X \rvert$	Absolute value of X.
$<$	Less than	π	Pi. The ratio of the circumference of any circle to its diameter. Approximate numerical value is 22/7.
$\leq$	Less than or equal to		
$>$	Greater than		
$\geq$	Greater than or equal to		Therefore
$\propto$	"Varies directly as" or "is proportional to" (Not to be mistaken for Greek alpha (α).)	$\angle$ or $\measuredangle$	Angle

Table 14-3.—Table of Decimal Equivalents of Fractions of an Inch

1/64	0.0156	17/64	0.2656	33/64	0.5156	49/64	0.7656
1/32	.0313	9/32	.2813	17/32	.5313	25/32	.7813
3/64	.0469	19/64	.2969	35/64	.5469	51/64	.7969
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.0781	21/64	.3281	37/64	.5781	53/64	.8281
3/32	.0938	11/32	.3438	19/32	.5938	27/32	.8438
7/64	.1094	23/64	.3594	39/64	.6094	55/64	.8594
1/8	.125	3/8	.375	5/8	.625	7/8	.875
9/64	.1406	25/64	.3906	41/64	.6406	57/64	.8906
5/32	.1563	13/32	.4063	21/32	.6563	29/32	.9063
11/64	.1719	27/64	.4219	43/64	.6719	59/64	.9219
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
13/64	.2031	29/64	.4531	45/64	.7031	61/64	.9531
7/32	.2188	15/32	.4688	23/32	.7188	31/32	.9688
15/64	.2344	31/64	.4844	47/64	.7344	63/64	.9844
1/4	.25	1/2	.5	3/4	.75	1	1.0

Table 14-4.—Weights and Measures

Distance

12 inches	= 1 foot (ft)
3 feet	= 1 yard (yd)
5-1/2 yards	= 1 rod (rd)
16-1/2 feet	= 1 rod
1,760 yards	= 1 statute mile (mi)
5,280 feet	= 1 statute mile

Additional measures of length occasionally used

1000 mils = 1 inch; 3 inches = 1 palm; 4 inches = 1 hand

9 inches = 1 span; 2-1/2 feet = 1 military space

5-1/2 yards or 16-1/2 feet = 1 rod; 2 yards = 1 fathom; a cable length = 120 fathoms = 720 feet;

1 inch = 0.0001157 cable length = 0.013889 fathom = 0.111111 span.

Old Land or Surveyors' Measure*

7.92 inches = 1 link (l.)

100 links, or 66 feet, or 4 rods = 1 chain (ch.)

10 chains or 220 yards = 1 furlong

8 furlongs or 80 chains = 1 mile (mi.)

*Sometimes called Gunter's Chain.

Nautical Measure

6080.26 feet or 1.15156 statute miles = 1 nautical mile or knot†

3 nautical miles = 1 league

60 nautical miles, or 69.169 statute miles = 1 degree at the equator

360 degrees = circumference of the earth at the equator

†The value varies according to different measures of the earth's diameter.

Square Measures–Measures of Surface

144 square inches (sq. in.) = 1 square foot (sq. ft.)

9 square feet = 1 square yard (sq. yd.)

$30\frac{1}{4}$ square yards or $272\frac{1}{4}$ square feet = 1 square rod (sq. rd.)

160 square rods or 43,560 square feet = 1 acre (A.)

640 acres = 1 square mile (sq. mi.)

Surveyors' Measure

16 square rods = 1 square chain (sq. ch.)

10 square chains = 1 acre (A.)

640 acres = 1 square mile (sq. mi.)

1 square mile = 1 section (sec.)

36 sections = 1 township (tp.)

Solid or Cubic Measure–Measures of Volume

1728 cubic inches (cu. in.) = 1 cubic foot (cu. ft.)

27 cubic feet = 1 cubic yard (cu. yd.)

The following measures are also used for wood and masonry.

1 cord of wood = a pile, 4 × 4 × 8 feet = 128 cubic feet

1 perch of masonry = $16\frac{1}{2} \times 1\frac{1}{2} \times 1$ foot = $24\frac{3}{4}$ cubic feet

Shipping Measure

Register Ton—For register tonnage or for measuring entire internal capacity of a ship or vessel:

100 cubic feet = 1 register ton

Shipping Ton—For the mreasurement of cargo.

40 cubic feet = 1 United States shipping ton = 32.143 U.S. bushels

42 cubic feet = 1 British shipping ton = 32.719 imperial bushels.

Carpenter's Rule—To find the weight a vessel will carry, multiply the length of keel by the breadth at main beam by the depth of the hold in feet and divide by 95 (the cubic feet allowed for a ton). The result will be the tonnage.

Dry Measure

2 cups = 1 pint (pt)

2 pints = 1 quart (qt)

4 quarts = 1 gallon (gal)

8 quarts = 1 peck (pk)

4 pecks = 1 bushel (bu)

Counting Units

12 units = 1 dozen (doz)

12 dozen = 1 gross

144 units = 1 gross

24 sheets = 1 quire

480 sheets = 1 ream

Equivalents

1 cubic foot of water weighs 62.5 pounds (approx) = 1,000 ounces

1 gallon of water weighs 8-1/3 pounds (approx)

1 cubic foot = 7.48 gallons

1 inch = 2.54 centimeters

1 foot = 30.4801 centimeters

1 meter = 39.37 inches

1 liter = 1.05668 quarts (liquid) = 0.90808 quart (dry)

1 nautical mile = 6,080 feet (approx)

1 fathom = 6 feet

1 shot of chain = 15 fathoms

Liquid Measure

3 teaspoons (tsp) = 1 tablespoon (tbsp)

16 tablespoons = 1 cup

2 cups = 1 pint

16 fluid ounces (oz) = 1 pint

4 gills (gi.) = 1 pint (pt.)

2 pints = 1 quart (qt.)

4 quarts = 1 gallon (gal.) $\begin{cases}\text{U.S. 231 cubic inches}\\\text{British 277.274 cubic inches}\end{cases}$

1 cubic foot = 7.48 U.S. gallons

Old Liquid Measure

$31\frac{1}{2}$ gallons	= 1 barrel (bbl.)
42 gallons	= 1 tierce
2 barrels or 63 gallons	= 1 hogshead (hhd.)
84 gallons or 2 tierces	= 1 puncheon
2 hogsheads or 4 barrels or 126 gallons	= 1 pipe or butt
2 pipes or 3 puncheons	= 1 tun

Apothecaries' Fluid Measure

60 minims = 1 fluid drachm; 8 drachms = 1 fluid ounce

1 U.S. fluid ounce = 8 drachms = 1.805 cubic inch = $\frac{1}{128}$ U.S. gallon. The fluid ounce in Great Britain is 1.732 cubic inches.

Measures of Weight

Avoirdupois or Commercial Weight

16 drachms or 437.5 grains	= 1 ounce (oz.)
16 ounces or 7000 grains	= 1 pound (lb.)
2000 pounds	= 1 net or short ton
2240 pounds	= 1 gross or long ton
2204.6 pounds	= 1 metric ton

Measures of weight occasionally used in collecting duties on foreign goods at U.S. custom houses and in freighting coal are:

1 hundredweight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundredweight); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal = 100 pounds.

Troy Weight*

24 grains	= 1 pennyweight (pwt.)
20 pennyweights	= 1 ounce (oz.)
12 ounces or 5760 grains	= 1 pound (lb.)

A carat of the jewelers, for precious stones = 3.2 grains in the United States. The International carat = 3.168 grains or 200 milligrams. In avoirdupois, apothecaries' and troy weights, the grain is the same, 1 pound troy = 0.82286 pound avoirdupois.

*Used for weighing gold, silver, jewels, etc.

Apothecaries' Weight†

20 grains (gr.)	= 1 scruple (℈)
3 scruples	= 1 drachm (ʒ)
8 drachms	= 1 ounce (℥)
12 ounces	= 1 pound troy (lb.)

†This table is used in compounding medicines and prescriptions.

Measures of Time

one millionth of a second	= 1 microsecond (µsec.)
one thousandth of a second	= 1 millisecond (msec.)
1/3600 hour	= 1 second (sec.)
60 seconds (sec.)	= 1 minute (min.)
60 minutes	= 1 hour (hr.)
24 hours	= 1 day (da.)
7 days	= 1 week (wk.)
365 days	= 1 solar year (yr.)
366 days	= 1 leap-year (every four years)
100 years	= 1 century

By the Gregorian calendar every year in which the number is divisible by 4 is a leap year except that the centesimal years (each 100 years: 1800, 1900, 2000, etc.) are leap-years only when the number of the year is divisible by 400.

Water Conversion Factors

U.S. gallons	×	8.33	=	pounds
U.S. gallons	×	0.13368	=	cubic feet
U.S. gallons	×	231	=	cubic inches
U.S. gallons	×	0.83	=	English gallo[illegible]
U.S. gallons	×	3.78	=	liters
English gallons (Imperial)	×	10	=	pounds
English gallons (Imperial)	×	0.16	=	cubic feet
English gallons (Imperial)	×	277.274	=	cubic inches
English gallons (Imperial)	×	1.2	=	U.S. gallons
English gallons (Imperial)	×	4.537	=	liters
Cubic inches of water (39.1°)	×	0.036024	=	pounds
Cubic inches of water (39.1°)	×	0.004329	=	U.S. gallons
Cubic inches of water (39.1°)	×	0.003607	=	English gallo[illegible]
Cubic inches of water (39.1°)	×	0.576348	=	ounces
Cubic feet (of water) (39.1°)	×	62.425	=	pounds
Cubic feet (of water) (39.1°)	×	7.48	=	U.S. gallons
Cubic feet (of water) (39.1°)	×	6.232	=	English gallo[illegible]
Cubic feet (of water) (39.1°)	×	0.028	=	tons
Pounds of water	×	27.72	=	cubic inches
Pounds of water	×	0.01602	=	cubic feet
Pounds of water	×	0.12	=	U.S. gallons
Pounds of water	×	0.10	=	English gallo[illegible]

Table 14-4.—Weights and Measures—Continued

Miscellaneous Tables

Numbers		Circular and Angular Measures	
12 units	= 1 dozen	60 seconds (″)	= 1 minute (′)
12 dozen	= 1 gross	60 minutes	= 1 degree (°)
12 gross	= 1 great gross	90 degrees	= 1 quadrant
20 units	= 1 score	360 degrees	= 1 circumference

Table 14-5.—Rectangular Capacities

RECTANGULAR TANKS
Capacity in U.S. Gallons Per Foot of Depth

Widths, Feet	Length of Tank—in Feet						
	2	2 1/2	3	3 1/2	4	4 1/2	5
2	29.92	37.40	44.88	52.36	59.84	67.32	74.81
2 1/2	—	46.75	56.10	65.45	74.81	84.16	93.51
3	—	—	67.32	78.55	89.77	101.0	112.2
3 1/2	—	—	—	91.64	104.7	117.8	130.9
4	—	—	—	—	119.7	134.6	149.6
4 1/2	—	—	—	—	—	151.5	168.3
5	—	—	—	—	—	—	187.0
	5 1/2	6	6 1/2	7	7 1/2	8	8 1/2
2	82.29	89.77	97.25	104.7	112.2	119.7	127.2
2 1/2	102.9	112.2	121.6	130.9	140.3	149.6	159.0
3	123.4	134.6	145.9	157.1	168.3	179.5	190.8
3 1/2	144.0	157.1	170.2	183.3	196.4	209.5	222.5
4	164.6	179.5	194.5	209.5	224.4	239.4	254.3
4 1/2	185.1	202.0	218.8	235.6	252.5	269.3	286.1
5	205.7	224.4	243.1	261.8	280.5	299.2	317.9
5 1/2	226.3	246.9	267.4	288.0	308.6	329.1	349.7
6	—	269.3	291.7	314.2	336.6	359.1	381.5
6 1/2	—	—	316.1	340.2	364.7	389.0	413.3
7	—	—	—	366.5	392.7	418.9	445.1
7 1/2	—	—	—	—	420.8	448.8	476.9
8	—	—	—	—	—	478.8	508.7
8 1/2	—	—	—	—	—	—	540.5
	9	9 1/2	10	10 1/2	11	11 1/2	12
2	134.6	142.1	149.6	157.1	164.6	172.1	179.5
2 1/2	168.3	177.7	187.0	196.4	205.7	215.1	224.4
3	202.0	213.2	224.4	235.6	246.9	258.1	269.3
3 1/2	235.6	248.7	261.8	274.9	288.0	301.1	314.2
4	269.3	284.3	299.2	314.2	329.1	344.1	359.1
4 1/2	303.0	319.3	336.6	353.5	370.3	387.1	403.9
5	336.6	355.3	374.0	392.7	411.4	430.1	448.8
5 1/2	370.3	390.9	411.4	432.0	452.6	473.1	493.7
6	403.9	426.4	448.8	471.3	493.7	516.2	538.6
6 1/2	437.6	461.9	486.2	510.5	534.9	559.2	583.5
7	471.3	497.5	523.6	549.8	576.0	602.2	628.4
7 1/2	504.9	533.0	561.0	589.1	617.1	645.2	673.2
8	538.6	568.5	598.4	628.4	658.3	688.2	718.1
8 1/2	572.3	604.1	635.8	667.6	699.4	731.2	763.0
9	605.9	639.6	673.2	706.9	740.6	774.2	807.9
9 1/2	—	675.1	710.6	746.2	781.7	817.2	852.3
10	—	—	748.1	785.5	822.9	860.3	897.7
10 1/2	—	—	—	824.7	864.0	903.3	942.5
11	—	—	—	—	905.1	946.3	987.4
11 1/2	—	—	—	—	—	989.3	1032
12	—	—	—	—	—	—	1077

U.S. Gallon of water weighs 8.34523 pounds avoirdupois at 4° C.

Table 14-6.—Circular Capacities

Diam., Ft.	In	Gallons	Diam., Ft.	In	Gallons	Diam., Ft.	In	Gallons
1		5.875	3	6	71.97	5	11	205.7
1	1	6.895	3	7	75.44	6		211.5
1	2	7.997	3	8	78.99	6	3	229.5
1	3	9.180	3	9	82.62	6	6	248.2
1	4	10.44	3	10	86.33	6	9	267.7
1	5	11.79	3	11	90.13	7		287.9
1	6	13.22	4		94.00	7	3	308.8
1	7	14.73	4	1	97.96	7	6	330.5
1	8	16.32	4	2	102.0	7	9	352.0
1	9	17.99	4	3	106.1	8		376.0
1	10	19.75	4	4	110.3	8	3	399.9
1	11	21.58	4	5	114.6	8	6	424.5
2		23.50	4	6	119.0	8	9	449.8
2	1	25.50	4	7	123.4	9		475.9
2	2	27.58	4	8	127.9	9	3	502.7
2	3	29.74	4	9	132.6	9	6	530.2
2	4	31.99	4	10	137.3	9	9	558.5
2	5	34.31	4	11	142.0	10		587.5
2	6	36.72	5		146.9	10	3	617.3
2	7	39.21	5	1	151.8	10	6	647.7
2	8	41.78	5	2	156.8	10	9	679.0
2	9	44.43	5	3	161.9	11		710.9
2	10	47.16	5	4	167.1	11	3	743.6
3	11	49.98	5	5	172.4	11	6	777.0
3		52.88	5	6	177.7	11	9	811.1
3	1	55.86	5	7	183.2	12		846.0
3	2	58.92	5	8	188.7	12	3	881.6
3	3	62.06	5	9	194.2	12	6	918.0
3	4	65.28	5	10	199.9	12	9	955.1
3	5	68.58						

U.S. Gallon of water weighs 8.34523 Pounds Avoirdupois at 4° C.

SUMMARY

In this chapter, you have been working problems that you will meet in your job. This chapter only presents the math basics. If you should need further help, see the references listed at the beginning of this chapter.