CHAPTER 1

MATHEMATICS

INTRODUCTION

The use of mathematics is so woven into every area of everyday life that seldom if ever does one fully realize how very helpless we would be in the performance of most of our daily work without the knowledge of even the simplest form of mathematics. Many persons have difficulty with relatively simple computations involving only elementary mathematics. Performing mathematical computations with success requires an understanding of the correct procedures and continued practice in the use of mathematical manipulations.

A person entering the aviation field will be required to perform with accuracy. The aviation mechanic is often involved in tasks that require mathematical computations of some sort. Tolerances in aircraft and engine components are often critical, making it necessary to measure within a thousandth or ten-thousandth of an inch. Because of the close tolerances to which he must adhere, it is important that the aviation mechanic be able to make accurate measurements and mathematical calculations.

Mathematics may be thought of as a kit of tools, each mathematical operation being compared to the use of one of the tools in the solving of a problem. The basic operations of addition, subtraction, multiplication, and division are the tools available to aid us in solving a particular problem.

WHOLE NUMBERS

Addition of Whole Numbers

The process of finding the combined amount of two or more numbers is called addition. The answer is called the sum.

When adding several whole numbers, such as 4567, 832, 93122, and 65, place them under each other with their digits in columns so that the last, or right hand, digits are in the same column.

When adding decimals such as 45.67, 8.32, 9.8122, and .65, place them under each other so that the decimal points are in a straight "up-and-down" line.

To check addition, either add the figures again in the same order, or add them in reverse order.

Subtraction of Whole Numbers

Subtraction is the process of finding the difference between two numbers by taking the smaller from the larger of the two numbers. The number which is subtracted is called the subtrahend, the other number the minuend, and their difference is called the remainder. To find the remainder, write the subtrahend under the minuend, as in addition. Beginning at the right, subtract each figure in the subtrahend from the figure above it and write the individual remainder below in the same column. When the process is completed, the number below the subtrahend is the remainder.

To check subtraction, add the remainder and the subtrahend together. The sum of the two should equal the minuend.

Multiplication of Whole Numbers

The process of finding the quantity obtained by repeating a given number a specified number of times is called multiplication. More simply stated, the process of multiplication is, in effect, a case of repeated addition in which all the numbers being added are identical. Thus, the sum of $6 + 6 + 6 + 6 = 24$ can be expressed by multiplication as $6 \times 4 = 24$. The numbers 6 and 4 are known as the factors of the multiplication, and 24 as the product.

In multiplication, the product is formed by multiplying the factors. When one of the factors is a single-digit integer (whole number), the product is formed by multiplying the single-digit integer with each digit of the other factor from right to left, carrying when necessary.

When both factors are multiple-digit integers, the product is formed by multiplying each digit in the multiplying factor with the other factor. Exercise care, when writing down the partial products formed, to make certain that the extreme right digit lines up under the multiplying digit. It is then a matter of simple addition to find the final product.

EXAMPLE

Determine the cost of 18 spark plugs that cost $3.25 each.

$$\begin{array}{r} 3.25 \\ \times 18 \\ \hline 2600 \\ 325 \\ \hline 58.50 \end{array}$$

When multiplying a series of numbers together, the final product will be the same regardless of the order in which the numbers are arranged.

EXAMPLE

MULTIPLY: (7) (3) (5) (2) = 210

$$\begin{array}{r} 7 \\ \times 3 \\ \hline 21 \end{array} \quad \begin{array}{r} 21 \\ \times 5 \\ \hline 105 \end{array} \quad \begin{array}{r} 105 \\ \times 2 \\ \hline 210 \end{array} \quad \text{or} \quad \begin{array}{r} 7 \\ \times 5 \\ \hline 35 \end{array} \quad \begin{array}{r} 3 \\ \times 2 \\ \hline 6 \end{array} \quad \begin{array}{r} 35 \\ \times 6 \\ \hline 210 \end{array}$$

Division of Whole Numbers

The process of finding how many times one number is contained in a second number is called division. The first number is called the divisor, the second the dividend, and the result is the quotient.

Of the four basic operations with integers, division is the only one that involves trial and error in its solution. It is necessary to guess at the proper quotient digits, and though experience will tend to lessen the number of trials, everyone will guess incorrectly at some time or another.

Placing the decimal point correctly in the quotient quite often presents a problem. When dividing a decimal by a decimal, an important step is to first remove the decimal from the divisor. This is accomplished by shifting the decimal point to the right the number of places needed to eliminate it. Next, move the decimal point to the right as many places in the dividend as was necessary to move it in the divisor, and then proceed as in ordinary division.

FRACTIONS

A fraction is an indicated division that expresses one or more of the equal parts into which a unit is divided. For example, the fraction $\frac{2}{3}$ indicates that the whole has been divided into 3 equal parts and that 2 of these parts are being used or considered. The number above the line is the numerator; and the number below the line is the denominator.

If the numerator of a fraction is equal to or larger than the denominator, the fraction is known as an improper fraction. In the fraction $\frac{15}{8}$, if the indicated division is performed, the improper fraction is changed to a mixed number, which is a whole number and a fraction:

$$\frac{15}{8} = 1\frac{7}{8}$$

A complex fraction is one that contains one or more fractions or mixed numbers in either the numerator or denominator. The following fractions are examples:

$$\frac{\frac{1}{2}}{\frac{2}{3}}; \quad \frac{\frac{5}{8}}{2}; \quad \frac{\frac{3}{4}}{\frac{5}{8}}; \quad \frac{\frac{3\frac{1}{2}}{2}}{3}$$

A decimal fraction is obtained by dividing the numerator of a fraction by the denominator and showing the quotient as a decimal. The fraction $\frac{5}{8}$ equals $5 \div 8 = .625$.

A fraction does not change its value if both numerator and denominator are multiplied or divided by the same number.

$$\frac{1}{4} \times \frac{3}{3} = \frac{3}{12} = \frac{1}{4}$$

The same fundamental operations performed with whole numbers can also be performed with fractions. These are addition, subtraction, multiplication, and division.

Addition and Subtraction of Common Fractions

In order to add or subtract fractions, all the denominators must be alike. In working with fractions, as in whole numbers, the rule of likeness applies. That is, only like fractions may be added or subtracted.

When adding or subtracting fractions that have like denominators, it is only necessary to add or subtract the numerators and express the result as the numerator of a fraction whose denominator is the common denominator. When the denominators are unlike, it is necessary to first reduce the fractions to a common denominator before proceeding with the addition or subtraction process.

EXAMPLES

1. A certain switch installation requires $\frac{5}{8}$-inch plunger travel before switch actuation occurs. If $\frac{1}{8}$-inch travel is required after actuation, what will be the total plunger travel?

FIRST: Add the numerators.

$$5 + 1 = 6$$

NEXT: Express the result as the numerator of a fraction whose denominator is the common denominator.

$$\frac{5}{8} + \frac{1}{8} = \frac{6}{8}$$

2. The total travel of a jackscrew is $\frac{13}{16}$ of an inch. If the travel in one direction from the neutral position is $\frac{7}{16}$ of an inch, what is the travel in the opposite direction?

FIRST: Subtract the numerators.

$$13 - 7 = 6$$

NEXT: Express the result as the numerator of a fraction whose denominator is the common denominator.

$$\frac{13}{16} - \frac{7}{16} = \frac{6}{16}$$

3. Find the outside diameter of a section of tubing that has a $\frac{1}{4}$-inch inside diameter and a combined wall thickness of $\frac{5}{8}$ inch.

FIRST: Reduce the fractions to a common denominator.

$$\frac{1}{4} = \frac{2}{8}; \quad \frac{5}{8} = \frac{5}{8}$$

NEXT: Add the numerators, and express the result as the numerator of a fraction whose denominator is the common denominator.

$$\frac{2}{8} + \frac{5}{8} = \frac{7}{8}$$

4. The tolerance for rigging the aileron droop of an airplane is $\frac{7}{8}$ inch plus or minus $\frac{1}{5}$ inch. What is the minimum droop to which the aileron can be rigged?

FIRST: Reduce the fractions to a common denominator.

$$\frac{7}{8} = \frac{35}{40}; \quad \frac{1}{5} = \frac{8}{40}$$

NEXT: Subtract the numerators, and express the result as in the above examples.

$$\frac{35}{40} - \frac{8}{40} = \frac{27}{40}$$

Finding the Least Common Denominator

When the denominators of fractions to be added or subtracted are such that a common denominator cannot be determined readily, the LCD (least common denominator) can be found by the continued division method.

To find the LCD of a group of fractions, write the denominators in a horizontal row. Next, divide the denominators in this row by the smallest integer that will exactly divide two or more of the denominators. Bring down to a new row all the quotients and numbers that were not divisible. Continue this process until there are no two numbers in the resulting row that are divisible by any integer other than one. Multiply together all the divisors and the remaining terms in the last row to obtain the least common denominator.

EXAMPLE

What is the LCD for $\frac{7}{8}$, $\frac{11}{20}$, $\frac{8}{36}$, $\frac{21}{45}$?

FIRST: Write the denominators in a horizontal row and divide this row by the smallest integer that will exactly divide two or more of the numbers.

$$\begin{array}{r|rrrr} 2 & 8 & 20 & 36 & 45 \\ \hline & 4 & 10 & 18 & 45 \end{array}$$

NEXT: Continue this process until there are no two numbers in the resulting row that are divisible by any integer other than one.

$$\begin{array}{r|rrrr} 2 & 8 & 20 & 36 & 45 \\ \hline 2 & 4 & 10 & 18 & 45 \\ \hline 3 & 2 & 5 & 9 & 45 \\ \hline 3 & 2 & 5 & 3 & 15 \\ \hline 5 & 2 & 5 & 1 & 5 \\ \hline & 2 & 1 & 1 & 1 \end{array}$$

THEN: Multiply together all the divisors and remaining terms in the last row to obtain the LCD.

$$LCD = 2 \times 2 \times 3 \times 3 \times 5 \times 2 = 360$$

Multiplication of Fractions

The product of two or more fractions is obtained by multiplying the numerators to form the numerator of the product and by multiplying the denominators to form the denominator of the product. The resulting fraction is then reduced to its lowest terms. A common denominator need not be found for this operation, as the new denominator in most cases will be different from that of all the original fractions.

EXAMPLE

What is the product of $\frac{3}{5} \times \frac{12}{22} \times \frac{1}{2}$?

FIRST: Multiply the numerators together.

$$3 \times 12 \times 1 = 36$$

NEXT: Multiply the denominators together.

$$5 \times 22 \times 2 = 220$$

THEN: Reduce the resulting fraction to its lowest terms.

$$\frac{36}{220} = \frac{9}{55}$$

Cancellation

Cancellation is a technique of dividing out or cancelling all common factors that exist between numerators and denominators. This aids in locating the ultimate product by eliminating much of the burdensome multiplication.

EXAMPLE

What is the product of $\frac{18}{10} \times \frac{5}{3}$?

The product could be found by multiplying 18×5 and 10×3, then dividing the product of the numerators by the product of the denominators. However, a much easier method of solution is by cancellation. It is apparent that the 10 in the denominator and the 5 in the numerator can both be divided an exact number of times by 5.

$$\frac{18}{\underset{2}{\cancel{10}}} \times \frac{\overset{1}{\cancel{5}}}{3} =$$

Also, the 18 and 3 are both exactly divisible by 3.

$$\frac{\overset{6}{\cancel{18}}}{\underset{2}{\cancel{10}}} \times \frac{\overset{1}{\cancel{5}}}{\underset{1}{\cancel{3}}} =$$

The resulting 6 in the numerator and the 2 in the denominator are both divisible by 2.

$$\frac{\overset{\overset{3}{\cancel{6}}}{\cancel{18}}}{\underset{\underset{1}{\cancel{2}}}{\cancel{10}}} \times \frac{\overset{1}{\cancel{5}}}{\underset{1}{\cancel{3}}} = \frac{3 \times 1}{1 \times 1} = \frac{3}{1} = 3$$

The fraction is thus reduced to its lowest terms, and the final multiplication and division steps are performed with ease when compared with the task of multiplying and dividing the larger fractions.

Division of Common Fractions

The division of common fractions is accomplished most conveniently by converting the problem into a multiplication of two common fractions. To divide one fraction by another fraction, invert the divisor fraction and multiply the numerators together and the denominators together. This is known as the inverted divisor method.

Always keep in mind the order in which the fractions are written. It is important in division that the operations be performed in the order indicated. Also, remember that it is always the divisor that is inverted, never the dividend.

MIXED NUMBERS

Mixed numbers can be added, subtracted, multiplied, or divided by changing them to improper fractions and proceeding as when performing the operations with other fractions.

EXAMPLE

A piece of tubing $6\frac{3}{16}$ inches long is cut from a piece $24\frac{1}{2}$ inches long. Allowing $\frac{1}{16}$ inch for the cut, what is the length of the remaining piece?

FIRST: Reduce the fractional parts to like fractions and complete the subtraction process.

$$\frac{1}{2} - \frac{3}{16} - \frac{1}{16} = \frac{8}{16} - \frac{3}{16} - \frac{1}{16} = \frac{4}{16} = \frac{1}{4}$$

NEXT: Subtract the integer parts.

$$24 - 6 = 18$$

THEN: Combine the results obtained in each step.

$$18 + \frac{1}{4} = 18\frac{1}{4} \text{ inches.}$$

DECIMALS

Decimals are fractions whose denominators are 10 or some multiple of 10, such as 100, 1,000, 10,000, etc. They are indicated by writing one or more digits to the right of a reference mark called a decimal point. Thus:

$$\frac{6}{10} = .6, \text{ both read six tenths.}$$

$$\frac{6}{100} = .06, \text{ both read six hundredths.}$$

$$\frac{6}{1,000} = .006, \text{ both read six thousandths.}$$

When writing a decimal, any number of zeros may be written at the right end without changing the value of the decimal. This may be illustrated in the following manner:

$$.5 = \frac{5}{10} = \frac{1}{2}; \ .50 = \frac{50}{100} = \frac{1}{2}; \ .500 = \frac{500}{1,000} = \frac{1}{2}.$$

A decimal fraction that is written where there is no whole number as .6, .06, etc., is called a pure decimal. When a whole number and a decimal fraction are written together as 3.6, 12.2, 131.12, etc., the number is known as a mixed decimal.

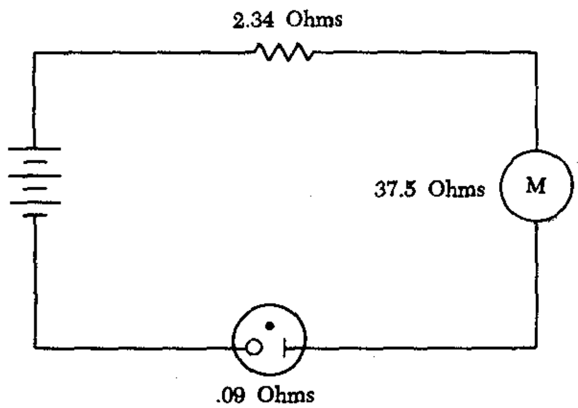


FIGURE 1-1. A series circuit.

Addition of Decimals

When computing decimals, the rule of likeness requires that we add or subtract only like denominations. This rule was discussed previously under addition and subtraction of whole numbers. To add or subtract decimal expressions, arrange the decimals so that the decimal points align vertically, and add or subtract as with integers. Place the decimal point in the result directly below the decimal points in the addends or minuend and subtrahend.

EXAMPLES

The total resistance of series circuit (figure 1-1) is equal to the sum of the individual resistances. What is the total resistance for the diagram shown in this example?

FIRST: Arrange the decimals in a vertical column so that the decimal points are in alinement.

$$\begin{array}{r} 2.34 \\ 37.5 \\ .09 \end{array}$$

NEXT: Complete the addition following the technique used in adding whole numbers. Place the decimal point in the result directly below the other decimal points.

$$\begin{array}{r} 2.34 \\ 37.5 \\ .09 \\ \hline 39.93 \text{ ohms} \end{array}$$

Subtraction of Decimals

A series circuit containing two resistors has a total resistance of 37.27 ohms. One of the resistors has a value of 14.88 ohms. What is the value of the remaining resistor?

FIRST: Arrange the decimals in a vertical column so that the decimal points are in alinement.

$$\begin{array}{r} 37.27 \\ -14.88 \end{array}$$

NEXT: Perform the subtraction process using the procedure for subtracting whole numbers. Place the decimal point in the result directly below the other decimal points.

$$\begin{array}{r} 37.27 \\ -14.88 \\ \hline 22.39 \text{ ohms} \end{array}$$

Multiplication of Decimals

The multiplication of a decimal by another decimal will always produce an answer smaller than either of the two numbers. When a decimal is multiplied by a whole number or by a mixed decimal, the answer will lie between the two numbers.

When multiplying a decimal fraction by an integer or another decimal, establishing the position of the decimal point in the product causes the greatest amount of difficulty.

To multiply decimals, ignore the decimal points and multiply the terms as though they were whole numbers. To locate the decimal point in the product, begin at the right of the product and point off toward the left the number of decimal places that will equal the sum of the decimal places in the quantities multiplied.

EXAMPLE

Using the formula, Watts = Amperes × Voltage, what is the wattage of an electric heater that uses 9.45 amperes from a 120-volt source?

FIRST: Arrange the terms and multiply. Ignore the decimal point.

```
   9.45
   ×120
    000
   1890
   945
 113400
```

NEXT: Locate the decimal point. Begin at the right of the product and point off toward the left the number of places that will equal the sum of the decimal places in the quantities multiplied.

```
   9.45
   ×120
  18900
   945
1134.00
```

In some problems the number of digits in the product will be less than the sum of the decimal places in the quantities multiplied. Where this occurs, merely add zeros to the left of the product until the number of digits equals the sum of the decimal places in the quantities multiplied.

EXAMPLE

Multiply .218 by .203.

FIRST: Arrange the terms and multiply, ignoring the decimal point.

```
 .218
 .203
  654
 4360
44254
```

NEXT: Locate the decimal point. Add a zero to the left of the product so that the number of places will equal the sum of the decimal places in the quantities multiplied.

```
    .218
   ×.203
     654
    4360
 .044254
```

Division of Decimals

When one or both of the terms of a division problem involve decimal expressions, the quotient is found by converting the problem to one involving a whole number.

Two facts relating to division of decimals that must be borne in mind are: (1) When the dividend and divisor are multiplied by the same number, the quotient remains unchanged; and (2) if the divisor is a whole number, the decimal place in the quotient will align vertically with the decimal in the dividend when the problem is expressed in long division form.

To divide decimal expressions, count off to the right of the decimal point in the dividend the same number of places that are located to the right of the decimal point in the divisor. Insert a caret ($\wedge$) to the right of the last digit counted. If the number of decimal places in the dividend is less than the number of decimal places in the divisor, add zeros to the dividend, remembering that there must be at least as many decimal places in the dividend as in the divisor. Divide the terms, disregarding the decimal points entirely. Place the decimal point in the quotient so that it alines vertically with the caret mark in the dividend.

EXAMPLE

The wing area of a certain airplane is 245 square feet; its span is 40.33 feet. What is the mean chord of its wings?

FIRST: Arrange the terms as in long division and move the decimal point to the right, adding zeros as necessary, and insert a caret.

$$40.33_{\wedge}\overline{)245.00_{\wedge}}$$

NEXT: Divide the terms, disregarding the decimal points entirely. Add additional zeros to the right to permit carrying the quotient to the desired accuracy.

$$\begin{array}{r} 6\ 07 \\ 40.33_{\wedge}\overline{)245.00_{\wedge}00} \\ \underline{241\ 98} \\ 3\ 020 \\ \underline{0\ 000} \\ 3\ 0200 \\ \underline{2\ 8221} \\ 1979 \end{array}$$

THEN: Place the decimal point in the quotient so that it alines vertically with the caret mark in the dividend.

$$\begin{array}{r} 6.07 \text{ feet} \\ 40.33_{\wedge}\overline{)24500_{\wedge}00} \\ \underline{24198} \\ 3020 \\ \underline{0000} \\ 30200 \\ \underline{28221} \\ 1979 \end{array}$$

Rounding Off Decimals

There is a general tendency to think of all numbers as being precise. Actually the whole realm of measurement involves numbers that are only approximations of precise numbers. For example, measurements of length, area, and volume are at best approximations. The degree of accuracy of these measurements depends on the refinement of the measuring instruments.

Occasionally it is necessary to round a number to some value that is practical to use. For example, a measurement is computed to be 29.4948 inches. It is impractical, if not impossible, to measure this accurately with a steel rule which is accurate only to $\frac{1}{64}$ of an inch.

To use this measurement, we can use the process of "rounding." A decimal expression is "rounded off" by retaining the digits for a certain number of places and discarding the rest. The retained number is an approximation of the computed or exact number. The degree of accuracy desired determines the number of digits to be retained. When the digit immediately to the right of the last retained digit is a 5, or greater than 5, increase the last retained digit by 1. When the digit immediately to the right of the last retained digit is less than 5, leave the last retained digit unchanged.

EXAMPLE

Round 29.4948 to the nearest tenth.

FIRST: Determine the number of digits to retain. In this case one—tenths being the first place to the right of the decimal point.

29.4948

NEXT: Change the value of the last retained digit, if required. In this case, since 9 is greater than 5, the final decimal is expressed thus:

29.4948 becomes 29.5 inches.

Converting Decimals to Common Fractions

To change a decimal fraction to a common fraction, count the number of digits to the right of the decimal point. Express the number as the numerator of a fraction whose denominator is 1 followed by the number of zeros that will equal the number of digits to the right of the decimal point.

EXAMPLE

Express .375 as a common fraction.

FIRST: Count the number of digits to the right of the decimal point.

.375

1 2 3

NEXT: Express the number as the numerator of a fraction whose denominator is 1 followed by the number of zeros that will equal the number of digits to the right of the decimal point.

$$.375 = \frac{375}{1000}$$

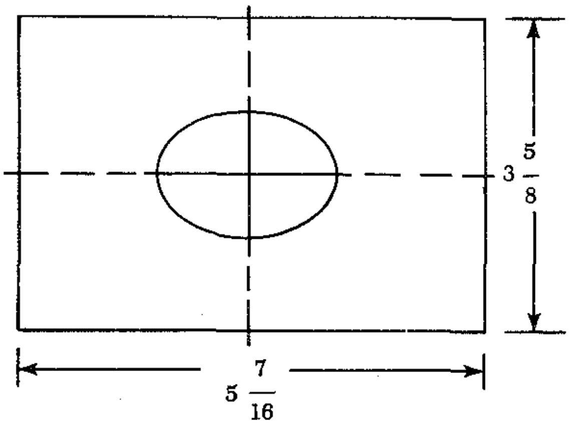


FIGURE 1–2. Locating the hole center.

Many times a dimension appearing in a maintenance manual or on a blueprint is expressed in decimal fractions. In order to use the dimension, it must be converted to some equivalent approximation applicable to the available measuring device. From the mechanic's standpoint, the steel rule will be the device most frequently used.

To change a decimal to the nearest equivalent fraction having a desired denominator, multiply the decimal by the desired denominator. The result will be the numerator of the desired fraction.

EXAMPLE

When accurate holes of uniform diameter are required, they are first drilled $\frac{1}{64}$ inch undersize and reamed to the desired diameter. What size drill would be used before reaming a hole to .763?

FIRST: Multiply the decimal by the desired denominator of 64.

$$\begin{array}{r} .763 \\ \times 64 \\ \hline 3052 \\ 4578 \\ \hline 48832 \end{array}$$

NEXT: Round the product to a whole number and express it as the numerator of the desired denominator.

$$48.832 = \frac{49}{64}$$

THEN: To determine the drill size, subtract $\frac{1}{64}$ inch from the finished hole size.

$$\frac{49}{64} - \frac{1}{64} = \frac{48}{64} = \frac{3}{4}\text{-inch drill.}$$

Converting Common Fractions to Decimals

To convert a common fraction, whether proper or improper, to a decimal, divide the numerator by the denominator. Add zeros to the right to permit carrying the quotient to the desired accuracy.

EXAMPLE

Find the distance the center of the hole (figure 1–2) is from the plate edges when the center of the hole is in the center of the plate. Express the length and width of the plate in decimal forms, and then divide each by 2. Express the final result to the nearest 32nd.

FIRST: Change the mixed numbers to improper fractions.

$$5\frac{7}{16} = \frac{87}{16}; \quad 3\frac{5}{8} = \frac{29}{8}$$

NEXT: Convert the improper fractions to decimal expressions.

$$\frac{87}{16} = 5.4375; \quad \frac{29}{8} = 3.625$$

THEN: Divide the decimal expressions by 2 to find the center of the plate.

$$\frac{5.4375}{2} = 2.7188; \quad \frac{3.625}{2} = 1.813$$

FINALLY: Express the final results to the nearest 32nd.

$$2.7188 = 2\frac{23}{32}; \quad 1.813 = 1\frac{26}{32}$$

PERCENTAGE

There are many problems that arise every day involving the percent expression. The greatest number of percentage problems involve some kind of comparison of a part to the whole. Such comparisons become percentage problems when the ratio fraction is expressed as a percent.

A fraction having the specific power of 100 for the denominator is given the name percent. When writing these fractions, the percent symbol (%) is substituted for the denominator. Any common fraction or decimal can be expressed as a percent. The fraction $\frac{1}{5}$ can thus be expressed as .20 or as 20 percent or simply as 20%. Note that the percent is the same as the decimal fraction except that the decimal point has been moved two places to the right and deleted after "percent" or the symbol "%" has been added.

Expressing a Decimal as a Percent

To express a decimal as a percent, move the decimal point two places to the right (add a zero if necessary) and affix the percent symbol.

EXAMPLE

Express .90 as a percent.

FIRST: Move the decimal point two places to the right.

90.

NEXT: Affix the percent symbol to the right after dropping the decimal point.

90%

Expressing a Percent as a Decimal

Sometimes it may be necessary to express a percent as a decimal. Keeping in mind that a percent is simply a decimal with the decimal point moved two places to the right, all that is necessary to express a percent as a decimal is to move the decimal point two places to the left.

Expressing a Common Fraction as a Percent

The technique involved in expressing a common fraction as a percent is essentially the same as that for a decimal fraction. The one difference is the procedure necessary to convert the fraction to a decimal.

EXAMPLE

Express $\frac{5}{8}$ as a percent.

FIRST: Convert the fraction to a decimal.

$$\frac{5}{8} = 5 \div 8 = .625$$

NEXT: Move the decimal point two places to the right and affix the percent symbol.

$$.625 = 62.5\%$$

Finding What Percent One Number is of Another

Determining what percent one number is of another is done by writing the part number as the numerator of a fraction and the whole number as the denominator of that fraction, and expressing this fraction as a percentage.

EXAMPLE

A motor rated as 12 horsepower is found to be delivering 10.75 horsepower. What is the motor efficiency expressed in percent?

FIRST: Write the part number, 10.75, as the numerator of a fraction whose denominator is the whole number, 12.

$$\frac{10.75}{12}$$

NEXT: Convert the fraction to its decimal equivalent.

$$10.75 \div 12 = .8958$$

THEN: Express the decimal as a percent.

$.8958 = 89.58\%$ efficient.

Finding a Percent of a Given Number

The technique used in determining a percent of a given number is based on the fundamental process of multiplication. It is necessary to state the desired percent as a decimal or common fraction and multiply the given number by the percent expressed as a decimal or other fraction.

EXAMPLE

The cruising speed of an airplane at an altitude of 7,500 feet is 290 knots. What is the cruising speed at 9,000 feet if it has increased 6 percent?

FIRST: State the desired percent as a decimal.

$$6\% = .06$$

NEXT: Multiply the given number by the decimal expression.

$$290 \times .06 = 17.40$$

THEN: Add the new product to the given number. This is the new cruising speed.

$290 + 17.4 = 307.4$ knots.

Finding a Number When a Percent of It is Known

To determine a number when a percent of it is known, express the percent as a decimal and divide the known number by the decimal expression.

EXAMPLE

Eighty ohms represent 52 percent of a circuit's total resistance. Find the total resistance of this circuit.

FIRST: Express the percent as a decimal.

$$52\% = .52$$

NEXT: Divide the known number by the decimal expression.

$$80 \div .52 = 153.8 \text{ ohms total resistance.}$$

RATIO

An important application of the common fraction is that of ratio. A ratio represents the comparison of one number to another number. Comparison by the use of ratios has widespread application in the field of aviation. A ratio is used to express the comparison of the volume of a cylinder when the piston is at bottom center to the volume of a cylinder when the piston is at top center. This is referred to as the compression ratio. The aspect ratio of an aircraft wing is a comparison of the wing span to the wing chord. The relationship of maximum speed, wing area, wing span, loaded weight, and horsepower of different makes and models of aircraft may be compared through the use of ratios.

A ratio is the quotient of one number divided by another number, expressed in like terms. A ratio, therefore, is the fractional part that one number is of another. A ratio may be expressed as a fraction, or it may be written using the colon (:) as the symbol for expressing ratio; thus the ratio $\frac{7}{8}$ can be written 7:8.

Finding the Ratio of Two Quantitites

To find a ratio, the first term is divided by the second term. Both quantities of both terms must be expressed in the same units, and reduced to their lowest terms.

EXAMPLES

1. What is the weight ratio of a fuel load of 800 gallons to one of 10,080 pounds? Assume that the fuel weighs 7.2 pounds per gallon.

FIRST: Express the fuel load in gallons as the numerator of a fraction whose denominator is the fuel load in pounds.

$$R = \frac{800 \text{ gal.}}{10{,}080 \text{ lb.}}$$

NEXT: Express both quantities in the same unit (pounds).

$$R = \frac{(800 \times 7.2) \text{ lb.}}{10{,}080 \text{ lb.}}$$

THEN: Perform the indicated mathematical manipulations and reduce to lowest terms.

$$R = \frac{(800 \times 7.2)}{10{,}080} = \frac{5760}{10{,}080} = \frac{4}{7}, \text{ or } 4:7$$

What is the ratio in gallons?

FIRST: Express the ratio in fractional form.

$$R = \frac{800 \text{ gal.}}{10{,}080 \text{ lb.}}$$

NEXT: Express both quantities in the same unit (gallons).

$$R = \frac{800 \text{ gal.}}{\frac{10{,}080}{7.2}}$$

THEN: Perform the indicated mathematical manipulations and reduce to lowest terms.

$$R = \frac{800}{\frac{10{,}080}{7.2}} = \frac{800}{1{,}400} = \frac{4}{7}, \text{ or } 4:7$$

2. If the cruising speed of an airplane is 200 knots and its maximum speed is 250 knots, what is the ratio of cruising speed to maximum speed?

FIRST: Express the cruising speed as the numerator of a fraction whose denominator is the maximum speed.

$$R = \frac{200}{250}$$

NEXT: Reduce the resulting fraction to its lowest terms.

$$R = \frac{200}{250} = \frac{4}{5}$$

THEN: Express the result as a ratio of one.

$$R = \frac{4}{5}, \text{ or } .8:1 \text{ (Read 8/10ths to one)}$$

Finding the Quantity of the First Term

Now consider the situation when the ratio and the quantity that corresponds to the second term are given, and it is required to find the quantity that corresponds to the first term. To solve this type problem, multiply the term that corresponds to the second term by the fraction that represents the ratio.

EXAMPLE

The given ratio is 5/7 and the quantity that corresponds to the second term is 35. Find the quantity that corresponds to the first term.

FIRST: Express the problem as the product of the second term times the ratio.

$$35 \times 5/7 =$$

NEXT: Perform the indicated operation.

$$\overset{5}{\cancel{35}} \times 5/\underset{1}{\cancel{7}} = 25$$

The first term is 25. The proof of this can be demonstrated by showing that the ratio of 25 to 35 is 5:7, reduced to lowest terms.

$$25/35 = 5/7$$

Finding the Quantity of the Second Term

To solve a problem of this type, the ratio of the two quantities and the quantity that corresponds to the first term must be known. The solution is obtained by dividing the known number by the fraction that represents the ratio.

EXAMPLE

The ratio of two quantities is 2/3; the quantity that corresponds to the first term is 100. Find the quantity that corresponds to the second term.

FIRST: Express the problem as the quotient of the first term divided by the ratio.

$$100 \div 2/3 =$$

NEXT: Perform the indicated operation.

$$100 \div 2/3 =$$

$$\overset{50}{\cancel{100}} \times 3/\underset{1}{\cancel{2}} = 150$$

The second term is 150. Again, this can be proved by expressing 100 as a ratio of 150.

$$100/150 = 2/3$$

PROPORTION

A proportion is a statement of equality between two or more ratios. Thus,

$$\frac{3}{4} = \frac{6}{8}; \text{ or } 3:4 = 6:8.$$

This is read 3 is to 4 as 6 is to 8. The first and last terms of the proportion are called the *extremes.* The second and third terms are called the *means.*

In any proportion, the product of the *extremes* is equal to the product of the *means.* In the proportion

$$2:3 = 4:6$$

the product of the *extremes,* 2×6, is 12; the product of the *means,* 3×4, also is 12. An inspection of *any* proportion will show this to be true. This rule simplifies the solution of many practical problems.

An airplane flying a distance of 300 miles used 24 gallons of gasoline. How many gallons will it need to travel 750 miles?

$$300:750 = 24:x$$

$$(300)(x) = (750)(24)$$

$$300x = 18{,}000$$

$$x = 60$$

Sixty gallons of gasoline will be required to travel a distance of 750 miles.

POSITIVE AND NEGATIVE NUMBERS

Positive and negative numbers are numbers that have directional value from a given starting point or from zero. Numbers above or to one side, usually right, of zero are designated as positive (+); those below or to the opposite side, usually left, of zero are designated as negative (−). Figure 1–3 is representative of signed numbers on a horizontal scale.

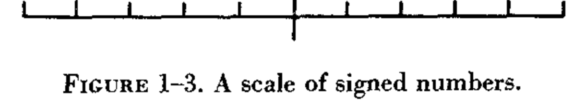


FIGURE 1–3. A scale of signed numbers.

The sum of positive numbers is positive.
The sum of negative numbers is negative.

Addition

To add a positive and a negative number, find the difference in their actual values and give this difference the sign (+ or −) of the larger number.

EXAMPLE

The weight of an aircraft is 2,000 pounds. A radio rack weighing 3 pounds and a transceiver weighing 10 pounds are removed from the aircraft. What is the new weight? For weight and balance purposes, all weight removed from an aircraft is given a minus sign, and all weight added is given a plus sign.

FIRST: Add the values for the removed weights.

$$10+3=13$$

NEXT: Prefix the sign for removed weights.

$$-13$$

THEN: Add the sum of the removed weights to the total weight, following the rule for unlike signs.

$$+2000-13=+1987 \text{ pounds.}$$

Subtraction

To subtract positive and negative numbers, change the sign of the subtrahend (the number to be subtracted from another) and proceed as in addition.

EXAMPLE

What is the temperature difference between a temperature reading of +20 at 5,000 feet and a reading of −6 at 25,000 feet? Follow the rule, "a change in temperature is equal to the first reading, subtracted from the second reading."

FIRST: Change the sign of the number to be subtracted. +20 becomes −20.

NEXT: Combine the two terms, following the rule for adding like signs.

$$(-6)+(-20)=-26 \text{ degrees.}$$

Multiplication

The product of two positive numbers is positive (+). The product of two negative numbers is positive (+). The product of a positive and a negative number is negative (−).

EXAMPLES

$$3\times6=18 \qquad -3\times6=-18$$
$$-3\times-6=18 \qquad 3\times-6=-18$$

Division

The quotient of two positive numbers is positive. The quotient of two negative numbers is positive. The quotient of a positive and negative number is negative.

EXAMPLES

$$6\div3=2 \qquad -6\div3=-2$$
$$-6\div-3=2 \qquad 6\div-3=-2$$

POWERS AND ROOTS

Power

When one number, the base, is used as a factor two or more times, the result is a power of the base. A positive integral exponent, written as a small number just to the right and slightly above the base number, indicates the number of times the base is used as a factor. Thus, 4 squared, or

4^2 means 4×4, which is 16. The 4 is the base, the 2 is the exponent, and the 16 is the power.

Roots

A root of a number is one of two or more equal numbers that, when multiplied together, will produce the number. Such a number is called an equal factor. Thus, two equal factors that will produce 9 when multiplied together are 3 and 3. Therefore, the square root of 9 equals 3. This may be written $\sqrt{9} = 3$. The symbol $\sqrt{\ }$ is called a radical sign. Another method of indicating the square root of a number is to use a fractional exponent such as $9^{1/2} = 3$. If the root to be taken is other than a square root, it may be shown in a similar manner; that is, the cube root of 9 may be written $9^{1/3}$. For example, the cube root of 8 equals 2 and may be written $\sqrt[3]{8} = 2$, or $8^{1/3} = 2$; the fourth root of 256 equals 4 and may be written $\sqrt[4]{256} = 4$, or $256^{1/4} = 4$.

Computation of Square Root

It is comparatively easy to determine the square root of such numbers as 4, 9, 16, and 144. The numbers are the perfect squares of small numbers. Unfortunately, all numbers are not perfect squares; neither are they small. The square of a number is the product of that number multiplied by itself. Extracting the square root of a number is the reverse process of squaring a number, and is essentially a special division process. A description of this process follows and is presented in example form.

EXAMPLE

Find the square root of 213.16

FIRST: Starting at the decimal point, and marking off in both directions from the decimal point, separate the number into periods of two figures each. The last period at the left end need not have two figures; all others must have two figures. A zero may be added to the right end so that the period will have two figures.

$\sqrt{2\underline{13}.\underline{16}}$

NEXT: Select the largest number that can be squared in the first period. Place the selected number above the radical sign, and place the square of this number under the first period and subtract.

```
       1
     √213.16
  1    1
       -
       1
```

THEN: Bring down the next pair.

(1) Multiply the root by 2 and place the product to the left of the remainder as the trial divisor.

(2) Determine the number of times the trial divisor will go into that portion of the remainder that is one digit more than the trial divisor. Write this number to the right of the digit in the trial divisor to form the final divisor and also to the right of the digit in the root.

(3) Multiply this number times the completed divisor. If the resulting product is larger than the remainder, reduce the number by one, both in the root and in the final divisor, and repeat the multiplication process.

(4) Subtract the product formed from the remainder and bring down the next pair to form a new remainder.

(5) To complete the solution of extracting the square root, simply repeat the procedure set forth in this step for each period of numbers remaining. It is unnecessary to carry the root beyond the number of digits possessed by the original number.

```
         1 4. 6
       √213.16
         1
         -
   24   113
         96
        ---
  286    17 16
         17 16
```

Two will divide into 11, 5 times. However, 5×25 is greater than 113, so the 5 must be reduced to a 4.

The decimal is placed in the root so that the number of digits in the whole number portion of the root is equal to the sum of the periods, or pairs, in the whole number portion of the number from which the root was extracted.

Powers of Ten

The difficulty of performing mathematical problems with very large (or very small) numbers and the counting and writing of many decimal places are both an annoyance and a source of error. The problems of representation and calculation are simplified by the use of "powers of ten." (See figure 1-4.). This system, sometimes referred to as "Engineer's Shorthand," requires an understanding of the principles of the exponent. These are summarized as follows:

(1) The positive exponent (or power) of a number is a shorthand method of indicating how many times the number is multiplied by itself. For example, 2^3 (read as 2-cubed or 2 to the third power) means 2 is to be multiplied by itself 3 times: $2 \times 2 \times 2 = 8$. A number with a negative exponent may be defined as its inverse or reciprocal (1 divided by the number) with the same exponent made positive. For example, 2^{-3} (read as 2 to the minus 3 power) is the same as

$$\frac{1}{(2)^3} = \frac{1}{2 \times 2 \times 2} = \frac{1}{8}.$$

(2) Any number, except zero, to the zero power is equal to 1. When a number is written without an exponent, the value of the exponent is 1. When an exponent has no sign (+ or −) preceding it, the exponent is positive.

(3) The value of a number does not change when it is both multiplied and divided by the same factor ($5 \times 10 \div 10 = 5$). Moving the decimal point of a number to the left is the same as dividing the number by 10 for each place the decimal point moves. Conversely, moving the decimal point to the right is the same as multiplying the number by 10 for each place the decimal point moves.

POWER OF TEN	EXPANSION	VALUE
Positive Exponent		
10^6	$10 \times 10 \times 10 \times 10 \times 10 \times 10$	1,000,000
10^5	$10 \times 10 \times 10 \times 10 \times 10$	100,000
10^4	$10 \times 10 \times 10 \times 10$	10,000
10^3	$10 \times 10 \times 10$	1,000
10^2	10×10	100
10^1	10	10
10^0		1

The velocity of light, 30, 000, 000, 000 centimeters per second, simplifies to 3×10^{10} centimeters per second.

POWER OF TEN	EXPANSION	VALUE
Negative Exponent		
$10^{-1} = \frac{1}{10}$	$\frac{1}{10}$	$\frac{1}{10} = 0.1$
$10^{-2} = \frac{1}{10^2}$	$\frac{1}{10 \times 10}$	$\frac{1}{100} = 0.01$
$10^{-3} = \frac{1}{10^3}$	$\frac{1}{10 \times 10 \times 10}$	$\frac{1}{1,000} = 0.001$
$10^{4-} = \frac{1}{10^4}$	$\frac{1}{10 \times 10 \times 10 \times 10}$	$\frac{1}{10,000} = 0.0001$
$10^{-5} = \frac{1}{10^5}$	$\frac{1}{10 \times 10 \times 10 \times 10 \times 10}$	$\frac{1}{100,000} = 0.00001$
$10^{-6} = \frac{1}{10^6}$	$\frac{1}{10 \times 10 \times 10 \times 10 \times 10 \times 10}$	$\frac{1}{1,000,000} = 0.000001$

The mass of an electron, 0.000, 000, 000, 000, 000, 000, 000, 000, 000, 911 gram, becomes 9.11×10^{-28} gram.

FIGURE 1–4. Powers of ten and their equivalents.

The procedure for use of powers of ten may be summarized as follows:

(1) Move the decimal point to the place desired. Count the number of places the decimal point is moved.

(2) Multiply the altered number by 10 to a power equal to the number of places the decimal point was moved.

(3) The exponent of 10 is negative if the decimal point is moved to the right, and it is positive if the decimal point is moved to the left. An aid for remembering the sign to be used is: L,

A, R, D. When the decimal point moves Left, you Add; and when the decimal point moves Right, you Deduct.

In most instances, you will find it convenient to reduce the numbers used to numbers between 1 and 10 times 10 to the proper power. Unless otherwise specified, all answers to problems using powers of ten will conform to that requirement.

Powers of Ten Added and Subtracted

Before using powers of ten in mathematical operations, it will be beneficial to review a few more principles governing exponents:

If two or more numbers are written with the same base, their product is equal to the base raised to a power equal to the algebraic sum of their exponents.

$$3^4 \times 3^5 \times 3^3 = 3^{4+5+3} = 3^{12}$$

If two numbers are written with the same base, their quotient is equal to the base raised to a power equal to the algebraic difference of their exponents (numerator's exponent minus denominator's exponent).

$$\frac{4^5}{4^3} = 4^{5-3} = 4^2$$

A factor may be moved from numerator to denominator or from denominator to numerator by changing the sign of its exponent. Thus we have

$$\frac{3^2}{4^{-3}} = 3^2 \times 4^3 = \frac{4^3}{3^{-2}} = \frac{1}{4^{-3} \times 3^{-2}}.$$

The bases must be the same before numbers can be multiplied or divided by the addition or subtraction of their exponents. Thus, $a^5 \times b^6$ cannot be combined because the bases (a and b) are not the same.

Note particularly that the rules specify algebraic addition and algebraic subtraction of the powers. Here are some summarizing examples:

$$3^7 \times 3^{-11} = 3^{7+(-11)} = 3^{7-11} = 3^{-4} = \frac{1}{3^4}.$$

$$4^{-5} \times 4^3 = 4^{-5+3} = 4^{-2} = \frac{1}{4^2}.$$

$$\frac{5^8}{5^{-6}} = 5^{8-(-6)} = 5^{8+6} = 5^{14}.$$

$$\frac{6^8}{6^{12}} = 6^{8-12} = 6^{-4} = \frac{1}{6^4}.$$

Multiplication and division employing powers of ten may be performed in three simple steps as follows:

(1) Reduce all numbers to values between 1 and 10 multiplied by 10 to the proper power.
(2) Perform the indicated operations.
(3) Change the result to a number between 1 to 10 multiplied by 10 multiplied by 10 to the proper power.

COMPUTING AREA

Mensuration formulas deal with the dimensions, areas, and volumes of geometric figures. There are five geometric figures with which you should be familiar, and there is a separate formula for finding the area of each. The area of a plane figure is equal to the number of square units it contains. Areas are measured in different units as compared to measuring length. An area that is square and 1 inch on each side is called a square inch. All area units are square units, such as square inch, square foot, square yard, square rod, and square mile. Other area units are the square centimeter, the square meter, et cetera, found in the metric system of measurement.

TABLES OF AREAS

144 square inches (sq. in.)	= 1 square foot (sq. ft.).
9 square feet	= 1 square yard (sq. yd.).
$30\frac{1}{4}$ square yards	= 1 square rod (sq. rd.).
160 square rods	= 1 acre (A).
640 acres	= 1 square mile (sq. mile).

The technique for determining the area of any geometric shape is based upon the use of formulas. To solve a problem by formula, it is necessary to—

(1) select the formula that covers the problem situation,
(2) insert the known values in the selected formula, and

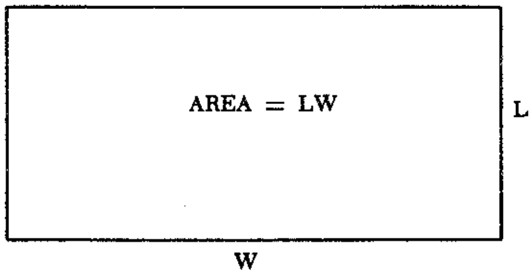


FIGURE 1–5. A rectangle.

(3) then make the necessary mathematical manipulations to find the unknown quantity.

The Rectangle

A rectangle is a four-sided plane figure whose opposite sides are equal and all of whose angles are right angles (90°). The rectangle is a very familiar area in mechanics. It is the cross-sectional area of many beams, rods, fittings, etc. (See figure 1–5.)

The area of a rectangle is the product of the measures of the length and width when they are expressed in the same units of linear measure. The area may be expressed by the formula:

$$A = LW$$

where: A = area.

L = length of rectangle.

W = width of rectangle.

EXAMPLE

A certain aircraft panel is in the form of a rectangle having a length of 24 inches and a width of 12 inches. What is the area of the panel expressed in square inches?

FIRST: Determine the known values and substitute them in the formula.

$$A = LW$$

$$A = 24 \times 12$$

NEXT: Perform the indicated multiplication; the answer will be the total area in square inches.

$$A = 24 \times 12 = 288 \text{ sq. in.}$$

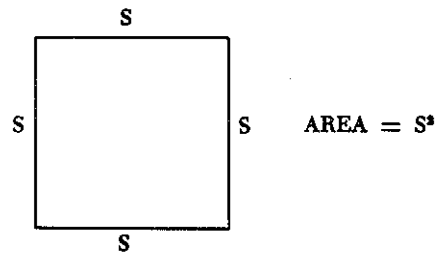


FIGURE 1–6. A square.

The Square

A square is a plane figure having four equal sides and four right angles (figure 1–6).

To determine the area of a square, find the product of the length of any two sides. Since a square is a figure whose sides are equal, the formula can be expressed as the square of the sides or:

$$A = S^2$$

where A is the area and S is the length of a side.

EXAMPLE

What is the area of a square plate whose side measures 25 inches?

FIRST: Determine the known value and substitute it in the formula

$$A = S^2$$

$$A = 25^2.$$

NEXT: Perform the indicated multiplication; the answer will be the total area in square inches.

$$A = 25 \times 25 = 625 \text{ sq. in.}$$

Triangles

A triangle is a three-sided polygon. There are three basic types of triangle: scalene, equilateral or equiangular, and isosceles. A scalene triangle is one in which all sides and angles are unequal, whereas the equilateral triangle, being just the opposite, has equal sides and equal angles. A triangle that has two equal sides and angles is known as an isosceles triangle.

Triangles may be further classified as to right, obtuse, or acute. These terms are descriptive of the included angles of the triangle. A right triangle is one that has one angle measuring 90°. In an obtuse triangle, one angle is greater than 90°,

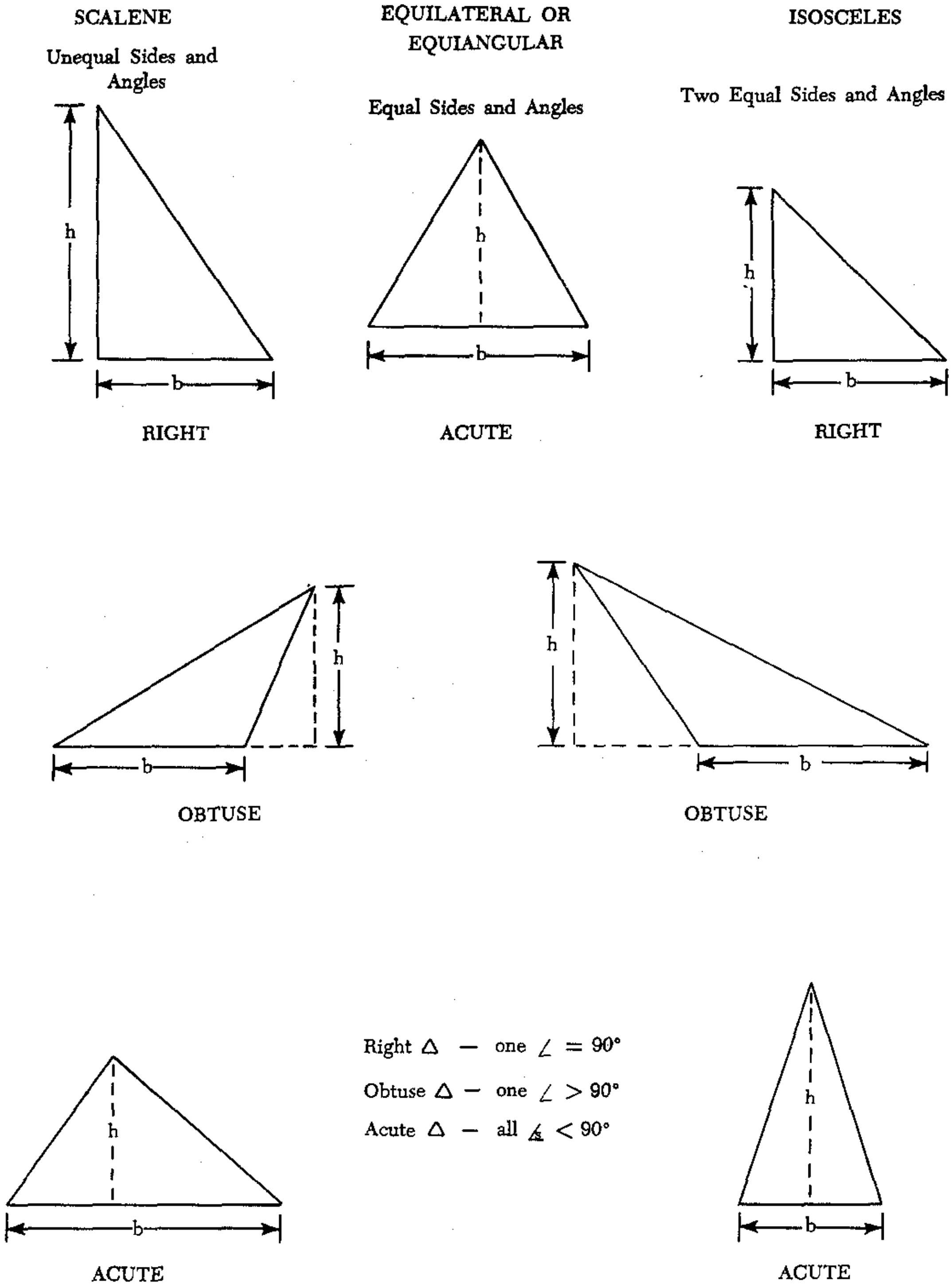


FIGURE 1–7. Types of triangles.

while in an acute triangle all the angles are less than 90°. The various types of triangles are shown in figure 1–7.

The altitude of a triangle is the perpendicular line drawn from the vertex to the base. In some triangles, as in figure 1–8, it may be necessary to extend the base so that the altitude will meet it.

The base of a triangle is the side upon which

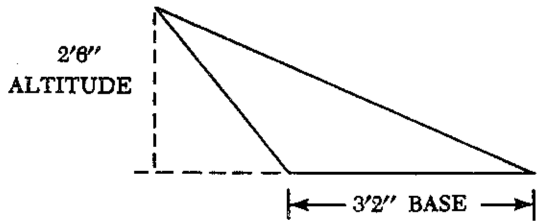


FIGURE 1–8. Triangle.

the triangle is supposed to stand. Any side may be taken as the base.

The area of any triangle may be calculated by using the formula:

$$A = \frac{1}{2}ab$$

where A is equal to Area; $\frac{1}{2}$ is a given constant; a is the altitude of the triangle; and b is the base.

EXAMPLE

Find the area of the triangle shown in figure 1–8.

FIRST: Substitute the known values in the area formula.

$$A = \frac{1}{2}ab = A = \frac{1}{2} \times 2'6'' \times 3'2''$$

NEXT: Solve the formula for the unknown value.

$$A = \frac{1}{2} \times 30 \times 38 = \frac{1140}{2}$$

$$A = 570 \text{ sq. in.}$$

Circumference and Area of a Circle

To find the circumference (distance around) or the area of a circle it is necessary to use a number called pi (π). This number represents the ratio of the circumference to the diameter of any circle. Pi cannot be found exactly because it is a never-ending decimal, but expressed to four decimal places it is 3.1416, which is accurate enough for most computations. (See figure 1–9.)

Circumference

The circumference of a circle may be found by using the formula:

$$C = \pi d$$

where C is the circumference; π is the given constant, 3.1416; and d is the diameter of the circle.

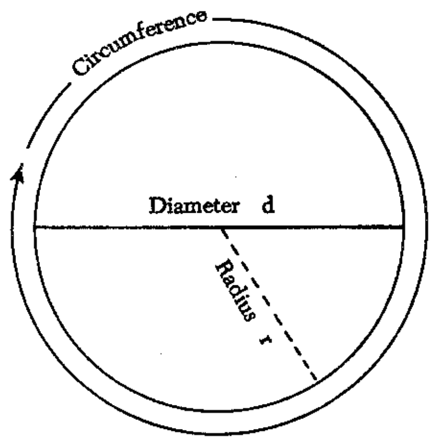


FIGURE 1–9. A circle.

EXAMPLE

The diameter of a certain piston is 5 inches. What is the circumference of the piston?

FIRST: Substitute the known values in the formula, $C = \pi d$.

$$C = 3.1416 \times 5$$

NEXT: Solve the formula for the unknown value.

$$C = 15.7080 \text{ inches.}$$

Area

The area of a circle, as in a rectangle or triangle, must be expressed in square units. The distance that is one-half the diameter of a circle is known as the radius. The area of any circle is found by squaring the radius and multiplying by π. The formula is expressed thus:

$$A = \pi r^2$$

where A is the area of a circle; π is the given constant; and r is the radius of the circle.

EXAMPLE

The bore (inside diameter) of a certain aircraft engine cylinder is 5 inches. Find the cross sectional area of this bore.

FIRST: Substitute the known values in the formula, $A = \pi r^2$.

$$A = 3.1416 \times 2.5^2$$

NEXT: Solve the formula for the unknown value.

$$A = 3.1416 \times 6.25$$

$$A = 19.635 \text{ sq. in.}$$

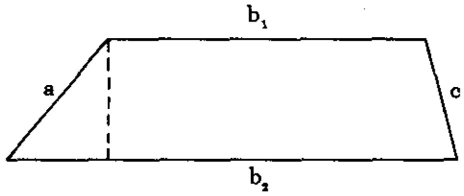


FIGURE 1–10. A trapezoid.

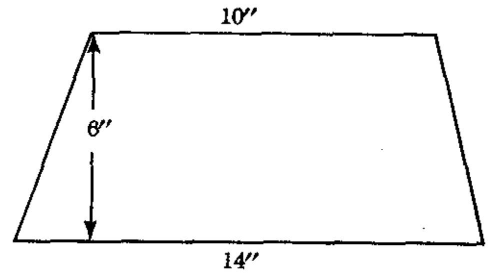


FIGURE 1–11. Computing the area of a trapezoid.

The Trapezoid

A trapezoid (figure 1–10) is a quadrilateral having one pair of parallel sides. The area of a trapezoid is determined by using the formula:

$$A = \frac{1}{2}(b_1 + b_2)h$$

where A is the area; $\frac{1}{2}$ is the given constant; b_1 and b_2 are the lengths of the two parallel sides; and h is the height.

EXAMPLE

What is the area of a trapezoid whose bases are 14 inches and 10 inches, and whose altitude is 6 inches? (See fig. 1–11.)

FIRST: Substitute the known values in the formula.

$$A = \frac{1}{2}(b_1 + b_2)h$$

$$A = \frac{1}{2}(10 + 14)6.$$

NEXT: Solve the formula for the unknown value.

$$A = \frac{1}{2}(24)6$$

$$A = \frac{1}{2} \times 144$$

$$A = 72 \text{ sq. in.}$$

Wing Area

To describe the planform of a wing (figure 1–12), several terms are required. To calculate wing area, it will be necessary to consider the meaning of the terms—span and chord. The wing *span* is the length of the wing from wing tip to wing tip. The *chord* is the width of the wing from leading edge to trailing edge. If the wing is a tapered wing, the average width or chord, known as the mean chord, must be known in finding the area. The formula for calculating wing area is:

$$A = SC$$

where A is the area expressed in square feet, S is the wing span, and C is the average chord.

The process used in calculating wing area will depend upon the shape of the wing. In some instances it will be necessary to use the formula for finding wing area in conjunction with one of the formulas for the area of a quadrilateral or a circle.

EXAMPLES

1. Find the area of the wing illustrated in figure 1–13.

To determine the area, it is necessary to decide what formula to use. It can be seen that the wing tips would form a 7-foot-diameter circle; the remainder of the wing planform is then in the shape of a rectangle. By combining the formulas for wing area and area of a circle, the area of a wing having circular tips can be calculated.

FIRST: Substitute the known value in the formula.

$$A = SC + \pi R^2$$

$$A = (25 - 7)(7) + (3.1416)(3.5^2).$$

The value for S is represented by the original wing span less the diameter of the circular tips.

NEXT: Solve the formula for the unknown value.

$$A = (18 \times 7) + (3.1416 \times 12.25)$$

$$A = 126 + 38.5$$

$$A = 164.5 \text{ sq. ft.}$$

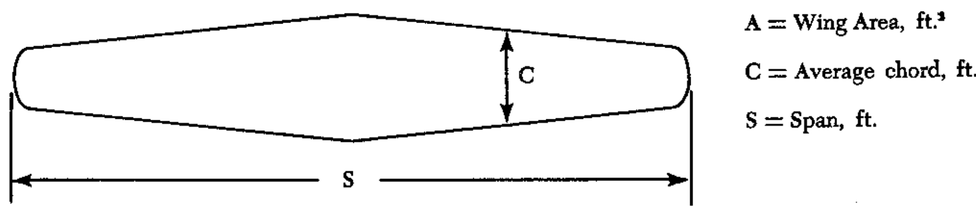


FIGURE 1–12. Wing planform.

2. Find the area of a tapered wing (figure 1–14) whose structural span is 50 feet and whose mean chord is 6'8".

FIRST: Substitute the known values in the formula.

$$A = SC$$

$$A = 50' \times 6'8''.$$

NEXT: Solve the formula for the unknown value.

$$A = 50' \times 6.67'$$

$$A = 333.5 \text{ sq. ft.}$$

3. Find the area of a trapezoidal wing (shown in figure 1–15) whose leading edge span measures 30 feet, whose trailing edge span measures 34 feet, and whose chord is 5 feet.

FIRST: Substitute the known values in the formula.

$$A = \frac{1}{2}(b_1 + b_2)h$$

$$A = \frac{1}{2}(30 + 34)5.$$

NEXT: Solve the formula for the unknown value.

$$A = \frac{1}{2}(64)5$$

$$A = \frac{1}{2}(320)$$

$$A = 160 \text{ sq. ft.}$$

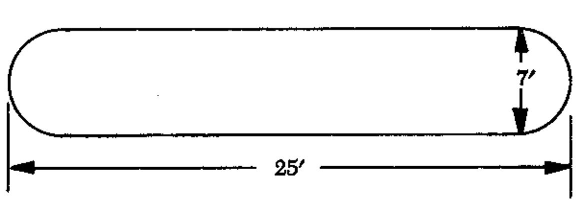


FIGURE 1–13. Wing with circular tips.

COMPUTING THE VOLUME OF SOLIDS

Solids are objects with three dimensions—length, breadth, and thickness. They are of many shapes, the most common of which are prisms, cylinders, pyramids, cones, and spheres. Occasionally, it is necessary to determine the volume of a rectangle, a cube, a cylinder, or a sphere.

Since all volumes are not measured in the same units, it is necessary to know all the common units of volume and how they are related to each other. For example, the mechanic may know the volume of a tank in cubic feet or cubic inches, but when the tank is full of gasoline, he will be interested in how many gallons it contains. The following table shows the relationship between some of the common units of volume.

UNITS OF SPACE MEASURE

1,728 cu. in.	=	1 cu. ft.
27 cu. ft.	=	1 cu. yd.
231 cu. in.	=	1 gal.
7.5 gals.	=	1 cu. ft.
2 pts.	=	1 qt.
4 qts.	=	1 gal.

Volume of a Rectangular Solid

A rectangular solid is a solid bounded by rectangles. In other words, it is a square-cornered

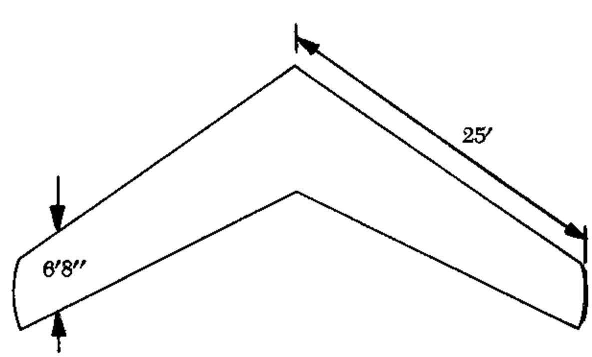


FIGURE 1–14. Tapered wing with sweepback.

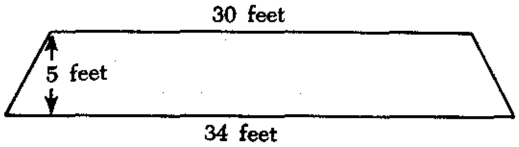


FIGURE 1-15. Trapezoid wing.

volume such as a box (figure 1-16). If the solid has equal dimensions, it is called a cube.

The formula for determining the volume of a rectangular solid may be expressed thus:

$$V = lwh$$

where: V = Volume.

l = length.

w = width.

h = height.

EXAMPLE

A rectangular-shaped baggage compartment measures 5 feet 6 inches in length, 3 feet 4 inches in width, and 2 feet 3 inches in height. How many cubic feet of baggage will it hold?

FIRST: Substitute the known values into the formula.

$$V = lwh$$

$$V = 5'6'' \times 3'4'' \times 2'3''.$$

NEXT: Solve the formula for the unknown value.

$$V = 5\frac{1}{2} \times 3\frac{1}{3} \times 2\frac{1}{4}$$

$$V = \frac{11}{2} \times \frac{10}{3} \times \frac{9}{4}$$

$$V = \frac{165}{4} = 41.25 \text{ cu. ft.}$$

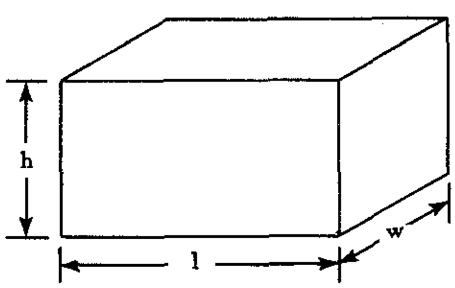


FIGURE 1-16. A rectangular solid.

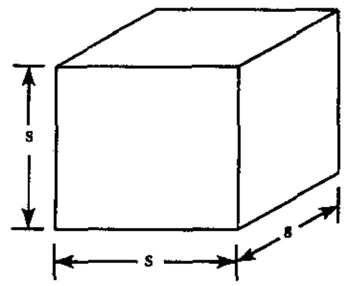


FIGURE 1-17. A cube.

If the rectangular solid is in the shape of a cube (figure 1-17), the formula can be expressed as the cube of the sides:

$$V = S^3$$

where V is the volume and S is the side measurement of the cube.

Area and Volume of a Cylinder

A solid having the shape of a can, length of pipe, or other such object is called a cylinder. The ends of a cylinder are identical circles as shown in figure 1-18.

Surface Area

The surface area of a cylinder is found by multiplying the circumference of the base by the altitude. The formula may be expressed as:

$$A = \pi dh$$

where A is the area, π is the given constant, d is the diameter, and h is the height of the cylinder.

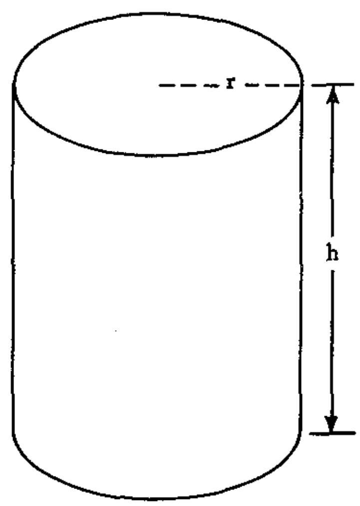


FIGURE 1-18. A cylinder.

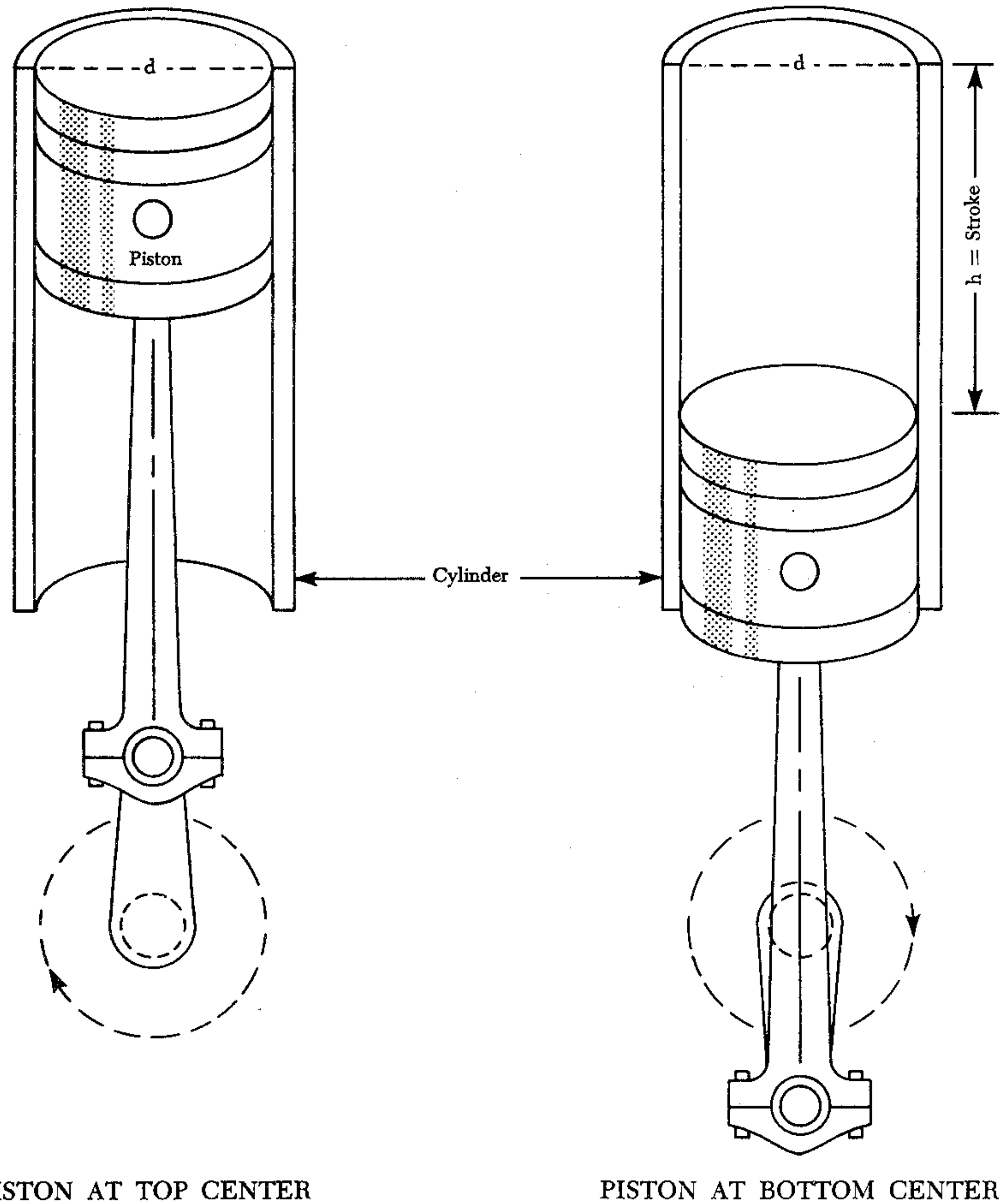


FIGURE 1–19. Cylinder displacement.

EXAMPLE

How many square feet of aluminum sheet would be needed to fabricate a cylinder 12 feet long and 3 feet 6 inches in diameter?

FIRST: Substitute the known values in the formula.

$A = \pi dh$

$A = 3.1416 \times 3'6'' \times 12'.$

NEXT: Solve the formula for the unknown value.

$$A = 3.1416 \times 3.5' \times 12'$$

$$A = 132.95, \text{ or } 133 \text{ sq. ft.}$$

Volume

The volume of a cylinder may be found by multiplying the cross-sectional area by the height of the cylinder. The formula may be expressed as:

$$V = \pi r^2 h$$

where V is the volume; π is the given constant; r^2 is the square of the radius of the cylinder; and h is the height of the cylinder (figure 1–19).

EXAMPLE

The cylinder of an aircraft engine has a bore (inside diameter) of 5.5 inches, and the engine has a stroke of 5.5 inches. What is the piston displacement of one cylinder? The stroke represents the height of the cylinder to be measured, because the volume displaced by the piston depends on the length of the stroke.

FIRST: Substitute the known values in the formula.

$$V = \pi r^2 h$$

$$V = (3.1416)(2.75^2)(5.5).$$

NEXT: Solve the formula for the unknown value.

$$V = 17.28 \times 7.56$$

$$V = 130.64 \text{ cu. in.}$$

GRAPHS AND CHARTS

Graphs and charts are pictorial presentations of data, equations, and formulas. Through their use the relationship between two or more quantities may be more clearly understood. Also, a person can see certain conditions or relationships at a glance, while it would require considerable time to obtain the same information from a written description. Graphs may be used in a number of ways, such as representing a single equation or formula, or they may be used to solve two equations for a common value.

Graphs and charts take many forms. A few of the more common forms are called bar graphs, pictographs, broken-line graphs, continuous-curved-line graphs, and circle graphs. An example of each is shown in figure 1–20. The most useful of these graphs in technical work is the continuous-curved-line graph.

Interpreting or Reading Graphs and Charts

It is more important, from the mechanic's viewpoint, to be able to read a graph properly than it is to draw one. The relationship between the horsepower of a certain engine at sea level and at any altitude up to 10,000 feet can be determined by use of the chart in figure 1–21. To use this type of chart, simply find the point on the horizontal axis that represents the desired altitude; move upward along this line to the point where it intersects the curved line; then move to the left, reading the percent of sea level horsepower available on the vertical axis.

EXAMPLE

What percent of the sea level horsepower is available at an altitude of 5,000 feet?

FIRST: Locate the point on the horizontal axis that represents 5,000 feet. Move upward to the point where the line intersects the curved line.

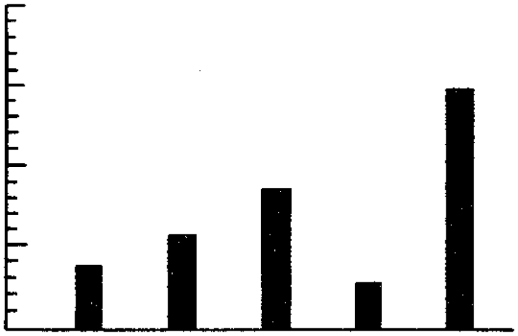
NEXT: Move to the left, reading the percent of sea level horsepower available at 5,000 feet. The available horsepower is 80%.

Nomograms

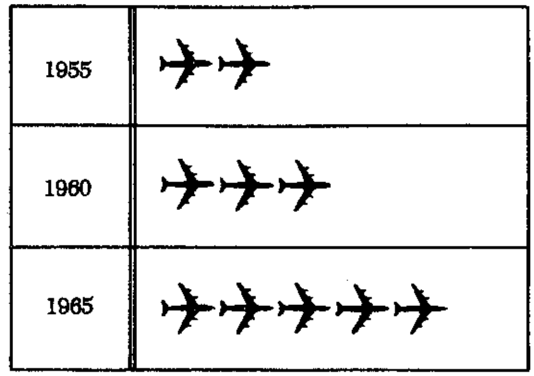
It is often necessary to make calculations using the same formula, but using different sets of values for the variables. It is possible to obtain a solution by use of a slide rule or by preparing a table giving the solution of the formula resulting from successive changes of each variable. However, in the case of formulas involving several mathematical operations, the labor entailed would usually be very great.

It is possible to avoid all this labor by using a diagram representing the formula, in which each variable is represented by one or more graduated lines. From this diagram, the solution of the formula for any given variable may be read by means of an index line. A diagram of this type is known as a nomogram.

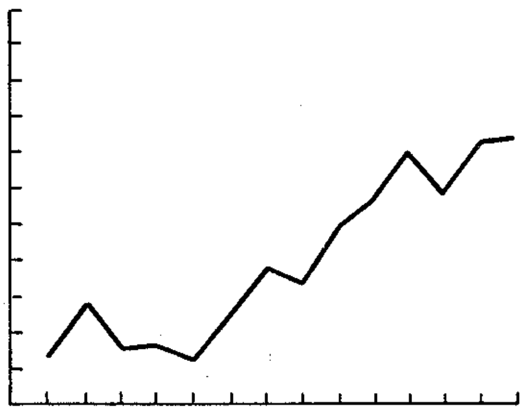
Much of the information needed to solve aeronautical problems will be presented in nomogram form. Instruction manuals for the various aircraft contain numerous nomograms, many of which



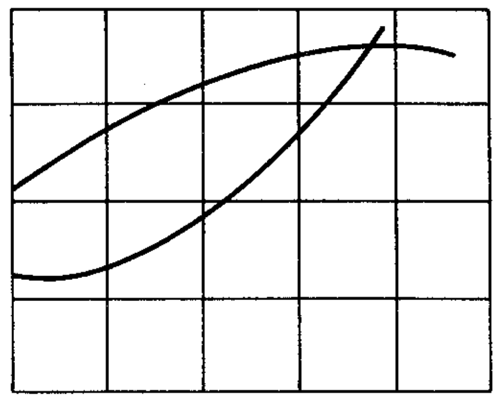
(a) Bar graph



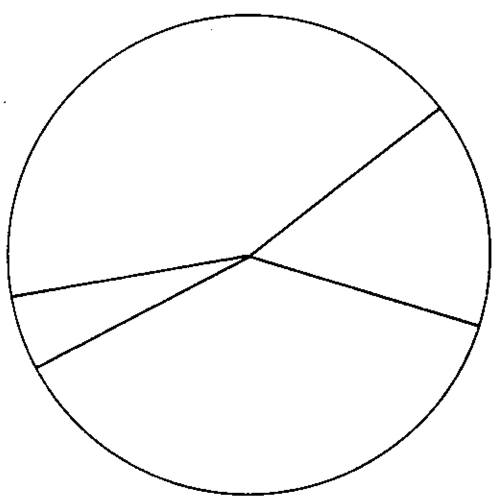
(b) Pictograph



(c) Broken line graph



(d) Continuous curved-line graph



(e) Circle graph

FIGURE 1–20. Types of graphs.

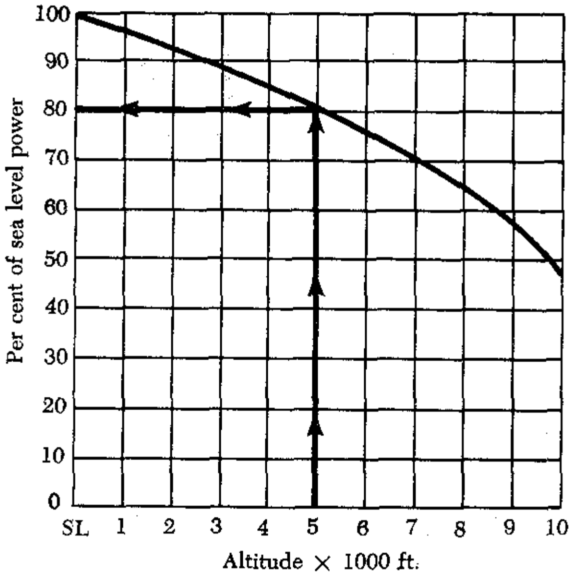


FIGURE 1–21. Horsepower vs. altitude chart.

appear quite complex. Many of the presentations will possess several curves on the same coordinate axis, each curve drawn for different constants in the equation. In the latter case, it is essential to select the proper curve for the desired conditions.

Again, as with the simpler graphs, it is more important for the mechanic to be able to read nomograms than it is to draw them.

The following example is taken from the maintenance manual for the Allison 501–D13 turboprop engine. A nomogram (figure 1–22) is used to determine the power requirements when the engine is operating at minimum torque. The OAT (outside air temperature), station barometric pressure, and engine r.p.m. are three factors that must be known to use this particular nomogram.

EXAMPLE

Determine the calculated horsepower of a certain engine, using the nomogram in figure 1–22. Assume that the OAT is 10° C., the barometric pressure is 28.5 in. Hg, and the engine is operating at 10,000 r.p.m.

FIRST: Locate the reference points on the OAT scale and on the barometric pressure scale that correspond to the given temperature and pressure readings. These are identified as ① and ②, respectively, on the chart. With the aid of a straightedge, connect these two points and establish point ③ on the pivot line.

NEXT: Locate the engine speed, identified as ④, on the engine speed r.p.m. scale. Using a straightedge, connect points ③ and ④ and establish point ⑤ on the calculated horsepower scale. The calculated horsepower is read at point ⑤. The calculated horsepower is 98%.

MODEL 501-D13 ENGINE AND MODEL 606 PROPELLER

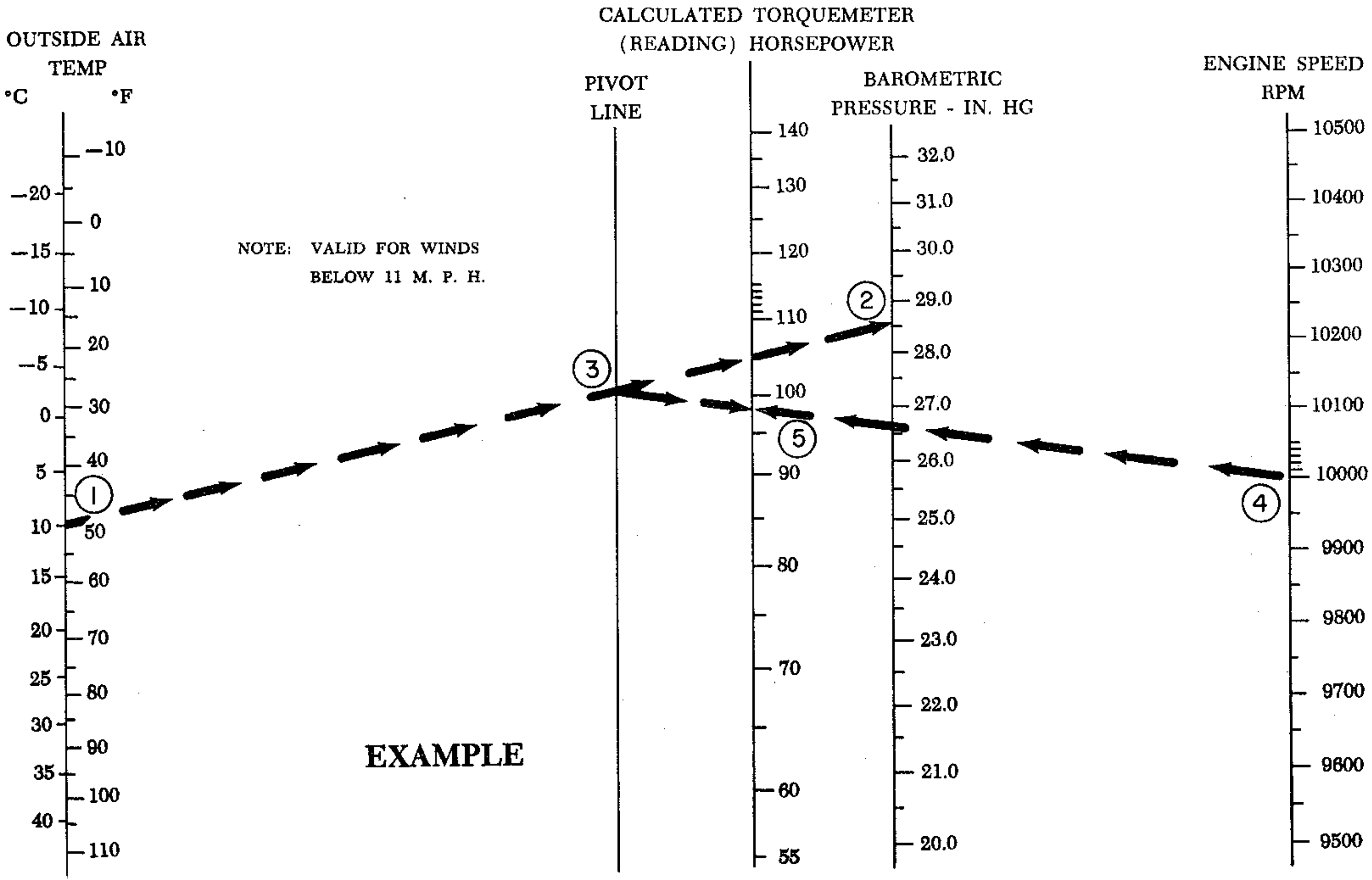


FIGURE 1–22. Power requirements at minimum torque.

MEASUREMENT SYSTEMS

Our customary system of measurement (figure 1–23) is part of our cultural heritage from the days when the thirteen colonies were under British rule. It started as a hodge-podge of Anglo-Saxon, Roman, and Norman-French weights and measures. Since medieval times, commissions appointed by various English monarchs had reduced the chaos of measurement by setting specific standards for some of the most important units. Early records, for instance, indicate that an inch was defined as the length of "three barleycorns, round and dry" when laid together; a pennyweight, or one-twentieth of a Tower ounce, was equal to 32 wheatcorns from the "midst of the ear."

The U.S. gallon is the British wine gallon, standardized at the beginning of the 18th century (and about 20 percent smaller than the Imperial gallon that the British adopted in 1824 and have since used to measure most liquids).

In short, as some of the founders of this country realized, the customary system was a makeshift based largely on folkways.

Metric System

The metric system is the dominant language of measurement in use today. Most of the world countries used the metric system prior to World War II. Since the war, more countries have converted or are in the process of converting to the metric system. Only the United States and 13 smaller countries have not made the conversion.

Congress has the power to define the standard of weights and measures. Repeatedly the metric system has been proposed and each time the question has been voted down.

The metric system was developed by a French statesman, Talleyrand, Bishop of Autum, using a "meter" as a standard; the meter being a specific portion of the circumference of the earth at the equator. From this base measurement the meter was developed and accepted as the standard. Divisions and multiples of the meter are based on the decimal system.

LENGTH	MASS	VOLUME	TEMPERATURE	ELECTRIC CURRENT	TIME
METRIC					
Meter	Kilogram	Liter	Celsius (Centigrade)	Ampere	Second
CUSTOMARY					
inch	ounce	fluid ounce	Fahrenheit	ampere	second
foot	pound	teaspoon			
year	ton	tablespoon			
fathom	grain	cup			
rod	dram	pint			
mile		quart			
		gallon			
		barrell			
		peck			
		bushel			

FIGURE 1–23. Some common units.

The Logic of Metric

No other system of measurement that has been actually used can match the inherent simplicity of International Metric. It was designed deliberately to fill all the needs of scientists and engineers. Laymen need only know and use a few simple parts of it. It is logically streamlined, whereas other systems developed more or less haphazardly. At this time there are only six base units in the International Metric System. The unit of length is the meter. The unit of mass is the kilogram. The unit of time is the second. The unit of electric current is the ampere. The unit of temperature is the kelvin (which in common use is translated into the degree Celsius, formerly called degree centigrade). The unit of luminous intensity is the candela.

All the other units of measurement in the International Metric System are derived from these six base units. *Area* is measured in square meters; *speed* in meters per second; *density* in kilograms per cubic meter. The *newton*, the unit of force, is a simple relationship involving meters, kilograms, and seconds; and the pascal, unit of *pressure*, is defined as one newton per square meter. In some other cases, the relationship between the derived and base units must be expressed by rather more complicated formulas—which is inevitable in any measurement system, owing to the innate complexity of some of the things we measure. Similar relationships among mass, area, time and other quantities in the customary system usually require similar formulas, made all the more complicated because they can contain arbitrary constants. For example, one horsepower is defined as 550 foot-pounds per second.

The third intrinsic advantage is that metric is based on the decimal system. Multiples and submultiples of any given unit are always related by powers of 10. For instance, there are 10 millimeters in one centimeter; 100 centimeters in one meter; and 1,000 meters in one kilometer. This greatly simplifies converting larger to smaller measurements. For example, in order to calculate the number of meters in 3.794 kilometers, multiply by 1,000 (move the decimal point three places to the right) and the answer is 3,794. For comparison, in order to find the number of inches in 3.794 miles, it is necessary to multiply first by 5,280 and then by 12.

Moreover, multiples and submultiples of all the International Metric units follow a consistent naming scheme, which consists of attaching a prefix to the unit, whatever it may be. For example, kilo stands for 1,000: one kilometer equals 1,000 meters, and one kilogram equals 1,000 grams. Micro is the prefix for one millionth: one meter equals one million micrometers, and one gram equals one million micrograms (figure 1–24).

PREFIX	MEANS
tera (10^{12})	One trillion times
giga (10^{9})	One billion times
mega (10^{6})	One million times
kilo (10^{3})	One thousand times
hecto (10^{2})	One hundred times
deca (10)	Ten times
deci (10^{-1})	One tenth of
centi (10^{-2})	One hundredth of
milli (10^{-3})	One thousandth of
micro (10^{-6})	One millionth of
nano (10^{-9})	One billionth of
pico (10^{-12})	One trillionth of

FIGURE 1–24. Names and symbols for metric prefixes.

Conversion: Metric To Conventional

People tend to resist changes, usually because they do not understand either the purpose of the change or the new order. Terminology for customary units and metric units have been discussed. A conversion table also has been included. Examples of its use follow:

To convert inches to millimeters, multiply the number of inches by 25. (Ex. 25 into mm=25 ×25=625 mm)

To convert millimeters to inches multiply millimeters by .04. (Ex. 625 mm×.04=25 inches.)

To convert square inches to square centimeters multiply by 6.5. (Ex. 100 sq. in.×6.5=650 sq. cm.)

To convert square centimeters to square inches multiply by .16. (Ex. 100×.16=16 sq. in.)

	WHEN YOU KNOW:	YOU CAN FIND:	IF YOU MULTIPLY BY:
LENGTH	inches	millimeters	25
	feet	centimeters	30
	yards	meters	0.9
	miles	kilometers	1.6
	millimeters	inches	0.04
	centimeters	inches	0.4
	meters	yards	1.1
	kilometer	miles	0.6
AREA	square inches	square centimeters	6.5
	square feet	square meters	0.09
	square yards	square meters	0.8
	square miles	square kilometers	2.6
	acres	square hectometers (hectares)	0.4
	square centimeters	square inches	0.16
	square meters	square yards	1.2
	square kilometers	square miles	0.4
	square hectometers (hectares)	acres	2.5
MASS	ounces	grams	28
	pounds	kilograms	0.45
	short tons	megagrams (metric tons)	0.9
	grams	ounces	0.035
	kilograms	pounds	2.2
	megagrams (metric tons)	short tons	1.1
LIQUID VOLUME	ounces	milliliters	30
	pints	liters	0.47
	quarts	liters	0.95
	gallons	liters	3.8
	milliliters	ounces	0.034
	liters	pints	2.1
	liters	quarts	1.06
	liters	gallons	0.26
TEMPERATURE	degrees Fahrenheit	degrees Celsius	5/9 (after subtracting 32)
	degrees Celsius	degrees Fahrenheit	9/5 (then add 32)

FIGURE 1-25. Converting customary to metric.

Figure 1–26 is practically self explanatory. Measurements starting at 1/64 inch up to 20 inches have been converted to decimal divisions of inches and to millimeters.

Inches		M M	Inches		M M	Inches		M M	Inches		M M
Fractions	Decimals		Fractions	Decimals		Fractions	Decimals		Fractions	Decimals	
–	.0004	.01	25/32	.781	19.844	–	2.165	55.	3-11/16	3.6875	93.663
–	.004	.10	–	.7874	20.	2-3/16	2.1875	55.563	–	3.7008	94.
–	.01	.25	51/64	.797	20.241	–	2.2047	56.	3-23/32	3.719	94.456
1/64	.0156	.397	13/16	.8125	20.638	2-7/32	2.219	56.356	–	3.7401	95.
–	.0197	.50	–	.8268	21.	–	2.244	57.	3-3/4	3.750	95.250
–	.0295	.75	53/64	.828	21.034	2-1/4	2.250	57.150	–	3.7795	96.
1/32	.03125	.794	27/32	.844	21.431	2-9/32	2.281	57.944	3-25/32	3.781	96.044
–	.0394	1.	55/64	.859	21.828	–	2.2835	58.	3-13/16	3.8125	96.838
3/64	.0469	1.191	–	.8661	22.	2-5/16	2.312	58.738	–	3.8189	97.
–	.059	1.5	7/8	.875	22.225	–	2.3228	59.	3-27/32	3.844	97.631
1/16	.062	1.588	57/64	.8906	22.622	2-11/32	2.344	59.531	–	3.8583	98.
5/64	.0781	1.984	–	.9055	23.	–	2.3622	60.	3-7/8	3.875	98.425
–	.0787	2.	29/32	.9062	23.019	2-3/8	2.375	60.325	–	3.8976	99.
3/32	.094	2.381	59/64	.922	23.416	–	2.4016	61.	3-29/32	3.9062	99.219
–	.0984	2.5	15/16	.9375	23.813	2-13/32	2.406	61.119	–	3.9370	100.
7/64	.109	2.778	–	.9449	24.	2-7/16	2.438	61.913	3-15/16	3.9375	100.013
–	.1181	3.	61/64	.953	24.209	–	2.4409	62.	3-31/32	3.969	100.806
1/8	.125	3.175	31/32	.969	24.606	2-15/16	2.469	62.706	–	3.9764	101.
–	.1378	3.5	–	.9843	25.	–	2.4803	63.	4	4.000	101.600
9/64	.141	3.572	63/64	.9844	25.003	2-1/2	2.500	63.500	4-1/16	4.062	103.188
5/32	.156	3.969	1	1.000	25.400	–	2.5197	64.	4-1/8	4.125	104.775
–	.1575	4.	–	1.0236	26.	2-17/32	2.531	64.294	–	4.1338	105.
11/64	.172	4.366	1-1/32	1.0312	26.194	–	2.559	65.	4-3/16	4.1875	106.363
–	.177	4.5	1-1/16	1.062	26.988	2-9/16	2.562	65.088	4-1/4	4.250	107.950
3/16	.1875	4.763	–	1.063	27.	2-19/32	2.594	65.881	4-5/16	4.312	109.538
–	.1969	5.	1-3/32.	1.094	27.781	–	2.5984	66.	–	4.3307	110.
13/64	.203	5.159	–	1.1024	28.	2-5/8	2.625	66.675	4-3/8	4.375	111.125
–	.2165	5.5	1-1/8	1.125	28.575	–	2.638	67.	4-7/16	4.438	112.713
7/32	.219	5.556	–	1.1417	29.	2-21/32	2.656	67.469	4-1/2	4.500	114.300
15/64	.234	5.953	1-5/32	1.156	29.369	–	2.6772	68.	–	4.5275	115.
–	.2362	6.	–	1.1811	30.	2-11/16	2.6875	68.263	4-9/16	4.562	115.888
1/4	.250	6.350	1-3/16	1.1875	30.163	–	2.7165	69.	4-5/8	4.625	117.475
–	.2559	6.5	1-7/32	1.219	30.956	2-23/32	2.719	69.056	4-11/16	4.6875	119.063
17/64	.2656	6.747	–	1.2205	31.	2-3/4	2.750	69.850	–	4.7244	120.
–	.2756	7.	1-1/4	1.250	31.750	–	2.7559	70.	4-3/4	4.750	120.650
9/32	.281	7.144	–	1.2598	32.	2-25/32	2.781	70.6439	4-13/16	4.8125	122.238
–	.2953	7.5	1-9/32	1.281	32.544	–	2.7953	71.	4-7/8	4.875	123.825
19/64	.297	7.541	–	1.2992	33.	2-13/16	2.8125	71.4376	–	4.9212	125.
5/16	.312	7.938	1-5/16	1.312	33.338	–	2.8346	72.	4-15/16	4.9375	125.413
–	.315	8.	–	1.3386	34.	2-27/32	2.844	72.2314	5	5.000	127.000
21/64	.328	8.334	1-11/32	1.344	34.131	–	2.8740	73.	–	5.1181	130.
–	.335	8.5	1-3/8	1.375	34.925	2-7/8	2.875	73.025	5-1/4	5.250	133.350
11/32	.344	8.731	–	1.3779	35.	2-29/32	2.9062	73.819	5-1/2	5.500	139.700
–	.3543	9.	1-13/32	1.406	35.719	–	2.9134	74.	–	5.518	140.
23/64	.359	9.128	–	1.4173	36.	2-15/16	2.9375	74.613	5-3/4	5.750	146.050
–	.374	9.5	1-7/16	1.438	36.513	–	2.9527	75.	–	5.9055	150.
3/8	.375	9.525	–	1.4567	37.	2-31/32	2.969	75.406	6	6.000	152.400
25/64	.391	9.922	1-15/32	1.469	37.306	–	2.9921	76.	6-1/4	6.250	158.750
–	.3937	10.	–	1.4961	38.	3	3.000	76.200	–	6.2992	160.
13/32	.406	10.319	1-1/2	1.500	38.100	3-1/32	2.0312	76.994	6-1/2	6.500	165.100
–	.413	10.5	1-17/32	1.531	38.894	–	3.0315	77.	–	6.6929	170.
27/64	.422	10.716	–	1.5354	39.	3-1/16	3.062	77.788	6-3/4	6.750	171.450
–	.4331	11.	1-9/16	1.562	39.688	–	3.0709	78.	7	7.000	177.800
7/16	.438	11.113	–	1.5748	40.	3-3/32	3.094	78.581	–	7.0866	180.
29/64	.453	11.509	1-19/32	1.594	40.481	–	3.1102	79.	–	7.4803	190
15/32	.469	11.906	–	1.6142	41.	3-1/8	3.125	79.375	7-1/2	7.500	190.500
–	.4724	12.	1-5/8	1.625	41.275	–	3.1496	80.	–	7.8740	200.
31/64	.484	12.303	–	1.6535	42.	3-5/32	3.156	80.169	8	8.000	203.200
–	.492	12.5	1-21/32	1.6562	42.069	3-3/16	3.1875	80.963	–	8.2677	210.
1/2	.500	12.700	1-11/16	1.6875	42.863	–	3.1890	81.	8-1/2	8.500	215.900
–	.5118	13.	–	1.6929	43.	3-7/32	3.219	81.756	–	8.6614	220.
33/64	.5156	13.097	1-23/32	1.719	43.656	–	3.2283	82.	9	9.000	228.600
17/32	.531	13.494	–	1.7323	44.	3-1/4	3.250	82.550	–	9.0551	230.
35/64	.547	13.891	1-3/4	1.750	44.450	–	3.2677	83.	–	9.4488	240.
–	.5512	14.	–	1.7717	45.	3-9/32	3.281	83.344	9-1/2	9.500	241.300
9/16	.563	14.288	1-25/32	1.781	45.244		3.3071	84.	–	9.8425	250.
–	.571	14.5	–	1.8110	46.	3-5/16	3.312	84.1377	10	10.000	254.001
37/64	.578	14.684	1-13/16	1.8125	46.038	3-11/32	3.344	84.9314		10.2362	260.
–	.5906	15.	1-27/32	1.844	46.831	–	3.3464	85.	–	10.6299	270.
19/32	.594	15.081	–	1.8504	47.	3-3/8	3.375	85.725	11	11.000	279.401
39/64	.609	15.478	1-7/8	1.875	47.625	–	3.3858	86.	–	11.0236	280.
5/8	.625	15.875	–	1.8898	48.	3-13/32	3.406	86.519	–	11.4173	290.
–	.6299	16.	1-29/32	1.9062	48.419	–	3.4252	87.	–	11.8110	300.
41/64	.6406	16.272	–	1.9291	49.	3-7/16	3.438	87.313	12	12.000	304.801
–	.6496	16.5	1-15/16	1.9375	49.213	–	3.4646	88.	13	13.000	330.201
21/32	.656	16.669	–	1.9685	50.	3-15/32	3.469	88.106	–	13.7795	350.
–	.6693	17.	1-31/32	1.969	50.006	3-1/2	3.500	88.900	14	14.000	355.601
43/64	.672	17.066	2	2.000	50.800	–	3.5039	89.	15	15.000	381.001
11/16	.6875	17.463	–	2.0079	51.	3-17/32	3.531	89.694	–	15.7480	400.
45/64	.703	17.859	2-1/32	2.03125	51.594	–	3.5433	90.	16	16.000	406.401
–	.7087	18.	–	2.0472	52.	3-9/16	3.562	90.4877	17	17.000	431.801
23/32	.719	18.256	2-1/16	2.062	52.388	–	3.5827	91.	–	17.7165	450.
–	.7283	18.5	–	2.0868	53.	3-19/32	3.594	91.281	18	18.000	457.201
47/64	.734	18.653	2-3/32	2.094	53.181	–	3.622	92.	19	19.000	482.601
–	.7480	19.	2-1/8	2.125	53.975	3-5/8	3.625	92.075	–	19.6350	500.
3/4	.750	19.050	–	2.126	54.	3-21/32	3.656	92.869	20	20.000	508.001
49/64	.7656	19.447	2-5/32	2.156	54.769	–	3.6614	93.			

FIGURE 1–26. Fractions, decimals, and millimeters.

FUNCTIONS OF NUMBERS

The Functions of Numbers chart (figure 1–27) is included in this chapter for convenience in making computations. Familiarization with the various parts of this chart will illustrate the advantages of using "ready-made" computations.

No.	Square	Cube	Square Root	Cube Root	Circum-ference	Area
1	1	1	1.0000	1.0000	3.1416	0.7854
2	4	8	1.4142	1.2599	6.2832	3.1416
3	9	27	1.7321	1.4422	9.4248	7.0686
4	16	64	2.0000	1.5874	12.5664	12.5664
5	25	125	2.2361	1.7100	15.7080	19.635
6	36	216	2.4495	1.8171	18.850	28.274
7	49	343	2.6458	1.9129	21.991	38.485
8	64	512	2.8284	2.0000	25.133	50.266
9	81	729	3.0000	2.0801	28.274	63.617
10	100	1,000	3.1623	2.1544	31.416	78.540
11	121	1,331	3.3166	2.2240	34.558	95.033
12	144	1,728	3.4641	2.2894	37.699	113.10
13	169	2,197	3.6056	2.3513	40.841	132.73
14	196	2,744	3.7417	2.4101	43.982	153.94
15	225	3,375	3.8730	2.4662	47.124	176.71
16	256	4,096	4.0000	2.5198	50.265	201.06
17	289	4,913	4.1231	2.5713	53.407	226.98
18	324	5,832	4.2426	2.6207	56.549	254.47
19	361	6,859	4.3589	2.6684	59.690	283.53
20	400	8,000	4.4721	2.7144	62.832	314.16
21	441	9,261	4.5826	2.7589	65.973	346.36
22	484	10,648	4.6904	2.8020	69.115	380.13
23	529	12,167	4.7958	2.8439	72.257	415.48
24	576	13,824	4.8990	2.8845	75.398	452.39
25	625	15,625	5.0000	2.9240	78.540	490.87
26	676	17,576	5.0990	2.9625	81.681	530.93
27	729	19,683	5.1962	3.0000	84.823	572.56
28	784	21,952	5.2915	3.0366	87.965	615.75
29	841	24,389	5.3852	3.0723	91.106	660.52
30	900	27,000	5.4772	3.1072	94.248	706.86
31	1,961	29,791	5.5678	3.1414	97.389	754.77
32	1,024	32,768	5.6569	3.1748	100.53	804.25
33	1,089	35,937	5.7446	3.2075	103.67	855.30
34	1,156	39,304	5.8310	3.2396	106.81	907.92
35	1,225	42,875	5.9161	3.2717	109.96	962.11
36	1,296	46,656	6.0000	3.3019	113.10	1,017.88
37	1,369	50,653	6.0828	3.3322	116.24	1,075.21
38	1,444	54,872	6.1644	3.3620	119.38	1,134.11
39	1,521	59,319	6.2450	3.3912	122.52	1,194.59
40	1,600	64,000	6.3246	3.4200	125.66	1,256.64
41	1,681	68,921	6.4031	3.4482	128.81	1,320.25
42	1,764	74,088	6.4807	3.4760	131.95	1,385.44
43	1,849	79,507	6.5574	3.5034	135.09	1,452.20
44	1,936	85,184	6.6332	3.5303	138.23	1,520.53
45	2,025	91,125	6.7082	3.5569	141.37	1,590.43
46	2,116	97,336	6.7823	3.5830	144.51	1,661.90
47	2,209	103,823	6.8557	3.6088	147.65	1,734.94
48	2,304	110,592	6.9282	3.6342	150.80	1,809.56
49	2,401	117,649	7.0000	3.6593	153.94	1,885.74
50	2,500	125,000	7.0711	3.6840	157.08	1,963.50

FIGURE 1–27. Functions of numbers.

Numbers

The number column contains the numbers 1 through 100. The other columns contain computations for each number.

No.	Square	Cube	Square Root	Cube Root	Circum-ference	Area
51	2,601	132,651	7.1414	3.7084	160.22	2,042.82
52	2,704	140,608	7.2111	3.7325	163.36	2,123.72
53	2,809	148,877	7.2801	3.7563	166.50	2,206.18
54	2,916	157,464	7.3485	3.7798	169.65	2,290.22
55	3,025	166,375	7.4162	3.8030	172.79	2,375.83
56	3,136	175,616	7.4833	3.8259	175.93	2,463.01
57	3,249	185,193	7.5498	3.8485	179.07	2,551.76
58	3,364	195,112	7.6158	3.8709	182.21	2,642.08
59	3,481	205,379	7.6811	3.8930	185.35	2,733.97
60	3,600	216,000	7.7460	3.9149	188.50	2,827.43
61	3,721	226,981	7.8102	3.9365	191.64	2,922.47
62	3,844	238,328	7.8740	3.9579	194.78	3,019.07
63	3,969	250,047	7.9373	3.9791	197.92	3,117.25
64	4,096	262,144	8.0000	4.0000	201.06	3,126.99
65	4,225	274,625	8.0623	4.0207	204.20	3,381.31
66	4,356	287,496	8.1240	4.0412	207.34	3,421.19
67	4,489	300,763	8.1854	4.0615	210.49	3,525.65
68	4,624	314,432	8.2462	4.0817	213.63	3,631.68
69	4,761	328,509	8.3066	4.1016	216.77	3,739.28
70	4,900	343,000	8.3666	4.1213	219.91	3,848.45
71	5,041	357,911	8.4261	4.1408	233.05	3,959.19
72	5,184	373,248	8.4853	4.1602	226.19	4,071.50
73	5,329	389,017	8.5440	4.1793	229.34	4,185.39
74	5,476	405,224	8.6023	4.1983	232.48	4,300.84
75	5,625	421,875	8.6603	4.2172	235.62	4,417.86
76	5,776	438,976	8.7178	4.2358	238.76	4,536.46
77	5,929	456,533	8.7750	4.2543	241.90	4,656.63
78	6,084	474,552	8.8318	4.2727	245.05	4,778.36
79	6,214	493,039	8.8882	4.2908	248.19	4,901.67
80	6,400	512,000	8.9443	4.3089	251.33	5,026.55
81	6,561	531,441	9.0000	4.3267	254.47	5,153.00
82	6,724	551,368	9.0554	4.3445	257.61	5,281.02
83	6,889	571,787	9.1104	4.3621	260.75	5,410.61
84	7,056	592,704	9.1652	4.3795	263.89	5,541.77
85	7,225	614,125	9.2195	4.3968	267.04	5,674.50
86	7,396	636,056	9.2376	4.4140	270.18	5,808.80
87	7,569	638,503	9.3274	4.4310	273.32	5,944.68
88	7,744	681,472	9.3808	4.4480	276.46	6,082.12
89	7,921	704,969	9.4340	4.4647	279.60	6,221.14
90	8,100	729,000	9.4868	4.4814	282.74	6,361.73
91	8,281	753,571	9.5394	4.4979	285.88	6,503.88
92	8,464	778,688	9.5917	4.5144	289.03	6,647.61
93	8,649	804,357	9.6437	4.5307	292.17	6,792.91
94	8,836	830,584	9.6954	4.5468	295.31	6,939.78
95	9,025	857,375	9.7468	4.5629	298.45	7,088.22
96	9,216	884,736	9.7980	4.5789	301.59	7,283.23
97	9,409	912,673	9.8489	4.5947	304.73	7,389.81
98	9,604	941,192	9.8995	4.6104	307.88	7,542.96
99	9,801	970,299	9.9499	4.6261	311.02	7,697.69
100	10,000	1,000,000	10.0000	4.6416	314.16	7,853.98

FIGURE 1-27. Functions of numbers (continued).

Square

Square is the product obtained by multiplying a number by itself: $1 \times 1 = 1$, $2 \times 2 = 4$, $17 \times 17 = 289$. Squaring may be considered a special form of area computation: Area = Length multiplied by Width, $A = L \times W$.

Cube

Cube is the product obtained by multiplying a number by itself, then multiplying that product by the number again: $1 \times 1 \times 1 = 1$, $2 \times 2 \times 2 = 8$, $13 \times 13 \times 13 = 2{,}197$. Cubing may be considered a specialized form of volumn computation: Volume = Length multiplied by Width by Heighth, $V = L \times W \times H$.

Square Root

Square root is the opposite of a "squared" number. The square root of a number is, that number which when multiplied by itself (squared) will produce the original or desired number: For example, the square root of 1 is 1, $1 \times 1 = 1$. The square root of 4 is 2. The square root of 24 is 4.8990. If an area of 24 square inches must be a perfect square, the length of each side would be 4.8990 inches.

Cube Root

A cube root is the opposite of a "cubed" number. The cube root of a number is that number which when multiplied by itself (cubed) will produce the original or desired number. The cube root of 1 is 1, $1 \times 1 \times 1 = 1$. The cube root of 27 is 3, $3 \times 3 \times 3 = 27$. If a container of 100 cubic inches and cubic in shape is desired, then the length of each side would be 4.6416.

Circumference of A Circle

Circumference is the linear measurement of the distance around a circle. The circumference is calculated by multiplying the diameter of the circle by the constant 3.1416 (π). This constant was calculated by dividing the circumference of circles by their diameter. For example, diameter = 1, circumference = 3.1416, $1 \times 3.1416 = 3.1416$. Diameter = 10, $10 \times 3.1416 = 31.4160$, diameter = 12, $12 \times 3.1416 = 37.699$.

Area of A Circle

Area of a circle is the number of square units of measurement contained in the area circumscribed by a circle of the diameter of the listed number. This is calculated by the formula $(\pi) \times r^2 = a$, (π) multiplied by the radius squared equals area. The radius is equal to one half the diameter. For example, diameter = 2, radius = 1. $3.1416 \times 1 =$ 3.1416 square units in a circle which has a diameter of 2. Another example, diameter = 4, radius = 2. $3.1416 \times 2^2 = 3.1416 \times 4 = 12.5664$ square units. lion micrograms.