# Unit 1. Mathematics



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.

## 1–1. Basic Math

A person entering the aerospace field will be required to perform with accuracy. The aerospace 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 you must adhere, it's important that you (the aerospace 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 in solving a particular problem. In this section, we'll explore the following four subject areas as they apply to basic math:

1. Whole numbers.
2. Fractions.
3. Mixed numbers.
4. Decimals.

### 001. Whole numbers

Whole numbers are the numbers beginning with 0, with each successive number greater than its predecessor by 1. There are four basic mathematical operations you can perform using whole numbers. They are as follows:

1. Addition of whole numbers.
2. Subtraction of whole numbers.

3. Multiplication of whole numbers.
4. Division of 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 you're 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 you're 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 that's subtracted is called the subtrahend, the other number is 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 you're writing down the partial products formed. Be certain that the extreme right digit lines up under the multiplying digit. It's then a matter of simple addition to find the final product.

**Example:**

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

$$\begin{array}{r} 3.25 \\ \underline{\times 18} \\ 2600 \\ \underline{3250} \\ 58.50 \end{array}$$

When you're 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

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | 21 | 105 | | 7 | 3 | 25 |
| ×3 | ×5 | ×2 | or | ×5 | ×2 | ×6 |
| 21 | 105 | 210 | | 35 | 6 | 210 |

**Division of whole numbers**

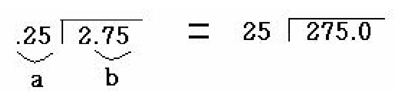
The process of finding how many times one number is contained in a second number is called division. The first number is called the divisor, the second the dividend, and the result is the quotient.

Of the four basic operations with integers, division is the only one that involves trial and error in its solution. It's necessary that you guess at the proper quotient digits, and through experience you'll 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 you're dividing a decimal by a decimal, an important step is to first remove the decimal from the divisor. Do this 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.

**Example:**

2.75 divided by .25




1. First, move the decimal point of the divisor two places to the right.
2. Then, move the decimal point of the dividend two places to the right.

**Order of operation when solving complex equations.**

When solving equations, many times more than one mathematical operation will be performed. For instance, two numbers may be added together and then divided by another. Brackets and parentheses are used to identify the necessary operations. These operations must be done in a certain order also. The operation within the parentheses is accomplished first and then the operation within the brackets is accomplished before solving the equation. Here is an example.

Solve the equation. [(2–1) + (5×2)] Divided by 2 = ?

Solve parentheses. [1+10] Divided by 2 = ?

Solve brackets. 11 Divided by 2 = ?

Solve equation. 11 divided (also represented by the symbol "/") 2 = 5.5

## 002. 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 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 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:

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

A decimal fraction is obtained by dividing the numerator of a fraction by the denominator and showing the quotient as a decimal. The fraction 5/8 equals 5 ÷ 8 = .625.

A fraction doesn't 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 four operations (addition, subtraction, multiplication, and division) you performed with whole numbers can also be performed with fractions.

**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 you're adding or subtracting fractions that have like denominators, it's only necessary for you 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's necessary that you first reduce the fractions to a common denominator before proceeding with the addition or subtraction process.

**Examples:**

1. A certain switch installation requires 5/8-inch plunger travel before switch actuation occurs. If 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 13/16 of an inch. If the travel in one direction from the neutral position is 7/16 of an inch, what's 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 1/4-inch inside diameter and a combined wall thickness of 5/8 inch.

   FIRST: Reduce the fractions to a common denominator. $\frac{1}{4}=\frac{2}{8}$ $\frac{5}{8}=\frac{5}{8}$

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 7/8 inch plus or minus 1/5 inch. What's the minimum droop to which the aileron can be rigged?

   FIRST: Reduce the fractions to a common denominator.

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

   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 can't 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 weren't 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's 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.

| Divisor | | | | |
|---|---|---|---|---|
| 2 | 8 | 20 | 36 | 45 |
| | 4 | 10 | 18 | 45 |

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

| Divisor | | | | |
|---|---|---|---|---|
| 2 | 8 | 20 | 36 | 45 |
| 2 | 4 | 10 | 18 | 45 |
| 3 | 2 | 5 | 9 | 45 |
| 3 | 2 | 5 | 3 | 15 |
| 5 | 2 | 5 | 1 | 5 |
| | 2 | 1 | 1 | 1 |

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

$$\text{LCD} = 2\times2\times3\times3\times5\times2 = 360$$

**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's the product of $\frac{3}{5}\times\frac{12}{22}\times\frac{1}{2}$?

FIRST: Multiply the numerators together. $3\times12\times1=36$

NEXT: Multiply the denominators together. $5\times22\times2=220$

THEN: Reduce the resulting fraction to its lowest terms.

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

***Cancellation***

Cancellation is a technique of dividing out or canceling 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's the product of $\frac{18}{10}\times\frac{3}{5}$?

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's apparent that the 10 in the denominator and the 5 in the numerator can both be divided an exact number of times by 5.

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

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.

$$\frac{\overset{\overset{3}{\cancel{6}}}{\cancel{18}}}{\underset{\underset{1}{\cancel{2}}}{\cancel{10}}}\times\frac{\overset{1}{\cancel{5}}}{\underset{1}{\cancel{3}}}=\frac{3\times1}{1\times1}=\frac{3}{1}=3$$

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. In division, it's important that you perform the operations in the order indicated.

**NOTE:** Remember, it's always the divisor that's inverted, never the dividend.

**Mixed numbers**

A mixed number is a number that's made up of a whole number and a fraction; for example, 2 1/2,

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 3/16 inches long is cut from a piece 24 1/2 inches long. Allowing 1/16 inch for the cut, what's 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.

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

## 003. Decimals

Decimals are fractions whose denominators are 10 or some multiple of 10, such as 100, 1,000, 10,000, and so forth. They're indicated by writing one or more digits to the right of a reference mark called a decimal point. Thus: $\frac{6}{10}=.6$ Both read as six tenths

$$\frac{6}{100}=.06 \text{ Both read as six hundredths}$$

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

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

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

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

There are four basic operations you may perform using decimals are as follows:

1. Addition.
2. Subtraction.
3. Multiplication.
4. Division.

In addition, you'll also need to know how to do the following:

1. Round off decimals.
2. Convert decimals to common fractions.
3. Convert common fractions to decimals.
4. Calculate percentage.

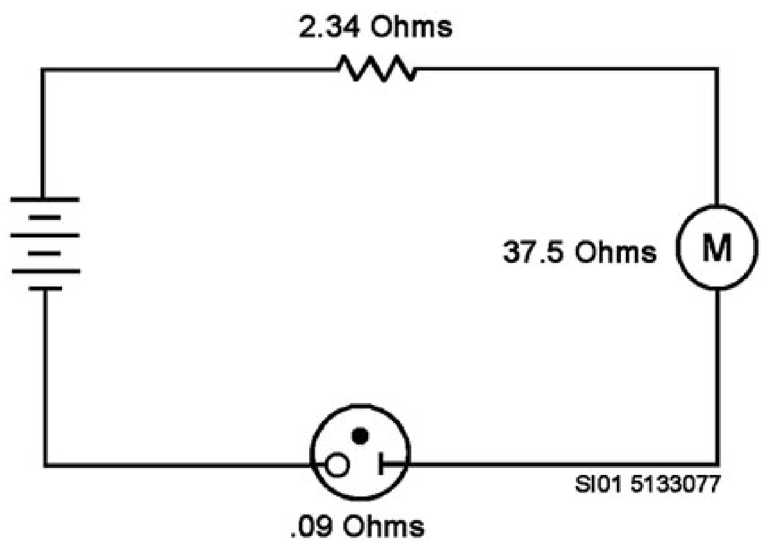



**Figure 1–1. Series circuit.**

### Addition of decimals

When you're computing decimals, the rule of likeness requires that you 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 the series circuit (fig. 1–1) is equal to the sum of the individual resistances. What's 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 alignment.

```
  2.34
 37.5
   .09
```

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.

```
  2.34
 37.5
   .09
 -----
 39.93   ohms
```

### Subtraction of decimals

Let's say a series circuit contains two resistors with a total resistance of 37.27 ohms. One of the resistors has a value of 14.88 ohms. What's the value of the remaining resistor?

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

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

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.

$$\begin{array}{rr} & 37.27 \\ - & \underline{14.88} \\ & 22.39 \end{array}$$

**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, let’s determine 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.

$$\begin{array}{r} 9.45 \\ \underline{\times 120} \\ 000 \\ 18900 \\ \underline{94500} \\ 113400 \end{array}$$

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.

$$\begin{array}{r} 9.45 \\ \underline{\times 120} \\ 000 \\ 18900 \\ \underline{94500} \\ 1134.00 \end{array}$$

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.

$$\begin{array}{r} .218 \\ \underline{.203} \\ 654 \\ \underline{43600} \\ 44254 \end{array}$$

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.

$$\begin{array}{r} .218 \\ \times\underline{.203} \\ 654 \\ \underline{43600} \\ .044254 \end{array}$$

**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 you must keep in mind are as follows:

1. When the dividend and divisor are multiplied by the same number, the quotient remains unchanged.
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 (^) 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 aligns 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's the average width, or "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.

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

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

```
             6.07
40.33^)24500^00
       24198
         3020
         0000
         30200
         28221
          1979
```

**Rounding off decimals**

There's 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's necessary for you to round a number to some value that's practical to use. For example, a measurement is computed to be 29.4948 inches. It's impractical, if not impossible, to measure this accurately with a steel rule that is accurate only to 1/64 of an inch.

To use this measurement, you 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, four-tenths is 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, 9 is greater than 5 and the final decimal is expressed: 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.

| | | | |
|---|---|---|---|
| | .3 | 7 | 5 |
| FIRST: Count the number of digits to the right of the decimal point. | ↓ | ↓ | ↓ |
| | 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.

$$.375 = \frac{375}{1{,}000}$$

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're first drilled 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.

$$\begin{array}{r} .763 \\ \underline{\times 64} \\ 3052 \\ \underline{45780} \\ 48832 \end{array}$$

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 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 (fig. 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.

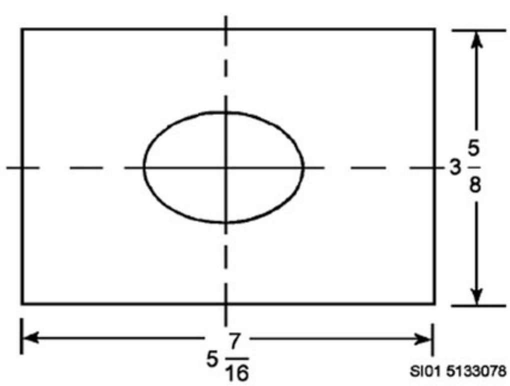



**Figure 1–2. Locating the hole center.**

FIRST: Change the mixed numbers to improper fractions.

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

NEXT: Convert the improper fractions to decimal expressions.

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

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

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

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

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

**Calculating percentage**

There are many problems that arise every day involving the percent expression. The greatest number of percentage problems involves 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. For example, the fraction 1/5 can 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.

We'll now present the following five examples of how you work with percentage:

1. Expressing a decimal as a percent.
2. Expressing a percent as a decimal.
3. Finding what percent one number is of another.
4. Finding a percent of a given number.
5. Finding a number when a percent of it is known.

***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's 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 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's 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. $0.8958 = 89.58\%$ 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's 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's 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.

$$290 + 17.4 = 307.4 \text{ knots}$$

***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.

$52\% = .052$

NEXT: Divide the known number by the decimal expression.

$80 \div .52 = 153.8$ ohms total resistance.

## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

**001. Whole numbers**

1. Solve the equation. [(4 –3) + (–9 × 2)] [divided by] 2 =.

2. Solve the equation. 4 – 3 [–6(2+3) + 4] =.

**002. Fractions**

1. What's the number above the line in a fraction called?

2. Solve the equation. (64 × 3/8) [divided by] 3/4 =.

3. Solve the word problem. A piece of tubing 6 5/16 inches long is cut from a piece 24 1/2 inches long. Allowing 1/16 inch for the cut, what is the length of the remaining piece?

4. Solve the word problem. A piece of tubing 7 1/4 inches long is cut from a piece 24 1/2 inches long. Allowing 1/8 inch for the cut, what is the length of the remaining piece?

5. Solve the word problem. A certain aircraft bolt has an overall length of 1 1/2 inches and a threaded portion length of 5/8 inch. What portion of the bolt is unthreaded?

**003. Decimals**

1. 1.21875 is equal to
   a. 83/64.
   b. 39/32.
   c. 19/16.

2. Multiply .230 by .203.

3. Express 5/6 as a decimal.

4. What is 15% of 95?

## 1–2. Advanced Math

In our last section, we covered the operations involved in basic math. In this section, we'll expand on that knowledge by looking at the operations involved in advanced math. To do this, we'll cover the following nine subject areas:

1. Ratios.
2. Proportion.
3. Positive and negative numbers.
4. Powers and roots.
5. Computing area.
6. Computing the volume of solids.
7. Graphs and charts.
8. Measurement systems.
9. Functions of numbers.

### 004. Ratios

In our last section, we looked at common fractions. 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 aerospace. For example, 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. In essence, a ratio is the quotient of one number divided by another number, expressed in like terms. Therefore, a ratio 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 7/8 can be written 7:8.

In this lesson, we'll cover the following three operations as they apply to ratios:

1. Finding the ratio of two quantities.
2. Finding the quantity of the first term.
3. Finding the quantity of the second term.

#### Finding the ratio of two quantities

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's 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.

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

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

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

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

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

What's the ratio in gallons?

FIRST: Express the ratio in fractional form.

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

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

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

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

$$R = \frac{800}{\frac{10{,}080}{7.2}} = \frac{800}{1400} = \frac{4}{7}, \quad or \quad 4:7$$

2. If the cruising speed of an airplane is 200 knots and its maximum speed is 250 knots, what's 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.

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

### Finding the quantity of the first term

We'll now consider a situation when the ratio and the quantity that corresponds to the second term are given and you want 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.

$$35 \times \frac{5}{7} =$$

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.

$$\frac{25}{35} = \frac{5}{7}$$

### 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.

$$100 \div \frac{2}{3} =$$

NEXT: Perform the indicated operation.

$$100 \div \frac{2}{3} =$$

$$\overset{50}{1\cancel{0}\cancel{0}} \div \frac{3}{\underset{1}{\cancel{2}}} = 150$$

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

$$\frac{100}{150} = \frac{2}{3}$$

## 005. Proportion

A proportion is a statement of equality between two or more ratios. $\frac{3}{4} = \frac{6}{8}$; *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 fuel. 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 fuel will be required to travel a distance of 750 miles.

## 006. 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.

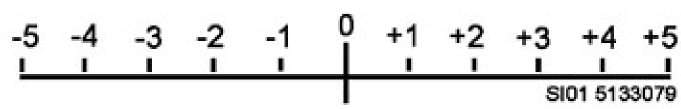



**Figure 1–3. Scale of signed numbers.**

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

With these thoughts in mind, we'll turn to the four following subject areas of this lesson:

1. Addition.
2. Subtraction.
3. Multiplication.
4. Division.

### 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's the new weight?

**NOTE:** 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.

$+2000 - 13 = 1987$ 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's 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.

$(-6) + (-20) = -26$ 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:**

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

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

**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:**

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

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

## 007. Powers and roots

In our last lesson, we covered how you work with positive and negative numbers. In this lesson, we'll expand you mathematical knowledge by covering another facet of advanced math. This time we'll explore how you work with powers and roots of numbers.

**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's 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 aren't 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

THEN: Bring down the next pair.

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

(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's 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's unnecessary to carry the root beyond the number of digits possessed by the original number.

```
       1  4.  6
     √2 13 . 16
       1
  24   1 13
         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 fig. 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:

| 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 |
| $10^2$ | $10 \times 10$ | 100 |
| $10^1$ | 10 | 10 |
| $10^0$ | | 1 |

The velocity of light, 30,000,000,000 centimeters per second, simplifies to $3 \times 10^{10}$ centimeters per second

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 electron, 0.000,000,000,000,000,000,000,000,000,911 gram, becomes $911 \times 10^{-26}$ gram.

**Figure 1–4. Powers of ten and their equivalents.**

(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 doesn't change when it's 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.

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

- Move the decimal point to the place desired. Count the number of places the decimal point is moved.
- Multiply the altered number by 10 to a power equal to the number of places the decimal point was moved.

**NOTE:** The exponent of 10 is negative if the decimal point is moved to the right, and it's 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'll 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, $a^5 \times b^6$ can't be combined because the bases (a and b) aren't the same.

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

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

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

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

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

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 and 10 multiplied by 10 to the proper power.

### 008. 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. They are as follows:

1. Rectangle.
2. Square.
3. Triangle.
4. Circle.
5. Trapezoid.

In addition to the working with the various geometric figures, you should also be able to calculate the wing area for different types of aircraft.

Before we get into each specific geometric figure, we'll first review some important geometric facts.

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's 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, and so forth, found in the metric system of measurement.

| ***Table of Areas*** | | |
|---|---|---|
| 144 square inches (sq. in.) | = | 1 square foot. (sq. ft.) |
| 9 square feet | = | 1 square yard (sq. yd.) |
| 30 1/4 square yards | = | 1 square rod (sq. rd.) |
| 160 square rod | = | 1 acre (A) |
| 640 acres | = | 1 square mile (sq. mile) |

As you'd expect, there's a separate formula for finding the area of each geometric figure; that is, the technique for determining the area of any geometric shape is based upon the use of formulas. To solve a problem by formula, it's necessary to:

1. Select the formula that covers the problem situation,
2. Insert the known values in the selected formula, and
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's the cross-sectional area of many beams, rods, fittings, and so forth. (fig. 1–5.)

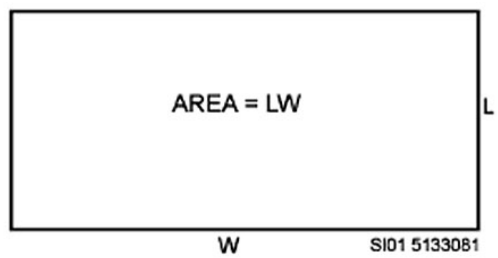



**Figure 1–5. Rectangle.**

The area of a rectangle is the product of the measures of the length and width when they're expressed in the same units of linear measure. The area may be expressed by the following 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's 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.

$$A = 24 \times 12 = 288 \text{ square inches}$$

**The square**

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

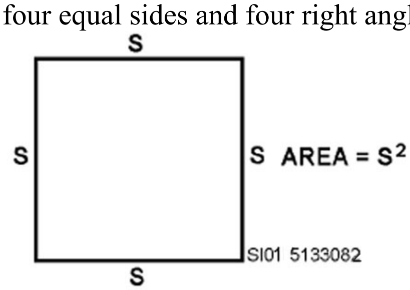



**Figure 1–6. Square.**

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's 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. $A = 25 \times 25 = 625$ square inches

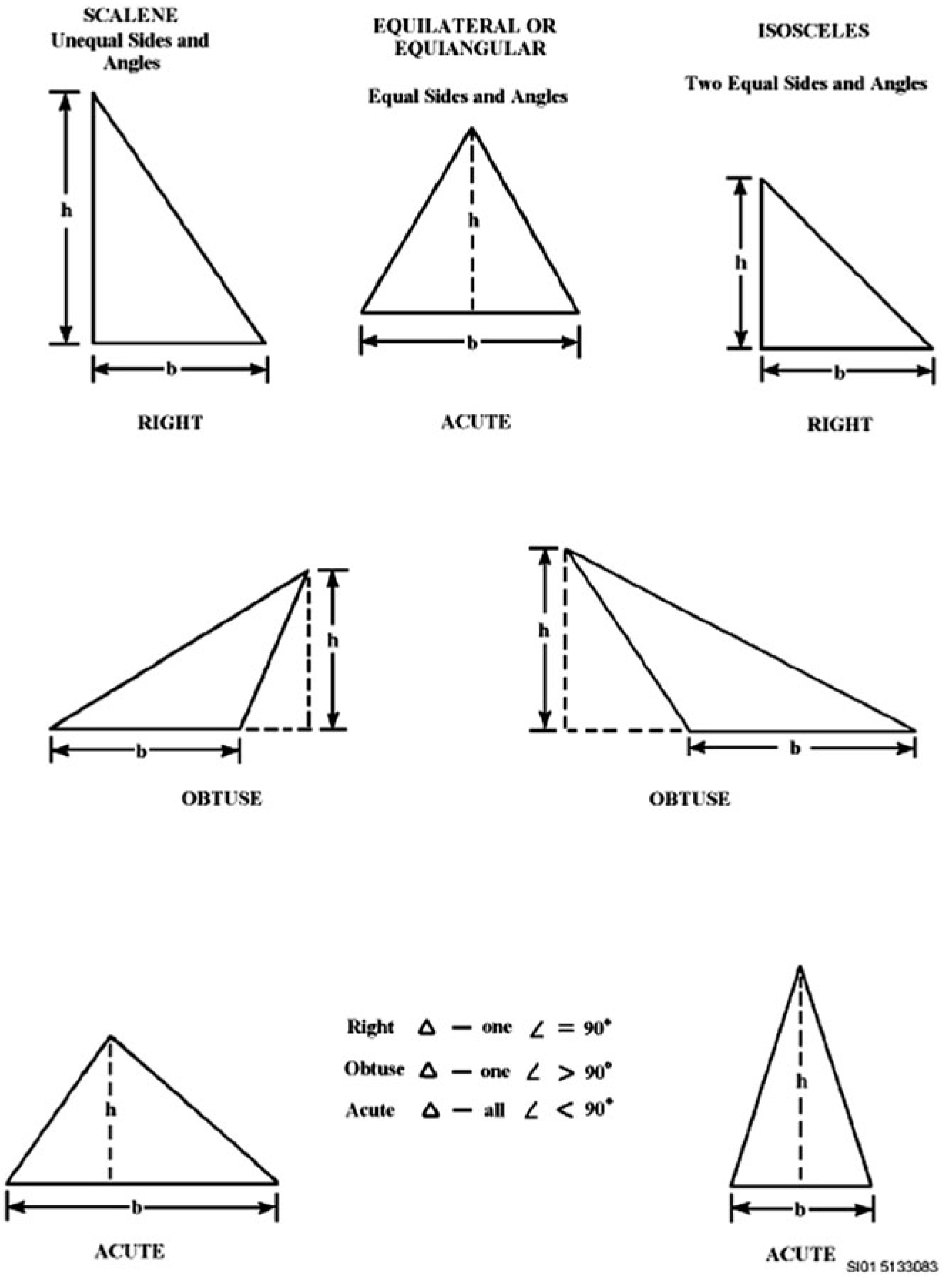



**Figure 1–7. Types of triangles.**

**Triangles**

A triangle is a three-sided polygon. There are three basic types of triangles.

1. Scalene.
2. Equilateral or equiangular.
3. 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 follows:

1. Right.
2. Obtuse.
3. 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°. 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.

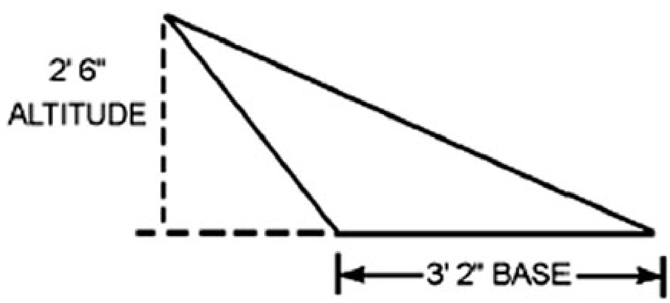



**Figure 1–8. Triangle.**

The base of a triangle is the side upon which 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; 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.

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

$$A = 570 \quad sq.inches$$

**Circle**

Two important factors come into play when you're dealing with circles.

1. Circumference of a circle.
2. Area of a circle.

***Circumference of a circle***

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

The circumference of a circle may be found by using the formula $C = \pi d$ where $C$ is the circumference; $\pi$ is the given constant, 3.1416; and $d$ is the diameter of the circle.

**Example:**

The diameter of a certain piston is 5 inches. What's 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.

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

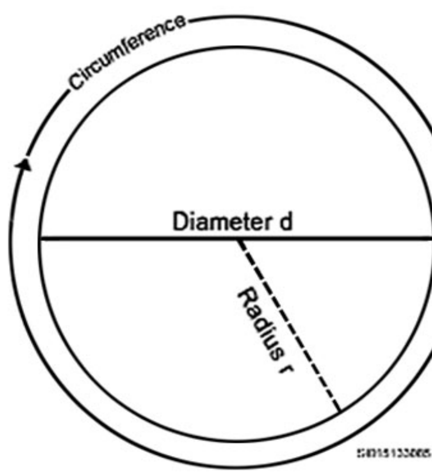



**Figure 1–9. Circle.**

***Area of a circle***

The area of a circle, as in a rectangle or triangle, must be expressed in square units. The distance that's 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 $\pi$. The formula is expressed $A = \pi r^2$ where $A$ is the area of a circle; $\pi$ 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, $A = \pi r^2$

**Note** [r = radius and is found by dividing the diameter by 2.]

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

NEXT: Solve the formula for the unknown value.

$$A = 3.1416 \times 6.25$$
$$A = 19.635\ sq.\ inches$$

**The trapezoid**

A trapezoid is shown on figure 1–10. It's 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; 1/2 is the given constant; $b_1$ and $b_2$ are the lengths of the two parallel sides; and $h$ is the height.

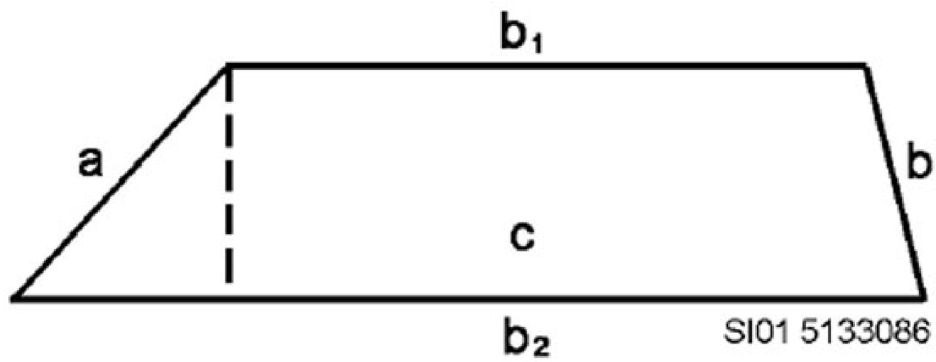



**Figure 1–10. Trapezoid.**

**Example:**

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

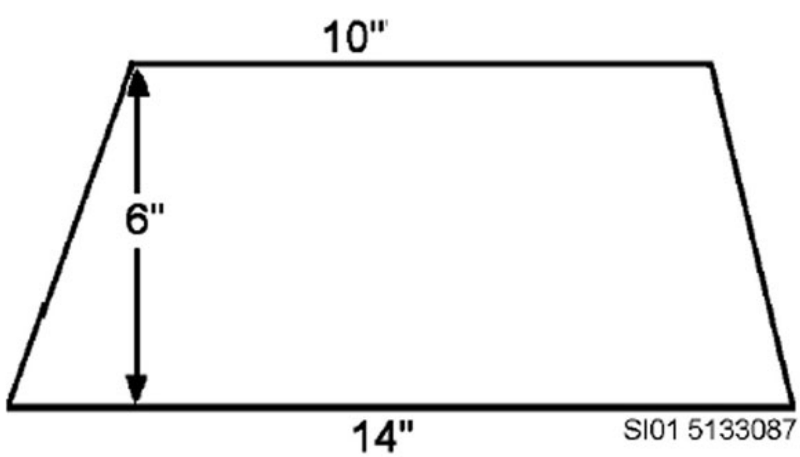



**Figure 1–11. Computing the area of a trapezoid.**

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.

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

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

$$A = 72 \ sq.\ inches$$

**Wing area**

To describe the planform of a wing like the one in figure 1–12, several terms are required. To calculate wing area, it will be necessary to consider the meaning of these two terms:

1. Span.
2. Chord.

***Span***

The wing span is the length of the wing from wing tip to wing tip.

***Chord***

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.

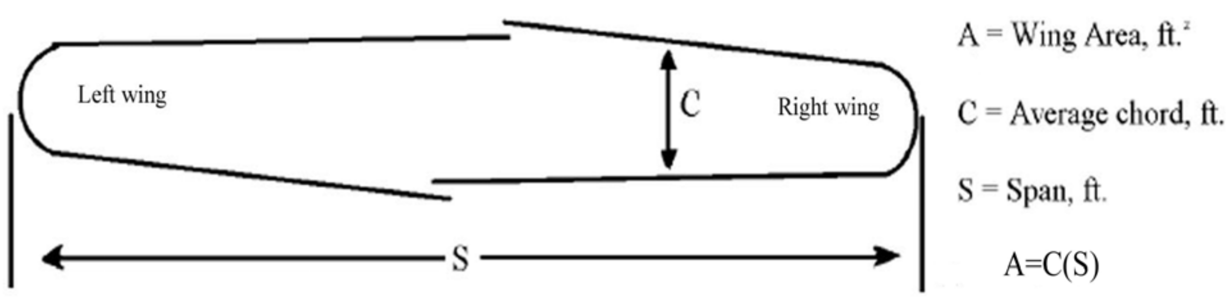



**Figure 1–12. Wing planform.**

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.

**Example:**

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

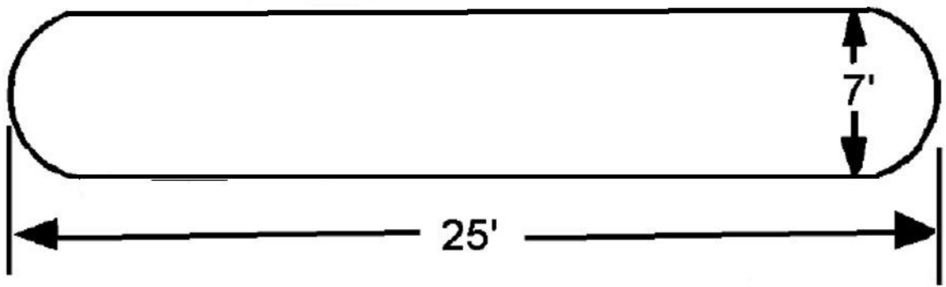



Figure 1–13. Wing with circular tips.

To determine the area, it's 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.

$$A = (18 \times 7) + (3.1416 \times 12.25)$$
$$A = 126 + 38.5$$
$$A = 164.5 \ sq.\ inches$$

Find the area of a tapered wing (fig. 1–14) whose structural span is 50 feet and whose mean chord is 6′ 8″.

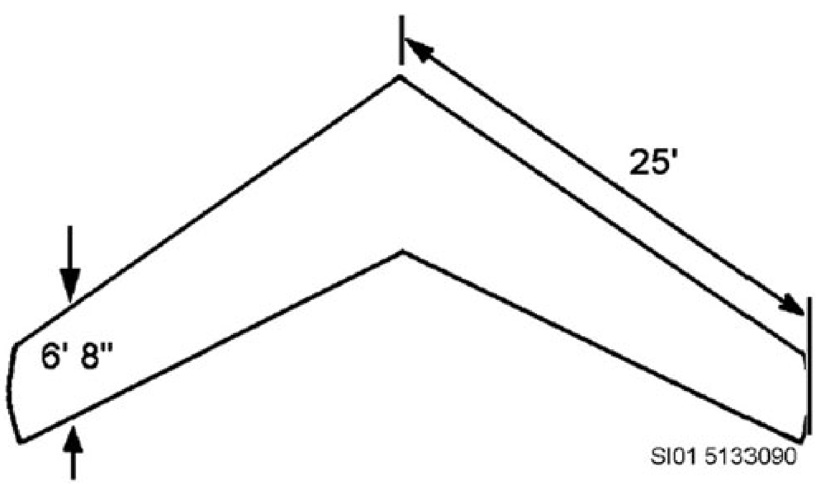



Figure 1–14. Tapered wing with sweepback.

FIRST: Substitute the known values in the formula.

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

NEXT: Solve the formula for the unknown value.

$$A = 50' \times 6.67'$$
$$A = 333.5\ sq.\ feet$$

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

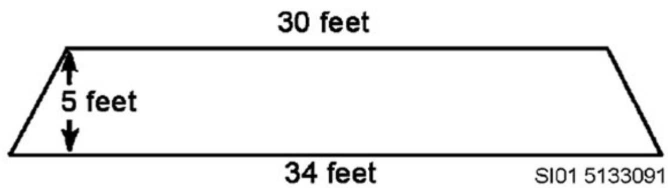



**Figure 1–15. Trapezoid wing.**

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.

$$A = \frac{1}{2}(64)5$$
$$A = \frac{1}{2}(320)$$
$$A = 160\ sq.\ feet$$

## 009. Computing the volume of solids

Solids are objects with these three dimensions:

1. Length.
2. Breadth.
3. Thickness.

In addition, solids are of many shapes, the most common of which are as follows:

1. Prisms.
2. Cylinders.
3. Pyramids.
4. Cones.
5. Spheres.

Occasionally, it will be necessary for you to determine the volume of a rectangle, a cube, a cylinder, or a sphere.

Since all volumes aren't measured in the same units, it's necessary to know all the common units of volume and how they're related to each other. For example, you may know the volume of a tank in cubic feet or cubic inches, but when the tank is full of gasoline, you'll 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. |

We'll now consider two practical examples of how to work with computations of solids as follows:

1. Volume of a rectangular solid.
2. Surface area and volume of a cylinder.

**Volume of a rectangular solid**

A rectangular solid is a solid bounded by rectangles. In other words, it's a square-cornered volume such as a box (fig. 1–16). If the solid has equal dimensions, it's 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.

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

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

$$V = \frac{165}{4} = 41.25 \textit{ cubic feet}$$

If the rectangular solid is in the shape of a cube (fig. l–17), the formula can be expressed as the cube of the sides as $V = S^3$ where $V$ is the volume and $S$ is the side measurement of the cube.

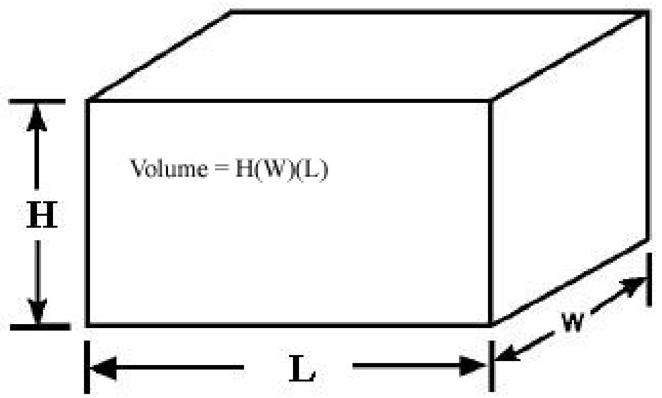



Figure 1–16. Rectangular solid.

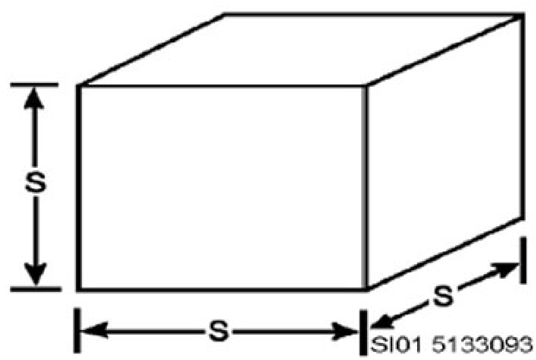



Figure 1–17. Cube.

**Surface 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, $\pi$ is the given constant, $d$ is the diameter, and $h$ is the height of the cylinder.

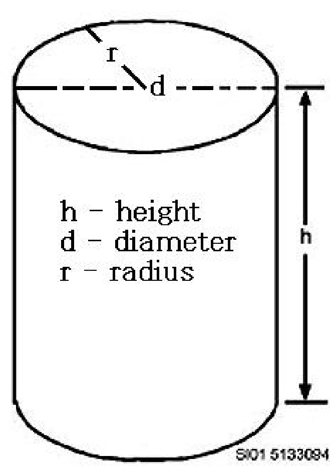



Figure 1–18. Cylinder.

**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.

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

$$A = 132.95 \textit{ or } 133 \textit{ sq feet}$$

***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; $\pi$ is the given constant; $r^2$ is the square of the radius of the cylinder; and $h$ is the height of the cylinder (fig. 1–19).

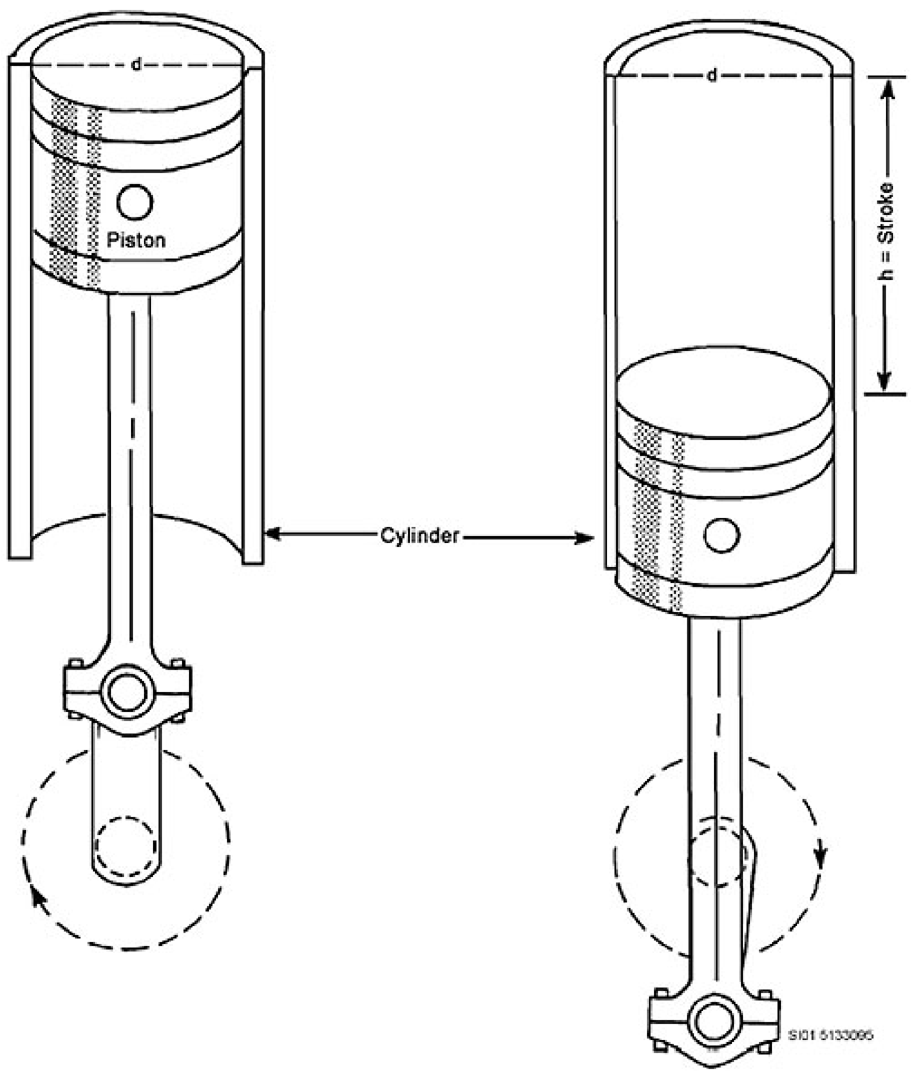



**Figure 1–19. Cylinder displacement.**

**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's 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.

$$V = 17.28 \times 7.56$$

$$V = 130.64 \ \textit{cubic inches}$$

## 010. 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, you 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 as follows:

1. Bar graphs.
2. Pictographs.
3. Broken-line graphs.
4. Continuous curved-line graphs.
5. Circle graphs.

An example of each is shown in figure 1–20.

**NOTE:** The most useful of these graphs in technical work is the continuous curved-line graph.

### Interpreting or reading graphs and charts

From the mechanic's viewpoint, it's more important for you 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 %.

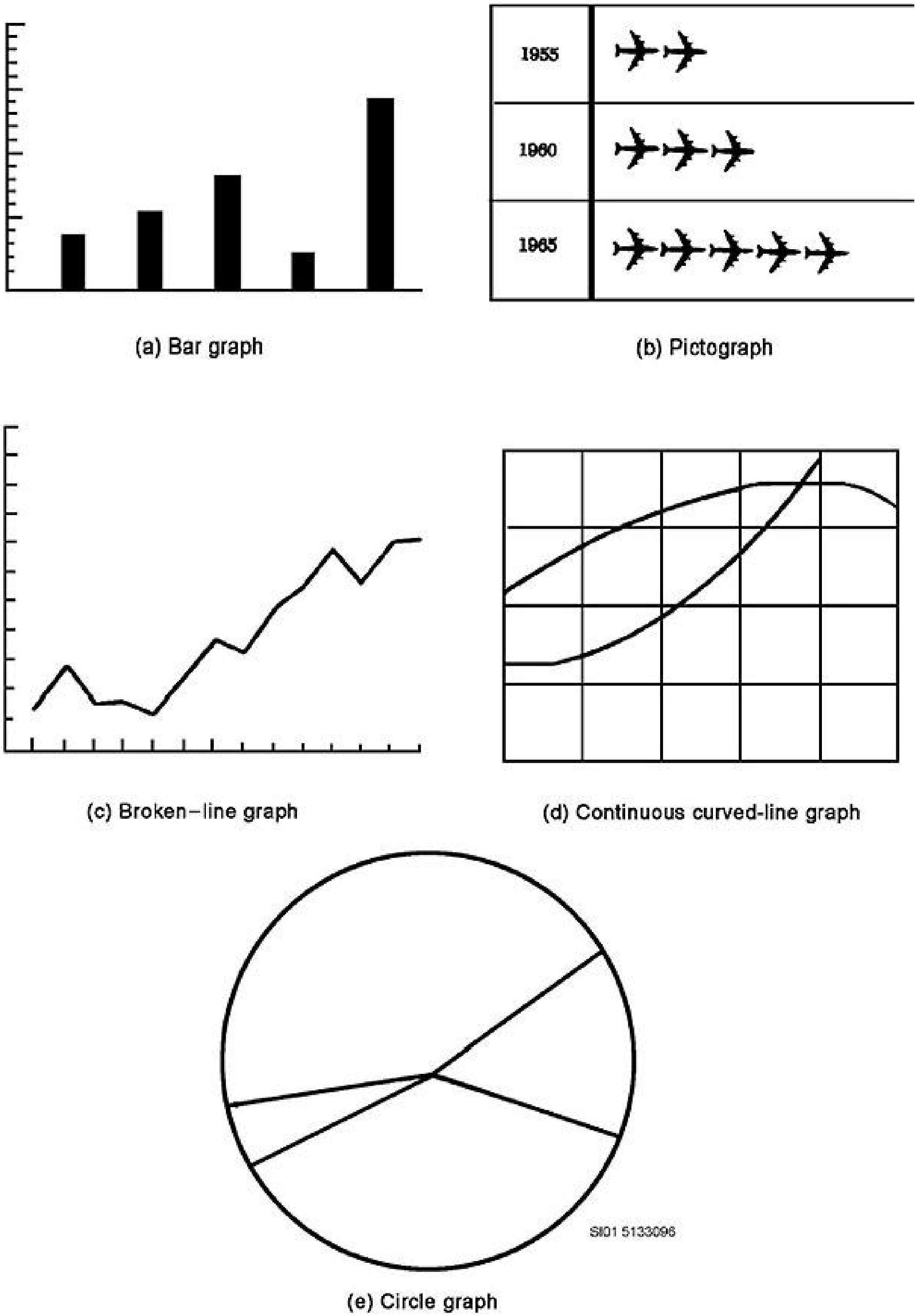



**Figure 1–20. Types of graphs.**

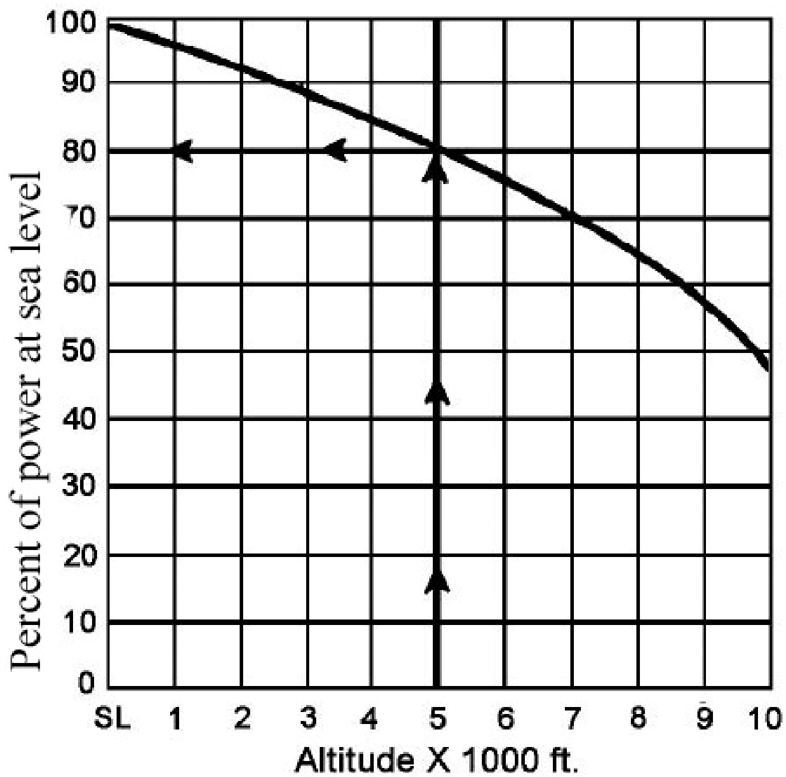



**Figure 1–21. Horsepower vs. altitude chart.**

***Nomograms***

It's often necessary to make calculations using the same formula, but using different sets of values for the variables. It's 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's 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 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's essential to select the proper curve for the desired conditions.

Again, as with the simpler graphs, it's more important for you (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 (fig. 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 RPM are three factors that must be known to use this particular nomogram.

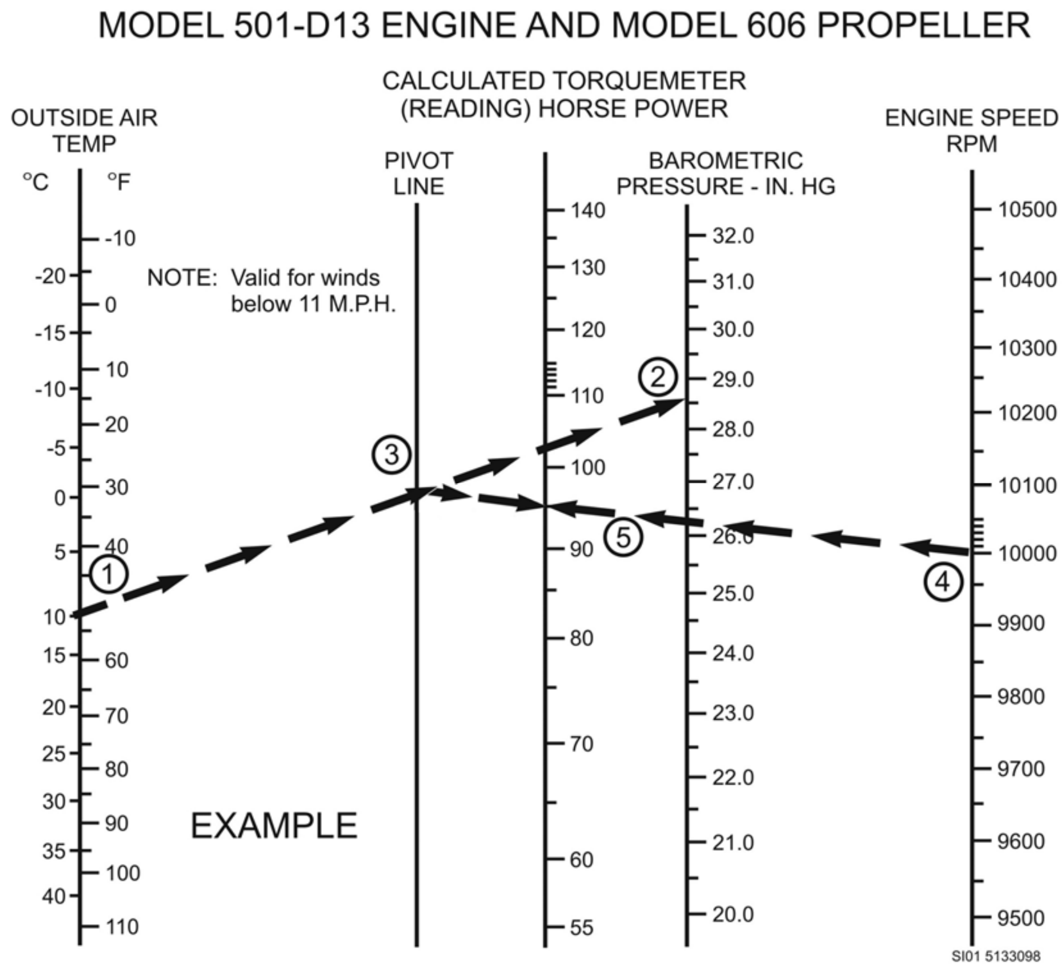



**Figure 1–22. Power requirements at minimum torque.**

**Example:**

Determine the calculated horsepower of a certain engine using the nomogram in figure 1–22. Assume that the OAT is 10º C., the barometric pressure is 28.5 in. Hg (inches of mercury), and the engine is operating at 10,000 RPM.

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 RPM 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 95%.

## 011. Measurement systems

Figure 1–23 shows some common units from our customary system of measurement. This system is part of our cultural heritage and dates back to the days when the 13 colonies were under British rule. The system 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 wheat corns from the "midst of the ear."

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

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**Figure 1–23. Some common units.**

The US gallon is the British wine gallon. It was standardized at the beginning of the eighteenth century. It's about 20 percent smaller than the Imperial gallon that the British adopted in 1824 and have used since 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. In more modern times, the trend in measurement systems has progressed to the metric system.

### Metric system

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.

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 haven't 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 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's logically streamlined, whereas other systems developed more or less haphazardly. At this time, there are only six base units in the International Metric System. They are as follows:

1. The unit of length is the meter.
2. The unit of mass is the kilogram.

3. The unit of time is the second.
4. The unit of electric current is the ampere.
5. The unit of temperature is the Kelvin (which in common use is translated into the degree Celsius, formerly called degree centigrade).
6. 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. For example:

- 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.
- The Pascal (the 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.
- There are 100 centimeters in one meter.
- There are 1,000 meters in one kilometer.

| 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 |

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**Figure 1–24. Names and symbols for metric prefixes.**

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's 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.
- One kilogram equals 1,000 grams.

Micro is the prefix for one millionth.

- One meter equals one million micrometers.
- One gram equals one million micrograms.

This concept is shown in figure 1–24.

### Conversion of metric to conventional

People tend to resist changes, usually because they don't understand either the purpose of the change or the new order. Terminology for customary units and metric units have been discussed. In addition, a conversion table also has been included (fig. 1–25).

| | 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 |
| TEMPER-ATURE | 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.**

Four examples of its use are as follows:

1. To convert inches to millimeters, multiply the number of inches by 25. (25 into mm. = 25 × 25 = 625 mm.)
2. To convert millimeters to inches multiply millimeters by .04. (625 mm. × .04 = 25 in.)
3. To convert square inches to square centimeters multiply by 6.5. (100 sq. in. × 6.5 = 650 sq. cm.)
4. To convert square centimeters to square inches multiply by .16. (100 ×.16 = 16 sq. in.)

## 012. Functions of numbers

A Functions of Numbers chart is shown in figures 1–26a and b. This chart is included in this unit for convenience in making computations. Familiarization with the various parts of this chart will illustrate the advantages of using "ready-made" computations.

We'll cover the following seven "ready-made" computations:

1. Numbers.
2. Square.
3. Cube.
4. Square root.
5. Cube root.
6. Circumference of a circle.
7. Area of a circle.

### Numbers

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

### Square

Square is the product obtained by multiplying a number by itself. For example, 1 × 1 = 1, 2 × 2 = 4, 17 × 17 = 289.

Squaring may be considered a special form of area computation. For example, 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. For example, 1 × 1 × 1 = 1, 2 × 2 × 2 = 8, 13 × 13 × 13 = 2,197.

Cubing may be considered a specialized form of volume computation. For example, Volume = Length multiplied by Width by Height (V = L × W × H).

### Square root

Square root is the opposite of a "squared" number. The square root of a number is that number when multiplied by itself (squared) will produce the original or desired number: For example, the square root of 1 is 1, 1 × 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 when multiplied by itself (cubed) will produce the original or desired number. For example, the cube root of 1 is 1, 1 × 1 × 1 = 1. The cube root of 27 is 3, 3 × 3 × 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.

| 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 |

SI01 5133103

**Figure 1–26a. Functions of numbers.**

| 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 |

SI01 5133104

**Figure 1–26b. Functions of numbers (continued).**

### 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 ($\pi$). 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 $(\pi) \text{ x } r^2 = a$, ($\pi$) 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 that has a diameter of 2. Another example, diameter = 4, radius=2. $3.1416 \times 2^2 = 3.1416 \times 4 = 12.5664$ square units.

## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

### 004. Ratios

1. If the cruising speed of an airplane is 400 knots and its maximum speed is 500 knots, what’s the ratio of cruising speed to maximum speed?

2. What’s the speed of a spur gear with 42 teeth driven by a pinion gear with 14 teeth turning 420 RPM?

### 005. Proportion

1. What’s the definition of a *proportion*?

2. What are the first and last terms of a proportion called?

### 006. Positive and negative numbers

1. When adding a positive and negative number together, how do you decide whether the answer is positive or negative?

2. When subtracting a positive and negative numbers, what must you do to the subtrahend?

**007. Powers and roots**

1. 8,019.0514 × 1/81 is equal to the square root of

   a. 9,108.

   b. 9,081.

   c. 9,801.

2. The number 3.47 × 10 to the negative fourth power is equal to

   a. .00347.

   b. 34,700.0.

   c. .000347.

3. What's the square root of 16 raised to the fourth power?

**008. Computing area**

1. Compute the area of a trapezoid: top 9 ft.; bottom 12 ft.; sides 5 ft.

**009. Computing volume of solids**

1. What size sheet of metal is required to fabricate a cylinder 20 inches long and 8 inches in diameter? (NOTE: C = pi × D)

2. Select the container size that will be equal in volume to 60 gallons of fuel. (7.5 gal = 1 cu. ft.)

   a. 7.5 cubic feet.

   b. 8.5 cubic feet.

   c. 8.0 cubic feet.

3. A four-cylinder aircraft engine has a cylinder bore of 3.78 inches and is 8.5 inches deep. With the piston on bottom center, the top of the piston measures 4.0 inches from the bottom of the cylinder. What's the approximate piston displacement of this engine?

**010. Graphs and charts**

1. What is a graph or chart?

2. (Refer to figure 1–27.) An aircraft reciprocating engine has a 1,830 cubic-inch displacement and develops 1,250 brake-horsepower at 2,500 RPM. What's the brake mean effective pressure of

   a. 217.

   b. 205.

   c. 225.

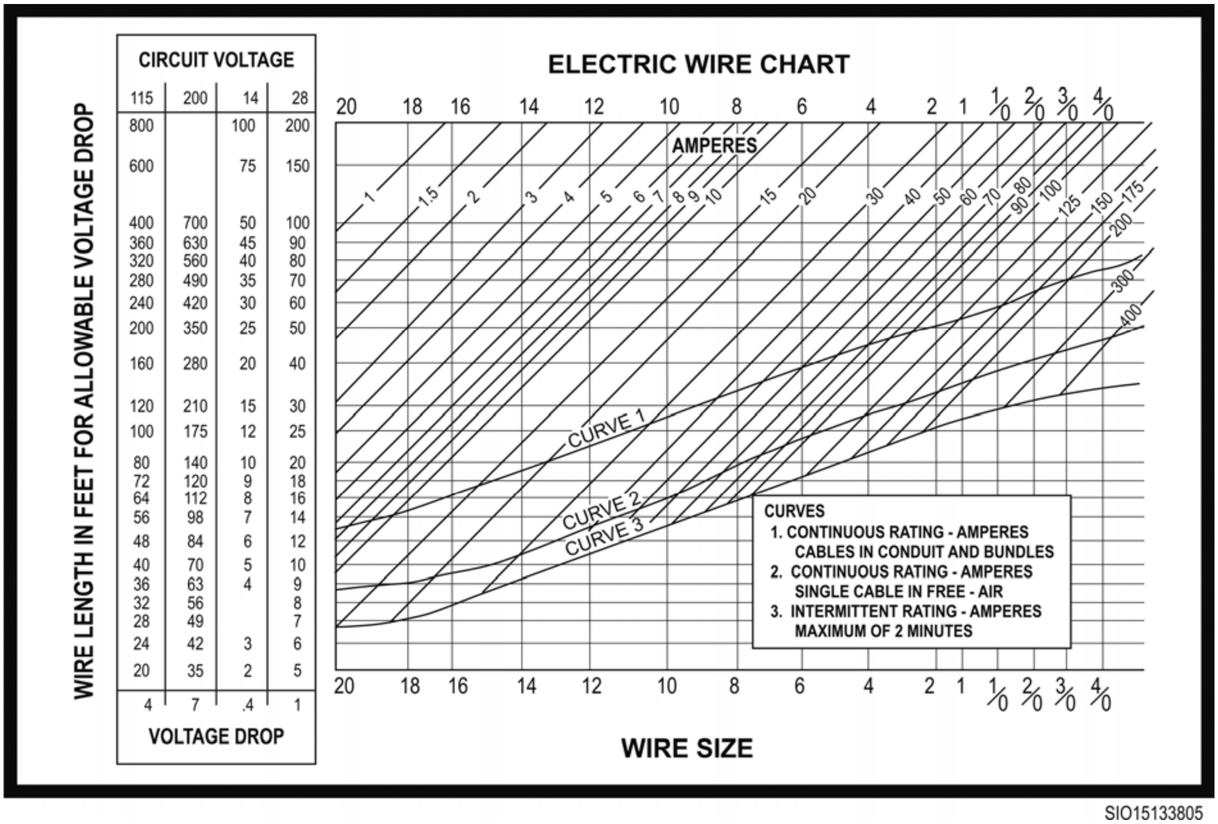


Figure 1–27. Electric wire chart.

3. (Refer to fig. 1–28.) An aircraft reciprocating engine has a 2,800 cubic-inch displacement and develops 2,000 brake-horsepower at 2,200 RPM. What’s the brake mean effective pressure?

   a. 275.0.

   b. 257.5.

   c. 242.5.

4. (Refer back to fig. 1–27.) Determine the maximum length of a no. 16 cable to be installed from a bus to the equipment in a 28-volt system with a 25-ampere intermittent load and a 1-volt drop.

   a. 12 feet.

   b. 10 feet.

   c. 8 feet.

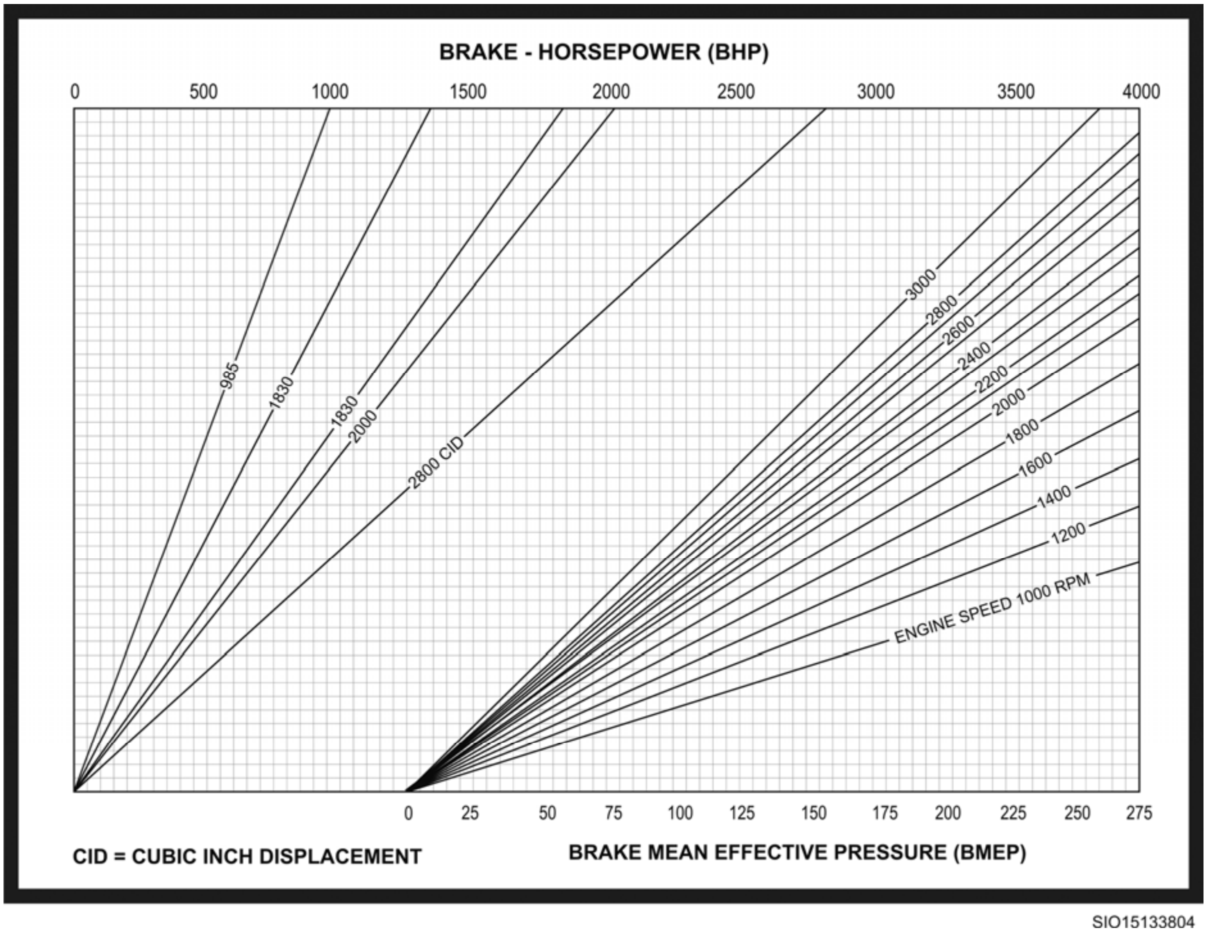


**Figure 1–28. Performance chart.**

**011. Measurement systems**

1. Why was the metric system originally designed?

2. What are the six basic units in the International Metric System?

**012. Functions of numbers**

1. Using the function of numbers chart, what's the area of a circle with a 43 inch diameter?

2. Using the function of numbers chart, what's the circumference of a 77-inch diameter circle?

## Answers to Self-Test Questions

**001**

1. –15.
2. 82.

**002**

1. The numerator.
2. 32.
3. 18 1/8
4. 17 1/8
5. 7/8

**003**

1. b. 39/32.

$$\begin{array}{r} .230 \\ \times .203 \\ \hline 690 \\ 0000 \\ 46000 \\ \hline 46690 \\ .046690 \end{array}$$

2. (see computation above)
3. Divide 5 by 6 = 0.83
4. Multiply 95 by .15 = 14.25

**004**

1. $R = \frac{400}{500}$

   $R = \frac{400}{500} = \frac{4}{5}$

   THEN: Express the result as a ratio of one.

   $R = \frac{4}{5}, or .8:1$

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

   $42 \div \frac{14}{420} =$

   NEXT: Perform the indicated operation.

   $42 \div \frac{14}{420} =$

   $42 \times \frac{420}{14} =$ Simplifies to $3 \times 420 = 1260$ RPM

**005**

1. A proportion is the statement of equality between two or more ratios.
2. The extremes.

**006**

1. Find the difference between the two and give the difference sign (+ or -) of the larger.
2. Change the sign and proceed as in addition.

**007**

1. c. 9,801.
2. c. .000347.
3. $16 \times 16 \times 16 \times 16 = 256$.

**008**

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

   $A = \frac{1}{2}(9 + 12)5$

   NEXT: Solve the formula for the unknown value.

   $A = \frac{1}{2}(21)5$

   $A = \frac{1}{2} \times 110$

   $A = 55$

**009**

1. $A = \pi\, dh$

   $A = 3.1416 \times 8 \times 20$

   $A = 502.656$

   Next solve for other side of sheet of metal. Since one side must be 20 use the formula for the area of a rectangle.

   $A = L \times W$

   $502.656 = 20 \times W$

   $502.656 = 20 \times W$

   $W = 25.1328$

   This will make the size of the sheet metal = 20″ × 25 9/64″.
2. c. $C = 60 \div 7.5 = 8.0$ cubic feet.
3. Determine stroke (distance traveled) by subtracting 4 from 8.5

   $V = \pi r^2 h$

   $V = (3.1416)(1.89^2)(4.5)$

   $V = 16.07445$

   Now the volume of one cylinder must be multiplied by 4 to find engine displacement.

   Displacement = 64.2978

**010**

1. A pictorial presentation of data, equations, and formulas.
2. a. 217.
3. b. 257.5.
4. c. 8 feet.

**011**

1. To meet the needs of scientists and engineers.
2. Meter, kilogram, second, ampere, Kelvin, and candela.

**012**

1. 1,452.20 square inches.
2. 24.90 inches.

**Complete the unit review exercises before going to the next unit.**

## Unit Review Exercises

**Note to Student:** Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to ECI (AFIADL) Form 34, Field Scoring Answer Sheet.

**Do not return your answer sheet to AFIADL.**

1. (001) Solve the equation. 6[9(8+4) – 2 (7 + 3)] =
   a. 428.
   b. 450.
   c. 528.
   d. 550.

2. (001) Solve the equation. (3 + 2) x (12 - 4) + (4 + 6) x 2 =
   a. 96.
   b. 98.
   c. 100.
   d. 106.

3. (002) Solve the equation. (32 x 3/8) [divided by] 1/6 =
   a. 72.
   b. 52.
   c. 12.
   d. 8.

4. (002) What must be done to a mixed number before it can be added, subtracted, multiplied, or divided?
   a. Nothing.
   b. Multiply the equation by negative one.
   c. It must be changed to improper fractions.
   d. Subtract the numerator from the denominator.

5. (003) Select the fraction, which is equal to .020
   a. 2/5.
   b. 1/5.
   c. 1/50.
   d. 2/50.

6. (003) The parts department’s profit on a new part is 12 percent. How much does the part cost if the selling price is $145.60?
   a. $125.60.
   b. $128.12.
   c. $130.00.
   d. $131.50.

7. (003) An engine of 98 horsepower maximum is running at 75 percent power. What is the horsepower being developed?
   a. 33.30.
   b. 35.30.
   c. 73.50.
   d. 87.00.

8. (003) Sixty-five engines are what percent of 80 engines?
   a. 52%.
   b. 65%.
   c. 81%.
   d. 87%.

9. (004) Recently, 27 engines were removed with an average life of 639 hours, or 71 percent of their maximum engine life. What is the ratio of average engine life to maximum engine life?
   a. 639:23.7
   b. 639:27
   c. 639:453.7
   d. 639:900

10. (005) A pinion gear with 14 teeth is driving a spur gear with 42 teeth at 140 RPM. Determine the speed of the pinion gear.
    a. 620 RPM.
    b. 588 RPM.
    c. 420 RPM.
    d. 240 RPM.

11. (006) What does the equation negative two divided by a negative 4 equal?
    a. –1/2.
    b. 1/2.
    c. –2.
    d. 2.

12. (006) What does the equation negative two divided by a positive 4 equal?
    a. –1/2.
    b. 1/2.
    c. –2.
    d. 2.

13. (007) What power of 10 is equal to 1,000,000?
    a. 10 to the fourth power.
    b. 10 to the seventh power.
    c. 10 to the sixth power.
    d. 10 to the fifth power.

14. (007) What is the square root of 4 raised to the fifth power??
    a. 32.
    b. 20.
    c. 64.
    d. 48.

15. (007) Which alternative answer is equal to 16,300?
    a. 163 x 10 to the fifth power.
    b. 1.63 x 10 to the fourth power.
    c. 1.63 x 10 to the negative third power.
    d. 163 x 10 to the negative second power.

16. (008) What is the circumference of a circle with a diameter of 6 inches?
    a. 18.5.
    b. 18.8.
    c. 19.5.
    d. 19.8.

17. (009) A rectangular-shaped fuel tank measures 60 inches in length, 30 inches in width, and 12 inches in depth. How many cubic feet are within the tank?
    a. 12.5.
    b. 15.0.
    c. 21.0.
    d. 18.0.

18. (009) A rectangular-shaped fuel tank measures 27 1/2 inches in length, 3/4 foot in width, and 8 1/4 inches in depth. How many gallons will the tank contain? (231 cu. in. = 1 gal.)
    a. 7.86.
    b. 8.80.
    c. 9.80.
    d. 10.9.

19. (009) A six-cylinder engine with a bore of 3.5 inches, a cylinder height of 7 inches and a stroke of 4.5 inches will have a total piston displacement of how much?
    a. 43.3 cubic inches.
    b. 259.77 cubic inches.
    c. 256.88 cubic inches.
    d. 53.4 cubic inches.

20. (010) What is the most useful of these graphs in technical work according to the text?
    a. Bar chart.
    b. Pie chart.
    c. Continuous straight-line graph.
    d. Continuous curved-line graph.

21. (011) What is the unit of temperature in the metric system?
    a. Fahrenheit.
    b. Candela.
    c. Kelvin.
    d. Joules.

22. (011) How is a Pascal defined?
    a. One Newton per square inch.
    b. One Newton per square meter.
    c. One inch divided by one Newton per square meter.
    d. One meter divided by one Newton per square meter.

23. (012) Find the square root of 3,722.1835.
    a. 61.00.
    b. 61.0097.
    c. 61.00971.
    d. 61.000097.

24. (012) Find the cube root of 64.
    a. 4.
    b. 8.
    c. 192.
    d. 262,144.

**Please read the unit menu for unit 2 and continue ➔**