Mathematics in Aviation Maintenance

Mathematics is woven into many areas of everyday life. Performing mathematical calculations with success requires an understanding of the correct methods and procedures, and practice and review of these principles. Mathematics may be thought of as a set of tools. The aviation mechanic will need these tools to successfully complete the maintenance, repair, installation, or certification of aircraft equipment.

Many examples of using mathematical principles by the aviation mechanic are available. Tolerances in turbine engine components are critical, making it necessary to measure within a ten-thousandth of an inch. Because of these close tolerances, it is important that the aviation mechanic be able to make accurate measurements and mathematical calculations. An aviation mechanic working on aircraft fuel systems will also use mathematical principles to calculate volumes and capacities of fuel tanks. The use of fractions and surface area calculations are required to perform sheet metal repair on aircraft structures.

Whole Numbers

Whole numbers are the numbers 0, 1, 2, 3, 4, 5, and so on.

Addition of Whole Numbers

Addition is the process in which the value of one number is added to the value of another. The result is called the sum. When working with whole numbers, it is important to understand the principle of the place value. The place value in a whole number is the value of the position of the digit within the number. For example, in the number 512, the 5 is in the hundreds column, the 1 is in the tens column, and the 2 is in the ones column. The place values of three whole numbers are shown in Figure 1-1.

<table>
<thead>
<tr>
<th>Ten Thousands</th>
<th>Thousands</th>
<th>Hundreds</th>
<th>Tens</th>
<th>Ones</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 shown as</td>
<td></td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>269 shown as</td>
<td></td>
<td>2</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>12,749 shown as</td>
<td></td>
<td>1</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

Figure 1-1. Example of place values of whole numbers.

When adding several whole numbers, such as 4,314, 122, 93,132, and 10, align them into columns according to place value and then add.

\[
\begin{align*}
4,314 \\
122 \\
93,132 \\
+ 10 \\
\hline
97,578
\end{align*}
\]

This is the sum of the four whole numbers.

Subtraction of Whole Numbers

Subtraction is the process in which the value of one number is taken from the value of another. The answer is called the difference. When subtracting two whole numbers, such as 3,461 from 97,564, align them into columns according to place value and then subtract.

\[
\begin{align*}
97,564 \\
-3,461 \\
\hline
94,103
\end{align*}
\]

This is the difference of the two whole numbers.

Multiplication of Whole Numbers

Multiplication is the process of repeated addition. For example, \(4 \times 3\) is the same as \(4 + 4 + 4\). The result is called the product.

Example: How many hydraulic system filters are in the supply room if there are 35 cartons and each carton contains 18 filters?
Therefore, there are 630 filters in the supply room.

**Division of Whole Numbers**

Division is the process of finding how many times one number (called the divisor) is contained in another number (called the dividend). The result is the quotient, and any amount left over is called the remainder.

Example: 218 landing gear bolts need to be divided between 7 aircraft. How many bolts will each aircraft receive?

\[
\begin{array}{c|c|c|c}
\text{dividend} & 7 & 218 \\
\hline
\text{divisor} & 18 & 35 \\
\hline
\text{quotient} & 31 & 21 \\
\end{array}
\]

The solution is 31 bolts per aircraft with a remainder of 1 bolt left over.

**Fractions**

A fraction is a number written in the form \( \frac{N}{D} \) where \( N \) is called the numerator and \( D \) is called the denominator. The fraction bar between the numerator and denominator shows that division is taking place.

Some examples of fractions are: \( \frac{17}{18}, \frac{2}{3}, \frac{5}{8} \)

The denominator of a fraction cannot be a zero. For example, the fraction \( \frac{2}{0} \) is not allowed. An improper fraction is a fraction in which the numerator is equal to or larger than the denominator. For example, \( \frac{4}{4} \) or \( \frac{15}{8} \) are examples of improper fractions.

**Finding the Least Common Denominator**

To add or subtract fractions, they must have a common denominator. In math, the least common denominator (LCD) is commonly used. One way to find the LCD is to list the multiples of each denominator and then choose the smallest one that they have in common.

Example: Add \( \frac{1}{7} \) to \( \frac{3}{7} \)

\[
\frac{1}{7} + \frac{3}{7} = \frac{1+3}{7} = \frac{4}{7}
\]

If the fractions do not have the same denominator, then one or all of the denominators must be changed so that every fraction has a common denominator.

Example: Find the total thickness of a panel made from \( \frac{3}{32} \)-inch thick aluminum, which has a paint coating that is \( \frac{1}{64} \)-inch thick. To add these fractions, determine a common denominator. The least common denominator for this example is 1, so only the first fraction must be changed since the denominator of the second fraction is already 64.

\[
\left( \frac{3}{32} + \frac{1}{64} \right) = \left( \frac{3 \times 2}{32 \times 2} + \frac{1}{64} \right) = \left( \frac{6}{64} + \frac{1}{64} \right) = \frac{6 + 1}{64} = \frac{7}{64}
\]

Therefore, \( \frac{7}{64} \) is the total thickness.

**Subtraction of Fractions**

In order to subtract fractions, they must have a common denominator.

Example: Subtract \( \frac{2}{17} \) from \( \frac{10}{17} \)

\[
\frac{10}{17} - \frac{2}{17} = \frac{10 - 2}{17} = \frac{8}{17}
\]
If the fractions do not have the same denominator, then one or all of the denominators must be changed so that every fraction has a common denominator.

Example: The tolerance for rigging the aileron droop of an airplane is \( \frac{7}{8} \) inch \( \pm \frac{1}{5} \) inch. What is the minimum droop to which the aileron can be rigged? To subtract these fractions, first change both to common denominators. The common denominator in this example is 40. Change both fractions to \( \frac{1}{40} \), as shown, then subtract.

\[
\left( \frac{7}{8} - \frac{1}{5} \right) = \left( \frac{7 \times 5 - 1 \times 8}{5 \times 8} \right) = \left( \frac{35 - 8}{40} \right) = \frac{27}{40}
\]

Therefore, \( \frac{27}{40} \) is the minimum droop.

**Multiplication of Fractions**

Multiplication of fractions does not require a common denominator. To multiply fractions, first multiply the numerators. Then, multiply the denominators.

Example:

\[
\frac{3}{5} \times \frac{7}{8} \times \frac{1}{2} = \frac{3 \times 7 \times 1}{5 \times 8 \times 2} = \frac{21}{80}
\]

The use of cancellation when multiplying fractions is a helpful technique which divides out or cancels all common factors that exist between the numerators and denominators. When all common factors are cancelled before the multiplication, the final product will be in lowest terms.

Example:

\[
\left( \frac{14}{15} \times \frac{3}{7} \right) = \frac{2}{5} \times \frac{1}{1} = \frac{2\times 1}{5 \times 1} = \frac{2}{5}
\]

**Division of Fractions**

Division of fractions does not require a common denominator. To divide fractions, first change the division symbol to multiplication. Next, invert the second fraction. Then, multiply the fractions.

Example: Divide \( \frac{7}{8} \) by \( \frac{4}{3} \)

\[
\left( \frac{7}{8} \div \frac{4}{3} \right) = \left( \frac{7}{8} \times \frac{3}{4} \right) = \frac{21}{32}
\]

Example: In Figure 1-2, the center of the hole is in the center of the plate. Find the distance that the center of the hole is from the edges of the plate. To find the answer, the length and width of the plate should each be divided in half. First, change the mixed numbers to improper fractions:

\[
1 \frac{3}{16} \quad 5 \frac{7}{16}
\]

Then, divide each improper fraction by 2 to find the center of the plate.

\[
\frac{87}{16} \div 2 = \frac{87}{16} \times \frac{1}{2} = \frac{87}{32} \quad \text{inches}
\]

\[
\frac{29}{8} \div 2 = \frac{29}{8} \times \frac{1}{2} = \frac{29}{16} \quad \text{inches}
\]

Finally, convert each improper fraction to a mixed number:

\[
\frac{87}{32} = 87 \div 32 = 2 \frac{23}{32} \quad \text{inches}
\]

\[
\frac{29}{16} = 29 \div 16 = 1 \frac{13}{16} \quad \text{inches}
\]

Therefore, the distance to the center of the hole from each of the plate edges is \( 2 \frac{23}{32} \) inches and \( 1 \frac{13}{16} \) inches.

**Reducing Fractions**

A fraction needs to be reduced when it is not in “lowest terms.” Lowest terms means that the numerator and denominator do not have any factors in common. That is, they cannot be divided by the same number (or factor). To reduce a fraction, determine what the common factor(s) are and divide these out of the numerator and denominator. For example when both the numerator and denominator are even numbers, they can both be divided by 2.

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

\[
\frac{13}{16} - \frac{7}{16} = \frac{13 - 7}{16} = \frac{6}{16}
\]
The fraction \( \frac{6}{16} \) is not in lowest terms because the numerator (6) and the denominator (16) have a common factor of 2. To reduce \( \frac{6}{16} \), divide the numerator and the denominator by 2. The final reduced fraction is \( \frac{3}{8} \) as shown below.

\[
\frac{6}{16} = \frac{6 \div 2}{16 \div 2} = \frac{3}{8}
\]

Therefore, the travel in the opposite direction is \( \frac{3}{8} \) inch.

**Mixed Numbers**

A mixed number is a combination of a whole number and a fraction.

**Addition of Mixed Numbers**

To add mixed numbers, add the whole numbers together. Then add the fractions together by finding a common denominator. The final step is to add the sum of the whole numbers to the sum of the fractions for the final result.

Example: The cargo area behind the rear seat of a small airplane can handle solids that are \( 4\frac{3}{4} \) feet long. If the rear seats are removed, then \( 2\frac{1}{2} \) feet is added to the cargo area. What is the total length of the cargo area when the rear seats are removed?

\[
4 \frac{3}{4} + 2 \frac{1}{2} = (4 + 2) + \left( \frac{3}{4} + \frac{1}{2} \right) = 6 + \left( \frac{9}{12} + \frac{4}{12} \right) = 6 \frac{13}{12} = 7 \frac{1}{12} \text{ feet of cargo room.}
\]

**Subtraction of Mixed Numbers**

To subtract mixed numbers, find a common denominator for the fractions. Subtract the fractions from each other (it may be necessary to borrow from the larger whole number when subtracting the fractions). Subtract the whole numbers from each other. The final step is to combine the final whole number with the final fraction.

Example: What is the length of the grip of the bolt shown in Figure 1-3? The overall length of the bolt is \( 3\frac{1}{2} \) inches, the shank length is \( 3\frac{1}{8} \) inches, and the threaded portion is \( 1\frac{5}{16} \) inches long. To find the grip, subtract the length of the threaded portion from the length of the shank.

\[
3\frac{1}{8} \text{ inches} - 1\frac{5}{16} \text{ inches} = \text{grip length}
\]

To subtract, start with the fractions. Borrowing will be necessary because \( \frac{5}{16} \) is larger than \( \frac{1}{8} \) (or \( \frac{2}{16} \)). From the whole number 3, borrow 1, which is actually \( \frac{16}{16} \). After borrowing, the first mixed number will now be

\[
2 \frac{18}{16}. \quad (\text{Because, } 3\frac{1}{8} = 3\frac{2}{16} = 2 + \frac{2}{16} = 2 + \frac{16}{16} = 2\frac{18}{16}.)
\]

\[
3 \frac{1}{8} - 1 \frac{5}{16} = 3 \frac{2}{16} - 1 \frac{5}{16} = 2 \frac{18}{16} - 1 \frac{5}{16} = 1 \frac{13}{16}
\]

Therefore, the grip length of the bolt is \( 1\frac{13}{16} \) inches.

(Note: The value for the overall length of the bolt was given in the example, but it was not needed to solve the problem. This type of information is sometimes referred to as a “distracter” because it distracts from the information needed to solve the problem.)

**The Decimal Number System**

**The Origin and Definition**

The number system that we use every day is called the decimal system. The prefix in the word decimal is a Latin root for the word “ten.” The decimal system probably had its origin in the fact that we have ten fingers (or digits). The decimal system has ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. It is a base 10 system and has been in use for over 5,000 years. A decimal is a number with a decimal point. For example, 0.515, .10, and 462.625 are all decimal numbers. Like whole numbers, decimal numbers also have place value. The place values are based on powers of 10, as shown in Figure 1-4.
Addition of Decimal Numbers

To add decimal numbers, they must first be arranged so that the decimal points are aligned vertically and according to place value. That is, adding tenths with tenths, ones with ones, hundreds with hundreds, and so forth.

Example: Find the total resistance for the circuit diagram shown in Figure 1-5. The total resistance of a series circuit is equal to the sum of the individual resistances. To find the total resistance, \( R_T \), the individual resistances are added together.

\[
R_T = 2.34 + 37.5 + .09
\]

Arrange the resistance values in a vertical column so that the decimal points are aligned and then add.

\[
\begin{align*}
2.34 \\
37.5 \\
+.09 \\
\hline
39.93
\end{align*}
\]

Therefore, the total resistance, \( R_T = 39.93 \) ohms.

Subtraction of Decimal Numbers

To subtract decimal numbers, they must first be arranged so that the decimal points are aligned vertically and according to place value. That is, subtracting tenths from tenths, ones from ones, hundreds from hundreds, and so forth.

Example: A series circuit containing two resistors has a total resistance \( (R_T) \) of 37.272 ohms. One of the resistors \( (R_1) \) has a value of 14.88 ohms. What is the value of the other resistor \( (R_2) \)?

\[
R_2 = R_T - R_1 = 37.272 - 14.88
\]

Arrange the decimal numbers in a vertical column so that the decimal points are aligned and then subtract.

\[
\begin{align*}
37.272 \\
-14.88 \\
\hline
22.392
\end{align*}
\]

Therefore, the second resistor, \( R_2 = 22.392 \) ohms.

Multiplication of Decimal Numbers

To multiply decimal numbers, vertical alignment of the decimal point is not required. Instead, align the numbers to the right in the same way as whole numbers are multiplied (with no regard to the decimal points or place values) and then multiply. The last step is to place the decimal point in the correct place in the answer. To do this, “count” the number of decimal places in each of the numbers, add the total, and then “give” that number of decimal places to the result.

Example: To multiply 0.2 \times 6.03, arrange the numbers vertically and align them to the right. Multiply the numbers, ignoring the decimal points for now.

\[
\begin{align*}
6.03 \\
\times 0.2 \\
\hline
1206 \ (\text{ignore the decimal points, for now})
\end{align*}
\]

After multiplying the numbers, count the total number of decimal places in both numbers. For this example, 6.03 has 2 decimal places and 0.2 has 1 decimal place. Together there are a total of 3 decimal places. The decimal point for the answer will be placed 3 decimal places from the right. Therefore, the answer is 1.206.

\[
\begin{align*}
6.03 & \quad \text{2 decimal places} \\
\times 0.2 & \quad \text{1 decimal place} \\
\hline
1.206 & \quad \text{3 decimal places}
\end{align*}
\]

Example: Using the formula \( \text{Watts} = \text{Amperes} \times \text{Voltage} \), what is the wattage of an electric drill that uses 9.45 amperes from a 120 volt source? Align the numbers to the right and multiply.

After multiplying the numbers, count the total number of decimal places in both numbers. For this example, 9.45 has 2 decimal places and 120 has no decimal place. Together there are 2 decimal places. The decimal point for the answer will be placed 2 decimal places from
the right. Therefore, the answer is 1,134.00 watts, or 1,134 watts.

\[
\begin{array}{c}
9.45 \\
\times \quad 120 \\
\hline
1890 \\
945 \\
\hline
1,134.00
\end{array}
\]

\[\text{2 decimal places}\]

**Division of Decimal Numbers**

Division of decimal numbers is performed the same way as whole numbers, unless the divisor is a decimal.

When the divisor is a decimal, it must be changed to a whole number before dividing. To do this, move the decimal in the divisor to the right until there are no decimal places. At the same time, move the decimal point in the dividend to the right the same number of places. Then divide. The decimal in the quotient will be placed directly above the decimal in the dividend.

**Example:** Divide 0.144 by 0.12

\[
\begin{array}{c}
.12 \overline{)0.144} \\
\hline
12 \\
12 \\
\hline
24 \\
24 \\
\hline
0
\end{array}
\]

Move the decimal in the divisor (0.12) two places to the right. Next move the decimal in the dividend (0.144) two places to the right. Then divide. The result is 1.2.

**Example:** The wing area of an airplane is 262.6 square feet and its span is 40.4 feet. Find the mean chord of its wing using the formula: Area ÷ span = mean chord.

\[
\begin{array}{c}
40.4 \overline{)262.6} \\
\hline
2424 \\
2020 \\
\hline
2020 \\
0
\end{array}
\]

Move the decimal in the divisor (40.4) one place to the right. Next move the decimal in the dividend (262.6) one place to the right. Then divide. The mean chord length is 6.5 feet.

**Rounding Off Decimal Numbers**

Occasionally, it is necessary to round off a decimal number to some value that is practical to use.

For example, a measurement is calculated to be 29.4948 inches. To use this measurement, we can use the process of “rounding off.” A decimal is “rounded off” by keeping the digits for a certain number of places and discarding the rest. 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 5 or greater, round up 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:** The wing area of an airplane is 262.6 square feet and its span is 40.4 feet. Find the mean chord of its wing using the formula: Area ÷ span = mean chord.

\[
\begin{array}{c}
40.4 \overline{)262.6} \\
\hline
2424 \\
2020 \\
\hline
2020 \\
0
\end{array}
\]

Move the decimal in the divisor (40.4) one place to the right. Next move the decimal in the dividend (262.6) one place to the right. Then divide. The mean chord length is 6.5 feet.

**Converting Decimal Numbers to Fractions**

To change a decimal number to a fraction, “read” the decimal, and then write it into a fraction just as it is read as shown below.

**Example:** One oversized rivet has a diameter of 0.52 inches. Convert 0.52 to a fraction. The decimal 0.52 is read as “fifty-two hundredths.”

Therefore,

\[
0.52 = \frac{52}{100} \quad \text{“fifty-two” \ \text{“hundredths”}}
\]

A dimension often appears in a maintenance manual or on a blueprint as a decimal instead of a fraction. In order to use the dimension, it may need to be converted
to a fraction. An aviation mechanic frequently uses a steel rule that is calibrated in units of \(\frac{1}{64}\) of an inch. To change a decimal to the nearest equivalent common fraction, multiply the decimal by 64. The product of the decimal and 64 will be the numerator of the fraction and 64 will be the denominator. Reduce the fraction, if needed.

Example: The width of a hex head bolt is 0.3123 inches. Convert the decimal 0.3123 to a common fraction to decide which socket would be the best fit for the bolt head. First, multiply the 0.3123 decimal by 64:

\[0.3123 \times 64 = 19.9872\]

Next, round the product to the nearest whole number: 19.98722 \(\approx\) 20.

Use this whole number (20) as the numerator and 64 as the denominator: \(\frac{20}{64}\).

Now, reduce \(\frac{20}{64}\) to \(\frac{5}{16}\).

Therefore, the correct socket would be the \(\frac{5}{16}\) inch socket (\(\frac{20}{64}\) reduced).

Example: When accurate holes of uniform diameter are required for aircraft structures, they are first drilled approximately \(\frac{1}{64}\) inch undersized and then reamed to the final desired diameter. What size drill bit should be selected for the undersized hole if the final hole is reamed to a diameter of 0.763 inches? First, multiply the 0.763 decimal by 64.

\[0.763 \times 64 = 48.832\]

Next, round the product to the nearest whole number: 48.832 \(\approx\) 49.

Use this number (49) as the numerator and 64 as the denominator: \(\frac{49}{64}\). This decimal can be represented with bar, or can be rounded. (A bar indicates that the number(s) beneath it are repeated to infinity.)

\[\frac{49}{64} = 0.763 \approx \frac{3}{4}\]

Therefore, a \(\frac{3}{4}\)-inch drill bit should be used for the initial undersized holes.

Converting Fractions to Decimals

To convert any fraction to a decimal, simply divide the top number (numerator) by the bottom number (denominator). Every fraction will have an approximate decimal equivalent.

Example:

\[\frac{1}{2} = 1 \div 2 = \frac{1.0}{2}\]

Therefore, \(\frac{1}{2} = .5\)

\[\frac{3}{8} = 3 \div 8 = \frac{3.75}{8}\]

Therefore, \(\frac{3}{8} = .375\)

Decimal Equivalent Chart

Figure 1-6 (on the next page) is a fraction to decimal to millimeter equivalency chart. Measurements starting at \(\frac{1}{64}\) inch and up to 23 inches have been converted to decimal numbers and to millimeters.

Ratio

A ratio is the comparison of two numbers or quantities. A ratio may be expressed in three ways: as a fraction, with a colon, or with the word “to.” For example, a gear ratio of 5:7 can be expressed as any of the following:

\(\frac{5}{7}\) or 5:7 or 5 to 7
<table>
<thead>
<tr>
<th>Fraction</th>
<th>Decimal</th>
<th>Millimeters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/64</td>
<td>0.015</td>
<td>0.396</td>
</tr>
<tr>
<td>1/32</td>
<td>0.031</td>
<td>0.793</td>
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<tr>
<td>3/64</td>
<td>0.046</td>
<td>1.190</td>
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<td>0.062</td>
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<td>0.140</td>
<td>3.571</td>
</tr>
<tr>
<td>5/32</td>
<td>0.156</td>
<td>3.968</td>
</tr>
<tr>
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<td>0.171</td>
<td>4.365</td>
</tr>
<tr>
<td>5/16</td>
<td>0.187</td>
<td>4.762</td>
</tr>
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<td>0.203</td>
<td>5.159</td>
</tr>
<tr>
<td>7/32</td>
<td>0.218</td>
<td>5.556</td>
</tr>
<tr>
<td>15/64</td>
<td>0.234</td>
<td>5.953</td>
</tr>
<tr>
<td>1/4</td>
<td>0.25</td>
<td>6.35</td>
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<td>17/64</td>
<td>0.265</td>
<td>6.746</td>
</tr>
<tr>
<td>9/32</td>
<td>0.281</td>
<td>7.143</td>
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<tr>
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<td>0.296</td>
<td>7.540</td>
</tr>
<tr>
<td>5/16</td>
<td>0.312</td>
<td>7.937</td>
</tr>
<tr>
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<td>0.328</td>
<td>8.334</td>
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<td>0.343</td>
<td>8.731</td>
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<td>23/64</td>
<td>0.359</td>
<td>9.128</td>
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<td>0.375</td>
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<td>0.390</td>
<td>9.922</td>
</tr>
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<td>13/32</td>
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<td>11.906</td>
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<td>12.7</td>
</tr>
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<td>13.096</td>
</tr>
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<td>13.493</td>
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<td>0.546</td>
<td>13.890</td>
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**Figure 1-6. Fractions, decimals, and millimeters.**
**Aviation Applications**

Ratios have widespread application in the field of aviation. For example:

Compression ratio on a reciprocating engine is the ratio of the volume of a cylinder with the piston at the bottom of its stroke to the volume of the cylinder with the piston at the top of its stroke. For example, a typical compression ratio might be 10:1 (or 10 to 1).

Aspect ratio is the ratio of the length (or span) of an airfoil to its width (or chord). A typical aspect ratio for a commercial airliner might be 7:1 (or 7 to 1).

Air-fuel ratio is the ratio of the weight of the air to the weight of fuel in the mixture being fed into the cylinders of a reciprocating engine. For example, a typical air-fuel ratio might be 14.3:1 (or 14.3 to 1).

Glide ratio is the ratio of the forward distance traveled to the vertical distance descended when an aircraft is operating without power. For example, if an aircraft descends 1,000 feet while it travels through the air for a distance of two linear miles (10,560 feet), it has a glide ratio of 10,560:1,000 which can be reduced to 10.56:1 (or 10.56 to 1).

Gear Ratio is the number of teeth each gear represents when two gears are used in an aircraft component. In Figure 1-7, the pinion gear has 8 teeth and a spur gear has 28 teeth. The gear ratio is 8:28 or 2:7.

Speed Ratio. When two gears are used in an aircraft component, the rotational speed of each gear is represented as a speed ratio. As the number of teeth in a gear decreases, the rotational speed of that gear increases, and vice-versa. Therefore, the speed ratio of two gears is the inverse (or opposite) of the gear ratio. If two gears have a gear ratio of 2:9, then their speed ratio is 9:2.

Example: A pinion gear with 10 teeth is driving a spur gear with 40 teeth. The spur gear is rotating at 160 rpm. Determine the speed of the pinion gear.

\[
\frac{\text{Teeth in Pinion Gear}}{\text{Teeth in Spur Gear}} = \frac{\text{Speed of Spur Gear}}{\text{Speed of Pinion Gear}}
\]

\[
\frac{10}{40} = \frac{160 \text{ rpm}}{S_p \text{ (speed of pinion gear)}}
\]

To solve for \(S_p\), multiply 40 \times 160, then divide by 10. The speed of the pinion gear is 640 rpm.

Example: If the cruising speed of an airplane is 200 knots and its maximum speed is 250 knots, what is the ratio of cruising speed to maximum speed? First, express the cruising speed as the numerator of a fraction whose denominator is the maximum speed.

\[
\frac{200}{250} = \frac{4}{5}
\]

Therefore, the ratio of cruising speed to maximum speed is 4:5.

Another common use of ratios is to convert any given ratio to an equivalent ratio with a denominator of 1.

Example: Express the ratio 9:5 as a ratio with a denominator of 1.

\[
\frac{9}{5} = \frac{9 \div 5}{5 \div 5} = \frac{1.8}{1}
\]

Therefore, 9:5 is the same ratio as 1.8:1. In other words, 9 to 5 is the same ratio as 1.8 to 1.

**Proportion**

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

\[
\frac{3}{4} = \frac{6}{8} \quad \text{or} \quad 3:4 = 6:8
\]

This proportion is read as, “3 is to 4 as 6 is to 8.”

**Extremes and Means**

The first and last terms of the proportion (the 3 and 8 in this example) are called the extremes. The second and third terms (the 4 and 6 in this example) 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, \(2 \times 6\), is 12; the product of the means, \(3 \times 4\), is also 12. An inspection of any proportion will show this to be true.
For example: Express the following percentages as decimal numbers:

- 90% = .90
- 50% = .50
- 5% = .05
- 150% = 1.5

Expressing a Fraction as a Percentage

To express a fraction as a percentage, first change the fraction to a decimal number (by dividing the numerator by the denominator), and then convert the decimal number to a percentage as shown earlier.

Example: Express the fraction \( \frac{5}{8} \) as a percentage.

\[
\frac{5}{8} = 5 \div 8 = 0.625 = 62.5\%
\]

Finding a Percentage of a Given Number

This is the most common type of percentage calculation. Here are two methods to solve percentage problems: using algebra or using proportions. Each method is shown below to find a percent of a given number.

Example: In a shipment of 80 wingtip lights, 15% of the lights were defective. How many of the lights were defective?

Algebra Method:

\[
15\% \text{ of } 80 \text{ lights} = N \text{ (number of defective lights)}
\]

\[
0.15 \times 80 = N
\]

\[
12 = N
\]

Therefore, 12 defective lights were in the shipment.

Proportion Method:

\[
\frac{N}{80} = \frac{15}{100}
\]

To solve for \( N \):

\[
N \times 100 = 80 \times 15
\]

\[
N \times 100 = 1200
\]

\[
N = 1200 \div 100
\]

\[
N = 12
\]

or

\[
N = (80 \times 15) \div 100
\]

\[
N = 12
\]

Finding What Percentage One Number Is of Another

Example: A small engine rated at 12 horsepower is found to be delivering only 10.75 horsepower. What is the motor efficiency expressed as a percent?
Addition of Positive and Negative Numbers

The sum (addition) of two positive numbers is positive. The sum (addition) of two negative numbers is negative. The sum of a positive and a negative number can be positive or negative, depending on the values of the numbers. A good way to visualize a negative number is to think in terms of debt. If you are in debt by $100 (or, \(-100\)) and you add $45 to your account, you are now only $55 in debt (or \(-55\)).

Therefore: \(-100 + 45 = -55\).

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

\[2,000 + -3 + -10 = 2,000 + -13 = 1987\]

Therefore, the new weight is 1,987 pounds.

Subtraction of Positive and Negative Numbers

To subtract positive and negative numbers, first change the “–” (subtraction symbol) to a “+” (addition symbol), and change the sign of the second number to its opposite (that is, change a positive number to a negative number or vice versa). Finally, add the two numbers together.

Example: The daytime temperature in the city of Denver was 6° below zero \((-6°\)). An airplane is cruising at 15,000 feet above Denver. The temperature at 15,000 feet is 20° colder than in the city of Denver. What is the temperature at 15,000 feet?

\[-6 - 20 = -6 + -20 = -26\]

The temperature is \(-26°\), or 26° below zero at 15,000 feet above the city.

Multiplication of Positive and Negative Numbers

The product of two positive numbers is always positive. The product of two negative numbers is always positive. The product of a positive and a negative number is always negative.
Examples:
3 \times 6 = 18 \quad -3 \times 6 = -18 \quad -3 \times -6 = 18 \quad 3 \times -6 = -18

**Division of Positive and Negative Numbers**
The quotient of two positive numbers is always positive. The quotient of two negative numbers is always positive. The quotient of a positive and negative number is always negative.

Examples:
6 \div 3 = 2 \quad -6 \div 3 = -2 \quad -6 \div -3 = 2 \quad 6 \div -3 = -2

**Powers**
The power (or exponent) of a number is a shorthand method of indicating how many times a number, called the base, is multiplied by itself. For example, 3^4 means “3 to the power of 4.” That is, 3 multiplied by itself 4 times. The 3 is the base and 4 is the power.

Examples:
2^3 = 2 \times 2 \times 2 = 8.
Read “two to the third power equals 8.”
10^5 = 10 \times 10 \times 10 \times 10 \times 10 = 100,000
Read “ten to the fifth power equals 100,000.”

**Special Powers**
Squared. When a number has a power of 2, it is commonly referred to as “squared.” For example, 7^2 is read as “seven squared” or “seven to the second power.” To remember this, think about how a square has two dimensions: length and width.

Cubed. When a number has a power of 3, it is commonly referred to as “cubed.” For example, 7^3 is read as “seven cubed” or “seven to the third power.” To remember this, think about how a cube has three dimensions: length, width, and depth.

Power of Zero. Any non-zero number raised to the zero power always equals 1.

Example:
7^0 = 1 \quad 181^0 = 1 \quad (-24)^0 = 1

**Negative Powers**
A number with a negative power equals its reciprocal with the same power made positive.

Example: The number 2^{-3} is read as “2 to the negative 3rd power,” and is calculated by:

\[ 2^{-3} = \frac{1}{2^3} = \frac{1}{2 \times 2 \times 2} = \frac{1}{8} \]

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**Figure 1-9. Powers of ten.**

When using a calculator to raise a negative number to a power, always place parentheses around the negative number (before raising it to a power) so that the entire number gets raised to the power.

**Law of Exponents**
When multiplying numbers with powers, the powers can be added as long as the bases are the same.

Example:
3^2 \times 3^4 = (3 \times 3) \times (3 \times 3 \times 3 \times 3) = 3 \times 3 \times 3 \times 3 \times 3 \times 3 = 3^6
or\ 3^2 \times 3^4 = 3^{2+4} = 3^6

When dividing numbers with powers, the powers can be subtracted as long as the bases are the same.

Example:
10^4 \div 10^2 = \frac{10 \times 10 \times 10 \times 10}{10 \times 10} = \frac{10 \times 10 \times 10}{10} = 10 \times 10 = 10^2
or\ 10^4 \div 10^2 = 10^{4-2} = 10^2

**Powers of Ten**
Because we use the decimal system of numbers, powers of ten are frequently seen in everyday applications. For example, scientific notation uses powers of ten. Also, many aircraft drawings are scaled to powers of ten. Figure 1-9 gives more information on the powers of ten and their values.

**Roots**
A root is a number that when multiplied by itself a specified number of times will produce a given number.
The two most common roots are the square root and the cube root. For more examples of roots, see the chart in Figure 1-10, Functions of Numbers (on page 1-14).

**Square Roots**

The square root of 25, written as $\sqrt{25}$, equals 5. That is, when the number 5 is squared (multiplied by itself), it produces the number 25. The symbol $\sqrt{\cdot}$ is called a radical sign. Finding the square root of a number is the most common application of roots. The collection of numbers whose square roots are whole numbers are called perfect squares. The first ten perfect squares are: 1, 4, 9, 16, 25, 36, 49, 64, 81, and 100. The square root of each of these numbers is 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, respectively.

For example, $\sqrt{36} = 6$ and $\sqrt{81} = 9$

To find the square root of a number that is not a perfect square, use either a calculator or the estimation method. A longhand method does exist for finding square roots, but with the advent of calculators and because of its lengthy explanation, it is no longer included in this handbook. The estimation method uses the knowledge of perfect squares to approximate the square root of a number.

Example: Find the square root of 31. Since 31 falls between the two perfect roots 25 and 36, we know that $\sqrt{31}$ must be between $\sqrt{25}$ and $\sqrt{36}$. Therefore, $\sqrt{31}$ must be greater than 5 and less than 6 because $\sqrt{25} = 5$ and $\sqrt{36} = 6$. If you estimate the square root of 31 at 5.5, you are close to the correct answer. The square root of 31 is actually 5.668.

**Cube Roots**

The cube root of 125, written as $\sqrt[3]{125}$, equals 5. That is, when the number 5 is cubed (5 multiplied by itself then multiplying the product (25) by 5 again), it produces the number 125. It is common to confuse the “cube” of a number with the “cube root” of a number. For clarification, the cube of 27 is $27^3 = 27 \times 27 \times 27 = 19,683$. However, the cube root of 27 is $\sqrt[3]{27} = 3$.

**Fractional Powers**

Another way to write a root is to use a fraction as the power (or exponent) instead of the radical sign. The square root of a number is written with a $^{\frac{1}{2}}$ as the exponent instead of a radical sign. The cube root of a number is written with an exponent of $^{\frac{1}{3}}$ and the fourth root with an exponent of $^{\frac{1}{4}}$ and so on.

Example: $\sqrt[3]{31} = 31^{\frac{1}{3}}$ $\sqrt[3]{125} = 125^{\frac{1}{3}}$ $\sqrt[4]{16} = 16^{\frac{1}{4}}$ $\sqrt[3]{27} = 27^{\frac{1}{3}}$

**Scientific Notation**

Scientific notation is used as a type of shorthand to express very large or very small numbers. It is a way to write numbers so that they do not take up as much space on the page. The format of a number written in scientific notation has two parts. The first part is a number greater than or equal to 1 and less than 10 (for example, 2.35). The second part is a power of 10 (for example, $10^6$). The number 2,350,000 is expressed in scientific notation as $2.35 \times 10^6$. It is important that the decimal point is always placed to the right of the first digit. Notice that very large numbers always have
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<th>Cube Root of N (N^(1/3))</th>
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Figure 1-10. Functions of numbers.
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**Figure 1-10. Functions of numbers. (continued)**
When converting, remember that large numbers always have positive powers of ten and small numbers always have negative powers of ten. Refer to Figure 1-11 to determine which direction to move the decimal point.

**Addition, Subtraction, Multiplication, and Division of Scientific Numbers**

To add, subtract, multiply, or divide numbers in scientific notation, change the scientific notation number back to standard notation. Then add, subtract, multiply or divide the standard notation numbers. After the computation, change the final standard notation number back to scientific notation.

**Algebra**

Algebra is the branch of mathematics that uses letters or symbols to represent variables in formulas and equations.

For example, in the equation \( D = V \times T \), where Distance = Velocity \( \times \) Time, the variables are: \( D \), \( V \), and \( T \).

**Equations**

Algebraic equations are frequently used in aviation to show the relationship between two or more variables. Equations normally have an equals sign (=) in the expression.

Example: The formula \( A = \pi \times r^2 \) shows the relationship between the area of a circle (\( A \)) and the length of the radius (\( r \)) of the circle. The area of a circle is equal to \( \pi \) (3.1416) times the radius squared. Therefore, the larger the radius, the larger the area of the circle.

**Algebraic Rules**

When solving for a variable in an equation, you can add, subtract, multiply or divide the terms in the equation, you do the same to both sides of the equals sign.
Examples: Solve the following equations for the value N.

3N = 21
To solve for N, divide both sides by 3.
3N ÷ 3 = 21 ÷ 3
N = 7

N + 17 = 59
To solve for N, subtract 17 from both sides.
N + 17 – 17 = 59 – 17
N = 42

N – 22 = 100
To solve for N, add 22 to both sides.
N – 22 + 22 = 100 + 22
N = 122

N/5 = 50
To solve for N, multiply both sides by 5.
N/5 × 5 = 50 × 5
N = 250

Solving for a Variable

Another application of algebra is to solve an equation for a given variable.

Example: Using the formula given in Figure 1-12, find the total capacitance \( C_T \) of the series circuit containing three capacitors with

\[
C_1 = .1 \text{ microfarad} \\
C_2 = .015 \text{ microfarad} \\
C_3 = .05 \text{ microfarad}
\]

First, substitute the given values into the formula:

\[
C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}
\]

Figure 1-12. Total capacitance in a series circuit.

\[
C_T = \frac{1}{\frac{1}{.1} + \frac{1}{.015} + \frac{1}{.05}} = \frac{1}{10 + 66.66 + 20} = 0.01034 \text{ microfarad}
\]

Therefore, \( C_T = 0.01034 \text{ microfarad} \). The microfarad \( (10^{-6} \text{ farad}) \) is a unit of measurement of capacitance. This will be discussed in greater length beginning on page 10-51 in chapter 10, Electricity.

Use of Parentheses

In algebraic equations, parentheses are used to group numbers or symbols together. The use of parentheses helps us to identify the order in which we should apply mathematical operations. The operations inside the parentheses are always performed first in algebraic equations.

Example: Solve the algebraic equation \( N = (4 + 3)^2 \).
First, perform the operation inside the parentheses. That is, \( 4 + 3 = 7 \). Then complete the exponent calculation \( N = (7)^2 = 7 \times 7 = 49 \).

When using more complex equations, which may combine several terms and use multiple operations, grouping the terms together helps organize the equation. Parentheses, \( ( ) \), are most commonly used in grouping, but you may also see brackets, \( [ ] \). When a term or expression is inside one of these grouping symbols, it means that any operation indicated to be done on the group is done to the entire term or expression.

Example:
Solve the equation \( N = 2 \times [(9 ÷ 3) + (4 + 3)^2] \).

First, complete the operations inside the parentheses, \( ( ) \), then perform the operations inside the brackets, \( [ ] \).

\[
N = 2 \times [(9 ÷ 3) + (4 + 3)^2] \\
N = 2 \times [3 + (7)^2] \\
N = 2 \times [3 + 49] \\
N = 2 \times [52] \\
N = 104
\]

Order of Operation

In algebra, rules have been set for the order in which operations are evaluated. These same universally accepted rules are also used when programming algebraic equations in calculators. When solving the following equation, the order of operation is given below:

\[
N = (62 – 54)^2 + 6^2 – 4 \times [8 + (10 ÷ 2)] + \sqrt{25} + (42 \times 2) \div 4 + \frac{3}{4}
\]

1. Parentheses. First, do everything in parentheses, \( ( ) \). Starting from the innermost parentheses. If the expression has a set of brackets, \( [ ] \), treat these exactly like parentheses. If you are working with a fraction, treat the top as if it were in parentheses and the denominator as if it were in parentheses, even if there are none shown. From the equation
above, completing the calculation in parentheses gives the following:
\[ N = (8)^2 + 6^2 - 4 + 3 \times [8 + (5)] + \sqrt{25} + (84) \div 4 + \frac{3}{4}, \]
then
\[ N = (8)^2 + 6^2 - 4 + 3 \times [13] + \sqrt{25} + 84 + 4 + \frac{3}{4} \]

2. Exponents. Next, clear any exponents. Treat any roots (square roots, cube roots, and so forth) as exponents. Completing the exponents and roots in the equation gives the following:
\[ N = 64 + 36 - 4 + 3 \times 13 + 5 + 84 \div 4 + \frac{3}{4} \]

3. Multiplication and Division. Evaluate all of the multiplications and divisions from left to right. Multiply and divide from left to right in one step. A common error is to use two steps for this (that is, to clear all of the multiplication signs and then clear all of the division signs), but this is not the correct method. Treat fractions as division. Completing the multiplication and division in the equation gives the following:
\[ N = 64 + 36 - 4 + 39 + 5 + 21 + \frac{3}{4} \]

4. Addition and Subtraction. Evaluate the additions and subtractions from left to right. Like above, addition and subtraction are computed left to right in one step. Completing the addition and subtraction in the equation gives the following:
\[ X = 161 \frac{3}{4} \]

Order of Operation for Algebraic Equations

1. Parentheses
2. Exponents
3. Multiplication and Division
4. Addition and Subtraction

Use the acronym PEMDAS to remember the order of operation in algebra. PEMDAS is an acronym for parentheses, exponents, multiplication, division, addition, and subtraction. To remember it, many use the sentence, “Please Excuse My Dear Aunt Sally.” Always remember, however, to multiply/divide or add/subtract in one sweep from left to right, not separately.

Computing Area of Two-dimensional Solids

Area is a measurement of the amount of surface of an object. Area is usually expressed in such units as square inches or square centimeters for small surfaces or in square feet or square meters for larger surfaces.

Rectangle

A rectangle is a four-sided figure with opposite sides of equal length and parallel. [Figure 1-13] All of the angles are right angles. A right angle is a 90° angle. The rectangle is a very familiar shape in mechanics. The formula for the area of a rectangle is:

\[ \text{Area} = \text{Length} \times \text{Width} = L \times W \]

Example: An aircraft floor panel is in the form of a rectangle having a length of 24 inches and a width of 12 inches. What is the area of the panel expressed in square inches? First, determine the known values and substitute them in the formula.

\[ A = L \times W = 24 \text{ inches} \times 12 \text{ inches} = 288 \text{ square inches} \]

Square

A square is a four-sided figure with all sides of equal length and parallel. [Figure 1-14] All angles are right angles. The formula for the area of a square is:

\[ \text{Area} = \text{Length} \times \text{Width} = L \times W \]

\[
\begin{align*}
\text{Figure 1-13. Rectangle.} \\
\text{Figure 1-14. Square.}
\end{align*}
\]
Since the length and the width of a square are the same value, the formula for the area of a square can also be written as:

\[ \text{Area} = \text{Side} \times \text{Side} = S^2 \]

Example: What is the area of a square access plate whose side measures 25 inches? First, determine the known value and substitute it in the formula.

\[ A = L \times W = 25 \text{ inches} \times 25 \text{ inches} = 625 \text{ square inches} \]

**Triangle**

A triangle is a three-sided figure. The sum of the three angles in a triangle is always equal to 180°. Triangles are often classified by their sides. An equilateral triangle has 3 sides of equal length. An isosceles triangle has 2 sides of equal length. A scalene triangle has three sides of differing length. Triangles can also be classified by their angles: An acute triangle has all three angles less than 90°. A right triangle has one right angle (a 90° angle). An obtuse triangle has one angle greater than 90°. Each of these types of triangles is shown in Figure 1-15.

The formula for the area of a triangle is

\[ \text{Area} = \frac{1}{2} \times (\text{Base} \times \text{Height}) = \frac{1}{2} \times (B \times H) \]

Example: Find the area of the obtuse triangle shown in Figure 1-16. First, substitute the known values in the area formula.

\[ A = \frac{1}{2} \times (B \times H) = \frac{1}{2} \times (2'6'' \times 3'2'') \]

Next, convert all dimensions to inches:

\[ 2'6'' = (2 \times 12'') + 6'' = (24 + 6) = 30 \text{ inches} \]
\[ 3'2'' = (3 \times 12'') + 2'' = (36 + 2) = 38 \text{ inches} \]

Now, solve the formula for the unknown value:

\[ A = \frac{1}{2} \times (30 \text{ inches} \times 38 \text{ inches}) = 570 \text{ square inches} \]

**Parallelogram**

A parallelogram is a four-sided figure with two pairs of parallel sides. [Figure 1-17] Parallelograms do not necessarily have four right angles. The formula for the area of a parallelogram is:

\[ \text{Area} = \text{Length} \times \text{Height} = L \times H \]

**Trapezoid**

A trapezoid is a four-sided figure with one pair of parallel sides. [Figure 1-18] The formula for the area of a trapezoid is:

\[ \text{Area} = \frac{1}{2} (\text{Base}_1 + \text{Base}_2) \times \text{Height} \]

Example: What is the area of a trapezoid in Figure 1-19 whose bases are 14 inches and 10 inches, and whose height (or altitude) is 6 inches? First, substitute the known values in the formula.
A = \frac{1}{2} (b_1 + b_2) \times H

= \frac{1}{2} (14 \text{ inches} + 10 \text{ inches}) \times 6 \text{ inches}

A = \frac{1}{2} (24 \text{ inches}) \times 6 \text{ inches}

= 12 \text{ inches} \times 6 \text{ inches} = 72 \text{ square inches.}

Circle

A circle is a closed, curved, plane figure. [Figure 1-20] Every point on the circle is an equal distance from the center of the circle. The diameter is the distance across the circle (through the center). The radius is the distance from the center to the edge of the circle. The diameter is always twice the length of the radius. The circumference, or distance around, a circle is equal to the diameter times π.

\text{Circumference} = C = d \pi

The formula for the area of a circle is:

\text{Area} = \pi \times \text{radius}^2 = \pi \times r^2

Example: The bore, or “inside diameter,” of a certain aircraft engine cylinder is 5 inches. Find the area of the cross section of the cylinder.

First, substitute the known values in the formula:

\text{A} = \pi \times r^2.

The diameter is 5 inches, so the radius is 2.5 inches.

A = 3.1416 \times (2.5 \text{ inches})^2 = 3.1416 \times 6.25 \text{ square inches} = 19.635 \text{ square inches}

Ellipse

An ellipse is a closed, curved, plane figure and is commonly called an oval. [Figure 1-21] In a radial engine, the articulating rods connect to the hub by pins, which travel in the pattern of an ellipse (i.e., an elliptical or obital path).

Wing Area

To describe the shape of a wing [Figure 1-23], several terms are required. To calculate wing area, it will be necessary to know the meaning of the terms “span” and “chord.” The wingspan, S, is the length of the wing from wingtip to wingtip. The chord is the average width.
of the wing from leading edge to trailing edge. If the wing is a tapered wing, the average width, known as the mean chord (C), must be known to find the area. The formula for calculating wing area is:

\[
\text{Area of a wing} = \text{Span} \times \text{Mean Chord}
\]

Example: Find the area of a tapered wing whose span is 50 feet and whose mean chord is 6’8”. First, substitute the known values in the formula.

\[
A = S \times C
= 50 \text{ feet} \times 6 \text{ feet } 8 \text{ inches}
\]

(Note: 8 inches = \(\frac{8}{12}\) feet = .67 feet)

\[
= 50 \text{ feet} \times 6.67 \text{ feet}
= 333.5 \text{ square feet}
\]

**Units of Area**

A square foot measures 1 foot by 1 foot. It also measures 12 inches by 12 inches. Therefore, one square foot also equals 144 square inches (that is, \(12 \times 12 = 144\)). To convert square feet to square inches, multiply by 144. To convert square inches to square feet, divide by 144.

A square yard measures 1 yard by 1 yard. It also measures 3 feet by 3 feet. Therefore, one square yard also equals 9 square feet (that is, \(3 \times 3 = 9\)). To convert square yards to square feet, multiply by 9. To convert square feet to square yards, divide by 9. Refer to Figure 1-37, Applied Mathematics Formula Sheet, at the end of the chapter for a comparison of different units of area.

Figure 1-23 summarizes the formulas for computing the area of two-dimensional solids.

**Computing Volume of Three-Dimensional Solids**

Three-dimensional solids have length, width, and height. There are many three-dimensional solids, but the most common are rectangular solids, cubes, cylinders, spheres, and cones. Volume is the amount of space within a solid. Volume is expressed in cubic units. Cubic inches or cubic centimeters are used for small spaces and cubic feet or cubic meters for larger spaces.

**Rectangular Solid**

A rectangular solid is a three-dimensional solid with six rectangle-shaped sides. [Figure 1-24] The volume is the number of cubic units within the rectangular solid. The formula for the volume of a rectangular solid is:

\[
\text{Volume} = \text{Length} \times \text{Width} \times \text{Height} = L \times W \times H
\]

In Figure 1-24, the rectangular solid is 3 feet by 2 feet by 2 feet.

The volume of the solid in Figure 1-24 is \(3 \text{ ft} \times 2 \text{ ft} \times 2 \text{ ft} = 12 \text{ cubic feet}\).
Example: A rectangular 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.

\[ V = L \times W \times H \]
\[ = 5'6'' \times 3'4'' \times 2'3'' \]
\[ = 5.5 \text{ ft} \times 3.33 \text{ ft} \times 2.25 \text{ ft} \]
\[ = 41.25 \text{ cubic feet} \]

**Cube**

A cube is a solid with six square sides. [Figure 1-25] A cube is just a special type of rectangular solid. It has the same formula for volume as does the rectangular solid which is \( \text{Volume} = \text{Length} \times \text{Width} \times \text{Height} = L \times W \times H \). Because all of the sides of a cube are equal, the volume formula for a cube can also be written as:

\[ \text{Volume} = \text{Side} \times \text{Side} \times \text{Side} = S^3 \]

Example: A large, cube-shaped carton contains a shipment of smaller boxes inside of it. Each of the smaller boxes is 1 ft \( \times \) 1 ft \( \times \) 1 ft. The measurement of the large carton is 3 ft \( \times \) 3 ft \( \times \) 3 ft. How many of the smaller boxes are in the large carton? First, substitute the known values into the formula.

\[ V = L \times W \times H \]
\[ = 3 \text{ ft} \times 3 \text{ ft} \times 3 \text{ ft} \]
\[ = 27 \text{ cubic feet of volume in the large carton} \]

Since each of the smaller boxes has a volume of 1 cubic foot, the large carton will hold 27 boxes.

**Cylinder**

A solid having the shape of a can, or a length of pipe, or a barrel is called a cylinder. [Figure 1-26] The ends of a cylinder are identical circles. The formula for the volume of a cylinder is:

\[ \text{Volume} = \pi \times \text{radius}^2 \times \text{height of the cylinder} = \pi r^2 \times H \]

One of the most important applications of the volume of a cylinder is finding the piston displacement of a cylinder in a reciprocating engine. Piston displacement is the total volume (in cubic inches, cubic centimeters, or liters) swept by all of the pistons of a reciprocating engine as they move in one revolution of the crankshaft. The formula for piston displacement is given as:

\[ \text{Piston Displacement} = \pi \times \left( \frac{\text{bore divided by } 2}{} \right)^2 \times \text{stroke} \times \left( \# \text{ cylinders} \right) \]

The bore of an engine is the inside diameter of the cylinder. The stroke of the engine is the length the piston travels inside the cylinder. [Figure 1-27]

Example: Find the piston displacement of one cylinder in a multi-cylinder aircraft engine. The engine has a cylinder bore of 5.5 inches and a stroke of 5.4 inches. First, substitute the known values in the formula.

\[ V = \pi \times r^2 \times h = (3.1416) \times (5.5 ÷ 2)^2 \times (5.4) \]
\[ V = 23.758 \times 5.4 = 128.29 \text{ cubic inches} \]

The piston displacement of one cylinder is 128.29 cubic inches. For an eight cylinder engine, then the total engine displacement would be:

Total Displacement for 8 cylinders = \( 8 \times 128.29 = 1026.32 \text{ cubic inches of displacement} \)
**Sphere**

A solid having the shape of a ball is called a sphere. [Figure 1-28] A sphere has a constant diameter. The radius \((r)\) of a sphere is one-half of the diameter \((D)\).

The formula for the volume of a sphere is given as:

\[ V = \frac{4}{3} \times \pi \times r^3 \]

Example: A pressure tank inside the fuselage of a cargo aircraft is in the shape of a sphere with a diameter of 34 inches. What is the volume of the pressure tank?

\[
V = \frac{4}{3} \times \pi \times \left(\frac{34}{2}\right)^3 = \frac{4}{3} \times (3.1416) \times (17)^3 = 1.33 \times 3.1416 \times 4913 \\
V = 20,528.125 \text{ cubic inches}
\]

---

**Cone**

A solid with a circle as a base and with sides that gradually taper to a point is called a cone. [Figure 1-29] The formula for the volume of a cone is given as:

\[ V = \frac{1}{3} \times \pi \times r^2 \times H \]

**Units of Volume**

Since all volumes are not measured in the same units, it is necessary to know all the common units of volume and how they are related to each other. For example, the mechanic may know the volume of a tank in cubic feet or cubic inches, but when the tank is full of gasoline, he or she will be interested in how many gallons it contains. Refer to Figure 1-37, Applied Mathematics Formula Sheet, at the end of the chapter for a comparison of different units of volume.

**Computing Surface Area of Three-dimensional Solids**

The surface area of a three-dimensional solid is the sum of the areas of the faces of the solid. Surface area is a different concept from that of volume. For example, surface area is the amount of sheet metal needed to build a rectangular fuel tank while volume is the amount of fuel that the tank can contain.

**Rectangular Solid**

The formula for the surface area of a rectangular solid [Figure 1-24] is given as:

\[
\text{Surface Area} = 2 \times [(\text{Width} \times \text{Length}) + (\text{Width} \times \text{Height}) + (\text{Length} \times \text{Height})] \\
= 2 \times [(W \times L) + (W \times H) + (L \times H)]
\]
Cube
The formula for the surface area of a cube [Figure 1-25] is given as:

\[ \text{Surface Area} = 6 \times (\text{Side} \times \text{Side}) = 6 \times S^2 \]

Example: What is the surface area of a cube with a side measure of 8 inches?

\[ \text{Surface Area} = 6 \times (\text{Side} \times \text{Side}) \\
= 6 \times S^2 = 6 \times 8^2 = 6 \times 64 \\
= 384 \text{ square inches} \]

Cylinder
The formula for the surface area of a cylinder [Figure 1-26] is given as:

\[ \text{Surface Area} = 2 \times \pi \times \text{radius}^2 + \pi \times \text{diameter} \times \text{height} \\
= 2 \times \pi \times r^2 + \pi \times D \times H \]

Sphere
The formula for the surface area of a sphere [Figure 1-28] is given as:

\[ \text{Surface Area} = 4 \times \pi \times \text{radius}^2 = 4 \times \pi \times r^2 \]

Cone
The formula for the surface area of a right circular cone [Figure 1-29] is given as:

\[ \text{Surface Area} = \pi \times \text{radius} \times \left[ \text{radius} + (\text{radius}^2 + \text{height}^2)^{1/2} \right] \\
= \pi \times r \times \left[ r + (r^2 + H^2)^{1/2} \right] \]

Figure 1-30 summarizes the formulas for computing the volume and surface area of three-dimensional solids.

<table>
<thead>
<tr>
<th>Solid</th>
<th>Volume</th>
<th>Surface Area</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular Solid</td>
<td>(L \times W \times H)</td>
<td>(2 \times [(W \times L) + (W \times H) + (L \times H)])</td>
<td>1-23</td>
</tr>
<tr>
<td>Cube</td>
<td>(S^3)</td>
<td>(6 \times S^2)</td>
<td>1-24</td>
</tr>
<tr>
<td>Cylinder</td>
<td>(\pi \times r^2 \times H)</td>
<td>(2 \times \pi \times r^2 + \pi \times D \times H)</td>
<td>1-25</td>
</tr>
<tr>
<td>Sphere</td>
<td>(\frac{4}{3} \times \pi \times r^3)</td>
<td>(4 \times \pi \times r^2)</td>
<td>1-27</td>
</tr>
<tr>
<td>Cone</td>
<td>(\frac{1}{3} \times \pi \times r^2 \times H)</td>
<td>(\pi \times r \times \left[ r + (r^2 + H^2)^{1/2} \right])</td>
<td>1-28</td>
</tr>
</tbody>
</table>

Trigonometric Functions

Trigonometry is the study of the relationship between the angles and sides of a triangle. The word trigonometry comes from the Greek *trigonon*, which means three angles, and *metro*, which means measure.

Right Triangle, Sides and Angles
In Figure 1-31, notice that each angle is labeled with a capital letter. Across each angle is a corresponding side, each labeled with a lower case letter. This triangle is a right triangle because angle \(C\) is a 90° angle. Side \(a\) is opposite from angle \(A\), and is sometimes referred to as the “opposite side.” Side \(b\) is next to, or adjacent to, angle \(A\) and is therefore referred to as the “adjacent side.” Side \(c\) is always across from the right angle and is referred to as the “hypotenuse.”

Sine, Cosine, and Tangent

The three primary trigonometric functions and their abbreviations are: sine (sin), cosine (cos), and tangent (tan). These three functions can be found on most scientific calculators. The three trigonometric functions are actually ratios comparing two of the sides of the triangle as follows:

\[
\begin{align*}
\text{Sine (sin) of angle } A &= \frac{\text{opposite side (side } a\text{)}}{\text{hypotenuse (side } c\text{)}} \\
\text{Cosine (cos) of angle } A &= \frac{\text{adjacent side (side } b\text{)}}{\text{hypotenuse (side } c\text{)}} \\
\text{Tangent (tan) of angle } A &= \frac{\text{opposite side (side } a\text{)}}{\text{adjacent side (side } b\text{)}}
\end{align*}
\]

Example: Find the sine of a 30° angle.

Calculator Method:
Using a calculator, select the “sin” feature, enter the number 30, and press “enter.” The calculator should display the answer as 0.5. This means that when angle
A equals 30°, then the ratio of the opposite side (a) to the hypotenuse (c) equals 0.5 to 1, so the hypotenuse is twice as long as the opposite side for a 30° angle. Therefore, \( \sin 30° = 0.5 \).

**Trigonometric Table Method:**
When using a trigonometry table, find 30° in the first column. Next, find the value for \( \sin 30° \) under the second column marked “sine” or “sin.” The value for \( \sin 30° \) should be 0.5.

**Pythagorean Theorem**
The Pythagorean Theorem is named after the ancient Greek mathematician, Pythagoras (~500 B.C.). This theorem is used to find the third side of any right triangle when two sides are known. The Pythagorean Theorem states that \( a^2 + b^2 = c^2 \). [Figure 1-32] Where \( c \) = the hypotenuse of a right triangle, \( a \) is one side of the triangle and \( b \) is the other side of the triangle.

Example: What is the length of the longest side of a right triangle, given the other sides are 7 inches and 9 inches? The longest side of a right triangle is always side \( c \), the hypotenuse. Use the Pythagorean Theorem to solve for the length of side \( c \) as follows:

\[
\begin{align*}
    a^2 + b^2 &= c^2 \\
    7^2 + 9^2 &= c^2 \\
    49 + 81 &= c^2 \\
    130 &= c^2
\end{align*}
\]

If \( c^2 = 130 \) then \( c = \sqrt{130} = 11.4 \) inches.
Therefore, side \( c = 11.4 \) inches.

Example: The cargo door opening in a military airplane is a rectangle that is 5 1/2 feet tall by 7 feet wide. A section of square steel plate that is 8 feet wide by 8 feet tall by 1 inch thick must fit inside the airplane. Can the square section of steel plate fit through the cargo door? It is obvious that the square steel plate will not fit horizontally through the cargo door. The steel plate is 8 feet wide and the cargo door is only 7 feet wide. However, if the steel plate is tilted diagonally, will it fit through the cargo door opening?

The diagonal distance across the cargo door opening can be calculated using the Pythagorean Theorem where “\( a \)” is the cargo door height, “\( b \)” is the cargo door width, and “\( c \)” is the diagonal distance across the cargo door opening.

\[
\begin{align*}
    a^2 + b^2 &= c^2 \\
    (5.5 \text{ ft})^2 + (7 \text{ ft})^2 &= c^2 \\
    30.25 + 49 &= c^2 \\
    79.25 &= c^2 \\
    c &= 8.9 \text{ ft}
\end{align*}
\]

The diagonal distance across the cargo door opening is 8.9 feet, so the 8-foot wide square steel plate will fit diagonally through the cargo door opening and into the airplane.

**Measurement Systems**

**Conventional (U.S. or English) System**
Our conventional (U.S. or English) system of measurement is part of our cultural heritage from the days when the thirteen colonies were under British rule. It started as a collection of Anglo-Saxon, Roman, and Norman-French weights and measures. For example, the inch represents the width of the thumb and the foot is from the length of the human foot. Tradition holds that King Henry I decreed that the yard should be the distance from the tip of his nose to the end of his thumb. Since medieval times, commissions appointed by various English monarchs have reduced the chaos of measurement by setting specific standards for some of the most important units. Some of the conventional units of measure are: inches, feet, yards, miles, ounces, pints, gallons, and pounds. Because the conventional system was not set up systematically, it contains a random collection of conversions. For example, 1 mile = 5,280 feet and 1 foot = 12 inches.

**Metric System**
The metric system, also known as the International System of Units (SI), is the dominant language of measurement used today. Its standardization and decimal features make it well-suited for engineering and aviation work.
The metric system was first envisioned by Gabriel Mouton, Vicar of St. Paul’s Church in Lyons, France. The meter is the unit of length in the metric system, and it is equal to one ten-millionth of the distance from the equator to the North Pole. The liter is the unit of volume and is equal to one cubic decimeter. The gram is the unit of mass and is equal to one cubic centimeter of water.

All of the metric units follow a consistent naming scheme, which consists of attaching a prefix to the unit. For example, since kilo stands for 1,000 one kilometer equals 1,000 meters. Centi is the prefix for one hundredth, so one meter equals one hundred centimeters. Milli is the prefix for one thousandths and one gram equals one thousand milligrams. Refer to Figure 1-33 for the names and definitions of metric prefixes.

**Measurement Systems and Conversions**

The United States primarily uses the conventional (U.S. or English) system, although it is slowly integrating the metric system (SI). A recommendation to transition to the metric system within ten years was initiated in the 1970s. However, this movement lost momentum, and the United States continues to use both measurement systems. Therefore, information to convert between the conventional (U.S., or English) system and the metric (SI) system has been included in Figure 1-37, Applied Mathematics Formula Sheet, at the end of this chapter. Examples of its use are as follows:

To convert inches to millimeters, multiply the number of inches by 25.4.

Example: 20 inches = 20 × 25.4 = 508 mm

To convert ounces to grams, multiply the number of ounces by 28.35.

Example: 12 ounces = 12 × 28.35 = 340.2 grams

**The Binary Number System**

The binary number system has only two digits: 0 and 1. The prefix in the word “binary” is a Latin root for the word “two” and its use was first published in the late 1700s. The use of the binary number system is based on the fact that switches or valves have two states: open or closed (on/off).

Currently, one of the primary uses of the binary number system is in computer applications. Information is stored as a series of 0s and 1s, forming strings of binary numbers. An early electronic computer, ENIAC (Electronic Numerical Integrator And Calculator), was built in 1946 at the University of Pennsylvania and contained 17,000 vacuum tubes, along with 70,000 resistors, 10,000 capacitors, 1,500 relays, 6,000 manual switches and 5 million soldered joints. Computers obviously have changed a great deal since then, but are still based on the same binary number system. The binary number system is also useful when working with digital electronics because the two basic conditions of electricity, on and off, can be represented by the two digits of the binary number system. When the system is on, it is represented by the digit 1, and when it is off, it is represented by the digit zero.

**Place Values**

The binary number system is a base-2 system. That is, the place values in the binary number system are based on powers of 2. An 8-bit binary number system is shown in Figure 1-34 on the next page.

**Converting Binary Numbers to Decimal Numbers**

To convert a binary number to a decimal number, add up the place values that have a 1 (place values that have a zero do not contribute to the decimal number conversion).

Example: Convert the binary number 10110011 to a decimal number. Using the Place Value chart shown in Figure 1-35, add up the place values of the ‘1s’ in the binary number (ignore the place values with a zero in the binary number).

The binary number 10110011

= 128 + 0 + 32 + 16 + 0 + 0 + 2 + 1
= 179 in the decimal number system

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>tera ($10^{12}$)</td>
<td>One trillion times</td>
</tr>
<tr>
<td>giga ($10^9$)</td>
<td>One billion times</td>
</tr>
<tr>
<td>mega ($10^6$)</td>
<td>One million times</td>
</tr>
<tr>
<td>kilo ($10^3$)</td>
<td>One thousand times</td>
</tr>
<tr>
<td>hecto ($10^2$)</td>
<td>One hundred times</td>
</tr>
<tr>
<td>deca ($10^1$)</td>
<td>Ten times</td>
</tr>
<tr>
<td>deci ($10^{-1}$)</td>
<td>One tenth of</td>
</tr>
<tr>
<td>centi ($10^{-2}$)</td>
<td>One hundredth of</td>
</tr>
<tr>
<td>milli ($10^{-3}$)</td>
<td>One thousandth of</td>
</tr>
<tr>
<td>micro ($10^{-6}$)</td>
<td>One millionth of</td>
</tr>
<tr>
<td>nano ($10^{-9}$)</td>
<td>One billionth of</td>
</tr>
<tr>
<td>pico ($10^{-12}$)</td>
<td>One trillionth of</td>
</tr>
</tbody>
</table>

Figure 1-33. Names and definitions of metric prefixes.
Converting Decimal Numbers to Binary Numbers

To convert a decimal number to a binary number, the place values in the binary system are used to create a sum of numbers that equal the value of the decimal number being converted. Start with the largest binary place value and subtract from the decimal number. Continue this process until all of the binary digits are determined.

Example: Convert the decimal number 233 to a binary number.

Start by subtracting 128 (the largest place value from the 8-bit binary number) from 233.

\[ 233 - 128 = 105 \]

A “1” is placed in the first binary digit space: 1XXXXXXX.

Continue the process of subtracting the binary number place values:

\[ 105 - 64 = 41 \]

A “1” is placed in the second binary digit space: 11XXXXXX.

\[ 41 - 32 = 9 \]

A “1” is placed in the third binary digit space: 111XXXXX.

Since 9 is less than 16 (the next binary place value), a “0” is placed in the fourth binary digit space: 1110XXXX.

\[ 9 - 8 = 1 \]

A “1” is placed in the fifth binary digit space: 11101XXX.

Since 1 is less than 4 (the next binary place value), a 0 is placed in the sixth binary digit space: 111010XX.

Since 1 is less than 2 (the next binary place value), a 0 is placed in the seventh binary digit space: 1110100X.

\[ 1 - 1 = 0 \]

A “1” is placed in the eighth binary digit space: 11101001.

The decimal number 233 is equivalent to the binary number 11101001, as shown in Figure 1-36.

Additional decimal number to binary number conversions are shown in Figure 1-36.
### Conversion Factors

<table>
<thead>
<tr>
<th>Length</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch</td>
<td>2.54 centimeters</td>
</tr>
<tr>
<td>1 foot</td>
<td>12 inches</td>
</tr>
<tr>
<td>1 yard</td>
<td>3 feet</td>
</tr>
<tr>
<td>1 mile</td>
<td>5,280 feet</td>
</tr>
<tr>
<td>1 millimeter</td>
<td>0.0394 inches</td>
</tr>
<tr>
<td>1 kilometer</td>
<td>0.62 miles</td>
</tr>
<tr>
<td></td>
<td>25.4 millimeters</td>
</tr>
<tr>
<td></td>
<td>30.48 centimeters</td>
</tr>
<tr>
<td></td>
<td>0.9144 meters</td>
</tr>
<tr>
<td></td>
<td>1,760 yards</td>
</tr>
<tr>
<td></td>
<td>0.9144 meters</td>
</tr>
<tr>
<td></td>
<td>0.155 square inches</td>
</tr>
<tr>
<td></td>
<td>1.195 square yards</td>
</tr>
<tr>
<td></td>
<td>0.384 square miles</td>
</tr>
<tr>
<td>1 square inch</td>
<td>6.45 square centimeters</td>
</tr>
<tr>
<td>1 square foot</td>
<td>144 square inches</td>
</tr>
<tr>
<td>1 square yard</td>
<td>9 square feet</td>
</tr>
<tr>
<td>1 square mile</td>
<td>640 acres</td>
</tr>
<tr>
<td>1 square centimeter</td>
<td>0.155 square inches</td>
</tr>
<tr>
<td>1 square meter</td>
<td>1.195 square yards</td>
</tr>
<tr>
<td>1 square kilometer</td>
<td>0.384 square miles</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 fluid ounce</td>
<td>29.57 cubic centimeters</td>
</tr>
<tr>
<td>1 cup</td>
<td>8 fluid ounce</td>
</tr>
<tr>
<td>1 pint</td>
<td>2 cups</td>
</tr>
<tr>
<td>1 quart</td>
<td>2 pints</td>
</tr>
<tr>
<td>1 gallon</td>
<td>4 quarts</td>
</tr>
<tr>
<td>1 gallon</td>
<td>231 cubic inches</td>
</tr>
<tr>
<td>1 liter</td>
<td>0.264 gallons</td>
</tr>
<tr>
<td>1 cubic foot</td>
<td>1,728 cubic inches</td>
</tr>
<tr>
<td>1 cubic foot</td>
<td>7.5 gallons</td>
</tr>
<tr>
<td>1 cubic yard</td>
<td>27 cubic feet</td>
</tr>
<tr>
<td>1 board foot</td>
<td>1 inch by 12 inches by 12 inches</td>
</tr>
<tr>
<td></td>
<td>0.0353 ounces</td>
</tr>
<tr>
<td>1 ounce</td>
<td>28.350 grams</td>
</tr>
<tr>
<td>1 pound</td>
<td>16 ounces</td>
</tr>
<tr>
<td>1 ton</td>
<td>2,000 pounds</td>
</tr>
<tr>
<td>1 milligram</td>
<td>0.001 grams</td>
</tr>
<tr>
<td>1 kilogram</td>
<td>1,000 grams</td>
</tr>
<tr>
<td>1 gram</td>
<td>0.0353 ounces</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Formula for Area of Two-Dimensional Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>degrees Fahrenheit to</td>
<td><strong>Object</strong></td>
</tr>
<tr>
<td>degrees Celsius</td>
<td>Rectangle</td>
</tr>
<tr>
<td></td>
<td>Square</td>
</tr>
<tr>
<td></td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Parallelogram</td>
</tr>
<tr>
<td></td>
<td>Trapezoid</td>
</tr>
<tr>
<td></td>
<td>Circle</td>
</tr>
</tbody>
</table>

*Figure 1-37. Applied Mathematics Formula Sheet.*
Order of Operation for Algebraic Equations

1. Parentheses
2. Exponents
3. Multiplication and Division
4. Addition and Subtraction

Use the acronym PEMDAS to remember the order of operation in algebra. PEMDAS is an acronym for parentheses, exponents, multiplication, division, addition, and subtraction. To remember it, many use the sentence, “Please Excuse My Dear Aunt Sally.”

Trigonometric Equations

\[
\text{Sine (sin) of angle } A = \frac{\text{opposite side (side } a)}{\text{hypotenuse (side } c)}
\]

\[
\text{Cosine (cos) of angle } A = \frac{\text{adjacent side (side } b)}{\text{hypotenuse (side } c)}
\]

\[
\text{Tangent (tan) of angle } A = \frac{\text{opposite side (side } a)}{\text{adjacent side (side } b)}
\]

Pythagorean Theorem

\[
a^2 + b^2 = c^2
\]

Circumference of a Circle

\[
\text{Circumference} = 2\pi \sqrt{\frac{a^2 + b^2}{2}}
\]

\[
\pi = 3.1416
\]
\[
a = \text{length of one of the semi-axes}
\]
\[
b = \text{length of the other semi-axis}
\]
\[
\text{Area} = \pi a b
\]

Formulas for Surface Area and Volume of Three-Dimensional Solids

<table>
<thead>
<tr>
<th>Solid</th>
<th>Volume</th>
<th>Surface Area</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular Solid</td>
<td>(L \times W \times H)</td>
<td>(2 \times [(W \times L) + (W \times H) + (L \times H)])</td>
<td>1-23</td>
</tr>
<tr>
<td>Cube</td>
<td>(S^3)</td>
<td>(6 \times S^2)</td>
<td>1-24</td>
</tr>
<tr>
<td>Cylinder</td>
<td>(\pi \times r^2 \times H)</td>
<td>(2 \times \pi \times r^2 + \pi \times D \times H)</td>
<td>1-25</td>
</tr>
<tr>
<td>Sphere</td>
<td>(\frac{4}{3} \pi r^3)</td>
<td>(4 \times \pi \times r^2)</td>
<td>1-27</td>
</tr>
<tr>
<td>Cone</td>
<td>(\frac{1}{3} \pi r^2 \times H)</td>
<td>(\pi \times r \times [r + (r^2 + H^2)^{1/2}])</td>
<td>1-28</td>
</tr>
</tbody>
</table>

Figure 1-37. Applied Mathematics Formula Sheet. (continued)
### Names and Symbols for Metric Prefixes

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>tera ($10^{12}$)</td>
<td>One trillion times</td>
</tr>
<tr>
<td>giga ($10^9$)</td>
<td>One billion times</td>
</tr>
<tr>
<td>mega ($10^6$)</td>
<td>One million times</td>
</tr>
<tr>
<td>kilo ($10^3$)</td>
<td>One thousand times</td>
</tr>
<tr>
<td>hecto ($10^2$)</td>
<td>One hundred times</td>
</tr>
<tr>
<td>deca ($10^1$)</td>
<td>Ten times</td>
</tr>
<tr>
<td>deci ($10^{-1}$)</td>
<td>One tenth of</td>
</tr>
<tr>
<td>centi ($10^{-2}$)</td>
<td>One hundredth of</td>
</tr>
<tr>
<td>milli ($10^{-3}$)</td>
<td>One thousandth of</td>
</tr>
<tr>
<td>micro ($10^{-6}$)</td>
<td>One millionth of</td>
</tr>
<tr>
<td>nano ($10^{-9}$)</td>
<td>One billionth of</td>
</tr>
<tr>
<td>pico ($10^{-12}$)</td>
<td>One trillionth of</td>
</tr>
</tbody>
</table>

### Powers of Ten

<table>
<thead>
<tr>
<th>Powers of Ten</th>
<th>Expansion</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Exponents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$10^6$</td>
<td>$10 \times 10 \times 10 \times 10 \times 10 \times 10$</td>
<td>$1,000,000$</td>
</tr>
<tr>
<td>$10^5$</td>
<td>$10 \times 10 \times 10 \times 10 \times 10$</td>
<td>$100,000$</td>
</tr>
<tr>
<td>$10^4$</td>
<td>$10 \times 10 \times 10 \times 10$</td>
<td>$10,000$</td>
</tr>
<tr>
<td>$10^3$</td>
<td>$10 \times 10 \times 10$</td>
<td>$1,000$</td>
</tr>
<tr>
<td>$10^2$</td>
<td>$10 \times 10$</td>
<td>$100$</td>
</tr>
<tr>
<td>$10^1$</td>
<td>$10$</td>
<td>$10$</td>
</tr>
<tr>
<td>$10^0$</td>
<td>$1$</td>
<td>$1$</td>
</tr>
<tr>
<td>Negative Exponents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$10^{-1}$</td>
<td>$1/10$</td>
<td>$1/10 = 0.1$</td>
</tr>
<tr>
<td>$10^{-2}$</td>
<td>$1/(10 \times 10)$</td>
<td>$1/100 = 0.01$</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>$1/(10 \times 10 \times 10)$</td>
<td>$1/1,000 = 0.001$</td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>$1/(10 \times 10 \times 10 \times 10)$</td>
<td>$1/10,000 = 0.0001$</td>
</tr>
<tr>
<td>$10^{-5}$</td>
<td>$1/(10 \times 10 \times 10 \times 10 \times 10)$</td>
<td>$1/100,000 = 0.00001$</td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td>$1/(10 \times 10 \times 10 \times 10 \times 10 \times 10)$</td>
<td>$1/1,000,000 = 0.000001$</td>
</tr>
</tbody>
</table>

*Figure 1-37. Applied Mathematics Formula Sheet. (continued)*