INTRODUCTION

During the twentieth century, more progress has been made in technology and science than was made in all the previous centuries since the beginning of time. The space shuttle program has established the reality of civilians traveling in space (see Figure 2-1). Interplanetary communication and exploration has been accomplished. Although less spectacular than space travel, great advances have been made in air transportation and the automatic control of aircraft. Widebody, multideck, and regional transport aircraft have brought air travel throughout the world to millions of people who could not have had this advantage a few years ago (see Figure 2-2). All these accomplishments are the result of the application of the laws of physics.

Today, the person concerned with the operation, maintenance, or design of any of the thousands of mechanical and electronic devices is constantly faced with the application of scientific law. A technician must have an understanding of the common laws of physics in such areas as motion, heat, light, and sound if he or she is to acquire the basic technical knowledge necessary to maintain and repair today's advanced aircraft and space vehicles.

MEASUREMENTS

In order to arrive at values of distance, weight, speed, volume, pressure, and so on, it is necessary to become familiar with the accepted methods for measuring these values and the units used to express them. Through the ages, human beings have devised many methods for measuring. In this text the English system and the metric system, both of which are used extensively throughout the world, will be examined.

Length and Distance

The system commonly used in the United States is the English system; it involves such units as the inch, foot, yard, mile, pint, gallon, pound, and ton.

Originally, the units inch, foot, yard, and mile were not exact multiples or factors of one another, but, for the sake of convenience, the foot was made equal to 12 inches (in), the yard was made 3 feet (ft), and the mile was made 5280 ft, or 1760 yards (yd). The nautical mile (nm), used internationally for navigation, is based on one-sixtieth of 1° of the earth's circumference at the equator. It is approximately 6080 ft. A speed of 1 nm/h is called 1 knot (kt). Most airplane airspeed indicators are calibrated in knots.

Most other countries, and scientists in this country, make use of a system called the International System of Units, or SI. This system is commonly referred to as the metric system, which has many advantages over the English system. In the metric system, prefixes are used to make the base units larger or smaller by multiples of 10. The prefixes most often used are shown in Table 2-1.
TABLE 2-1 Metric Prefixes

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Multiplying Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilo-</td>
<td>k</td>
<td>1000</td>
</tr>
<tr>
<td>deci-</td>
<td>d</td>
<td>0.1</td>
</tr>
<tr>
<td>centi-</td>
<td>c</td>
<td>0.01</td>
</tr>
<tr>
<td>milli-</td>
<td>m</td>
<td>0.001</td>
</tr>
<tr>
<td>micro-</td>
<td>μ</td>
<td>0.000 001</td>
</tr>
</tbody>
</table>

In the metric system all the measurements of length are either multiples or subdivisions of the meter, based on multiples of 10. The following table shows how the units of length are related:

- 10 millimeters = 1 centimeter
- 10 centimeters = 1 decimeter
- 10 decimeters = 1 meter
- 10 meters = 1 decameter
- 10 decameters = 1 hectometer
- 10 hectometers = 1 kilometer

One meter (m) is equal to 39.37 in, which is a little longer than the U.S. yard. Thus 1 decimeter (dm) is equal to 3.937 in. One centimeter (cm) is equal to 0.3937 in, and 1 millimeter (mm) equals 0.03937 in. In practice, the units of length most commonly used are the millimeter, the centimeter, the meter, and the kilometer.

Since today's aircraft are used all over the world, many manufacturers will provide both systems of measurement in their technical manuals. An example of this is illustrated in Figure 2-3.

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**Area**

Measurements of area are usually indicated in units that are the squares of the units of length. In the English system the units of area are the square inch (in²), the square foot (ft²), the square yard (yd²), and the square mile (mi²).

Area in the metric system is indicated in square metric units. These are the square centimeter (cm²), the square meter (m²), and the square kilometer (km²).

**Volume and Capacity**

The amount of space occupied by an object is the object's volume or capacity. The units used to measure volume are derived from units of length. Volume and capacity are indicated in three-dimensional units, or cubes, of the basic linear units. The cubic inch (in³), cubic foot (ft³), and cubic yard (yd³) are the common units of volume in the English system. An example of a cubic inch is shown in Figure 2-4.

Other units of volume and capacity are the pint, quart, and gallon. In general, when speaking of volume, cubed units are used, and when speaking of capacity, the pint, quart, or gallon measurements are used.

The metric system employs the cubed metric units as units of volume. The most commonly expressed units are the cubic centimeter (cm³) and the cubic meter (m³). For capacity, the liter is generally employed. The liter (L) is equal to 1000 cm³. It is also equal to 1.056 U.S. liquid quarts. One cubic meter equals 1000 L.
For example, items such as force, density, electrical values, light intensity, sound intensity, velocity, energy, and numerous other values must also be measured. In this section only the most commonly known units of measurement have been discussed. As other areas of physical laws and phenomena are explored, the units of measurement required in each area will be discussed.

Conversion factors to show the relationships among various units are given in the appendix of this text.

### Gravity, Weight, and Mass

Gravity, or gravitation, is the universal force that all bodies exert upon one another. It is defined by the universal law of gravitation, which states: The attraction between particles of matter is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. This can be expressed by the equation

\[
F = G \frac{m_1 m_2}{r^2}
\]

where 
- \( F \) is attractive force
- \( r \) is distance between two bodies (particles)
- \( m_1 \) and \( m_2 \) are masses of bodies
- \( G \) is the universal gravitation constant

\[
G = 6.67 \times 10^{-11} \text{ newtons m}^2 \text{kg}^{-2}
\]

The terms weight and mass are, many times, used interchangeably; however, weight and mass have different definitions.

The weight of a body is the pull exerted upon the body by the gravitation of the earth. The weight of a body may change depending upon its distance from the center of the earth. The farther away an object is from the center of the earth, the less it will weigh.

The mass of a body is a measure of the amount of material the body contains. Regardless of the location to the earth's center, the mass of a body will never change as long as no matter is added to or removed from it. Remember, however, that 1 lb of mass will not be exactly 1 lb of weight if the mass is not at the proper distance from the center of the earth.

Both mass and weight are measured in units of pounds or kilograms. Another unit of measuring mass that may be encountered is that of the slug. A slug is defined as being a unit of mass having a value of approximately 32.175 lb under standard atmospheric conditions.

### Density

An important physical property of a substance is its density \( (\rho) \), which is its mass per unit volume. Table 2-2 is a list of the densities of various common substances. In metric units, density is properly expressed in kilograms per cubic meter. The density of water is 1000 kg/m\(^3\), since 1 m\(^3\) of water has a mass of 1000 kg.
Specific Gravity

The specific gravity of a substance is the ratio of the density of the substance to the density of water. To determine the specific gravity of a substance when the density is known, divide the weight of a given volume of the substance by the weight of an equal volume of water. For example, if the specific gravity of lead is unknown and the density in pounds per cubic foot is 708.21 lb, divide 708.21 by 62.4 (the density per cubic foot of water) and 11.34 is obtained, which is the specific gravity of lead. Table 2-2 lists the specific gravity for various substances.

A device called a hydrometer is used for measuring the specific gravity of liquids. This device consists of a tubular-shaped glass float contained in a larger glass tube (see Figure 2-5). The float is weighted and has a vertically graduated scale. To determine specific gravity, the scale is read at the surface of the liquid in which the float is immersed. A specific gravity of 1.000 is read when the float is immersed in pure water. When immersed in a liquid of greater density, the float rises, indicating a greater specific gravity. For liquids of lesser density the float sinks, indicating a lower specific gravity.

A hydrometer is often used to determine the specific gravity of the electrolyte (battery liquid) in an aircraft battery. When a battery is discharged, the calibrated float immersed

In the English system, density should be expressed in slugs per cubic foot, since the slug is the unit of mass used in this system. In these units the density of water is 1.94 slugs/ft³.

Because weights rather than masses are usually specified in the English system, a quantity called weight density is commonly used. As the name suggests, weight density is weight per unit volume, and its units are pounds per cubic foot.

Changes in temperature will not change the mass of a substance but will change the volume of the substance by expansion or contraction, thus changing its density. To find the density of a substance, its mass and volume must be known. Its mass is then divided by its volume to find the mass per unit volume.

![FIGURE 2-5 Hydrometer measuring the electrolyte in an aircraft battery.](image-url)