

Appendix G

Units of Measure

Magnitudes of measurements are typically given in terms of a specific unit. In surveying, the most commonly used units define quantities of length (or distance), area, volume, and horizontal or vertical angles. The two systems used for specifying units of measure are the English and metric systems. Units in the English system are historical units of measurement used in medieval England, which evolved from the Anglo-Saxon and Roman systems. The metric system is a decimalized system of measurement developed in France in late 18th century. The metric system is also referred to as the International System of Units (abbreviated SI).

A. Length

1. English Units

The basic units for length or distance measurements in the English system are the inch, foot, yard, and mile. Other units of length also include the rod, furlong, and chain.

$$1 \text{ foot} = 12 \text{ inches}$$

$$1 \text{ yard} = 3 \text{ feet}$$

$$1 \text{ rod} = 5.5 \text{ yards} = 16.5 \text{ feet}$$

$$1 \text{ chain} = 4 \text{ rods} = 66 \text{ feet} = 100 \text{ links}$$

$$1 \text{ furlong} = 10 \text{ chains} = 40 \text{ rods} = 660 \text{ feet}$$

$$1 \text{ mile} = 8 \text{ furlongs} = 80 \text{ chains} = 320 \text{ rods} = 1,760 \text{ yards} = 5,280 \text{ feet}$$

2. Metric Units

The basic unit of length in the SI system is the meter. The meter was originally intended to be one ten-millionth of the distance from the Equator to the North Pole (at sea level). The meter has since been redefined as the distance travelled by light in a vacuum in $1/299,792,458$ seconds (i.e. the speed of light in a vacuum is $299,792,458$ m/sec). Subdivisions of the meter are the millimeter, centimeter, and the decimeter, while multiples of meters include the decameter, hectometer, and kilometer.

$$1 \text{ meter} = 1,000 \text{ millimeters}$$

$$1 \text{ meter} = 100 \text{ centimeters}$$

$$1 \text{ meter} = 10 \text{ decimeters}$$

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$$1 \text{ decameter} = 10 \text{ meters}$$

$$1 \text{ hectometer} = 100 \text{ meters}$$

$$1 \text{ kilometer} = 1,000 \text{ meters}$$

3. English to Metric Conversions

There are two different conversions to relate the foot and the meter. In 1893, the United States officially defined a meter as 39.37 inches. Under this standard, the foot was equal to $12/39.37$ m (approximately 0.3048 m). In 1959, a new standard was adopted that defined an inch equal to 2.54 cm. Under this standard, the foot was equal to exactly 0.3048 m. The older standard is now referred to as the U.S. survey foot, while the new standard is referred to as the international foot.

As of January 1, 2023, the U.S. Survey Foot will no longer be used on new projects and will be replaced by the international foot (equal to 0.3048 meters). The conversion is the result of a collaborative effort by the National Institute of Standards and Technology (NIST), National Geodetic Survey (NGS), and National Oceanic Service (NOS), and National Oceanic and Atmospheric Administration (NOAA) to provide national uniformity in the measure of length.

$$1 \text{ foot} = 0.3048 \text{ meters}$$

$$1 \text{ meter}/0.3048 \cong 3.2808 \text{ feet}$$

$$1 \text{ mile} \cong 1609.344 \text{ meters} \cong 1.609344 \text{ kilometers}$$

B. Area

1. English Units

In the English system, areas are typically given in square feet or square yards. For larger area measurements, the acre or square mile may be used. Historically, the acre was originally established as an area one furlong in length and four rods in width. Laying out ten of these acres side by side is a square furlong (10 acres). Since a mile is eight furlongs in length, there are exactly 640 acres in a square mile. A survey township is a square unit of land six miles on each side and conforms to meridians and parallels. Each township is further divided into 36 one-square mile sections. Because some of the townships have boundaries designed to correct for the convergence of meridian lines, not all townships and their sections are exactly square.

$$1 \text{ square foot} = 12 \text{ inches} * 12 \text{ inches} = 144 \text{ square inches}$$

$$1 \text{ square yard} = 3 \text{ feet} * 3 \text{ feet} = 9 \text{ square feet}$$

$$1 \text{ square rod} = 16.5 \text{ feet} * 16.5 \text{ feet} = 272.25 \text{ square feet}$$

*1 square chain = 66 feet * 66 feet = 4,356 square feet*

*1 square furlong = 660 feet * 660 feet = 435,600 square feet*

1 acre = 4,840 square yards = 43,560 square feet

1 acre = 1/10 square furlong = 10 square chains = 160 square rods

1 square mile = 1 section = 640 acres

1 township = 36 sections = 36 square miles

2. Metric Units

Areas in the metric system are given in square meters while larger measurements are given in hectares.

*1 square meter = 1,000 mm * 1,000 mm = 1,000,000 square mm*

*1 square meter = 100 cm * 100 cm = 10,000 square cm*

*1 hectare = 100 meters * 100 meters = 10,000 square meters*

*1 square kilometer = 1,000 m * 1,000 m = 1,000,000 square m*

1 square kilometer = 100 hectares

3. English to Metric Conversions

1 square meter \cong 1.196 square yards

1 square meter \cong 10.764 square feet

1 hectare \cong 2.471 acres

1 square kilometer \cong 247.105 acres

1 square mile \cong 2.590 square kilometers \cong 258.999 hectares

C. Volume

1. English Units

Volumes in the English system are typically given in cubic feet or cubic yards. For larger volumes, such as the quantity of water in a reservoir, the acre-foot unit is used. It is equivalent to the area of an acre having a depth of 1 foot.

*1 cubic foot = 12 inches * 12 inches * 12 inches = 1,728 cubic inches*

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$$1 \text{ cubic yard} = 3 \text{ feet} * 3 \text{ feet} * 3 \text{ feet} = 27 \text{ cubic feet}$$

$$1 \text{ acre} \cdot \text{foot} = 43,560 \text{ square feet} * 1 \text{ foot} = 43,560 \text{ cubic feet}$$

2. Metric Units

Volumes in the metric system are given in cubic meters.

$$1 \text{ cubic meter} = 1,000 \text{ mm} * 1,000 \text{ mm} * 1,000 \text{ mm} = 1,000,000,000 \text{ cubic mm}$$

$$1 \text{ cubic meter} = 100 \text{ cm} * 100 \text{ cm} * 100 \text{ cm} = 1,000,000 \text{ cubic cm}$$

3. English to Metric Conversions

$$1 \text{ cubic meter} \cong 1.308 \text{ cubic yards}$$

$$1 \text{ cubic meter} \cong 35.315 \text{ cubic feet}$$

D. Mass

The mass of an object is often referred to as its weight though these are different concepts and quantities. Mass refers to the amount of matter in an object, whereas weight refers to the force experienced by an object due to gravity. In other words, an object with a specific mass will weigh more on the Earth than the moon.

1. English Units

The avoirdupois pound is the primary unit of mass in the English system. Avoirdupois is a system of weight based on 16 ounces per pound rather than 12 ounces per pound in the troy system of weight.

$$1 \text{ ounce} = 16 \text{ drams}$$

$$1 \text{ pound} = 16 \text{ ounces}$$

$$1 \text{ hundredweight (short)} = 100 \text{ pounds}$$

$$1 \text{ hundredweight (long)} = 112 \text{ pounds}$$

$$1 \text{ ton (short)} = 2,000 \text{ pounds}$$

$$1 \text{ ton (long)} = 2,240 \text{ pounds}$$

2. Metric Units

The kilogram is the unit of mass in the metric system.

$$1 \text{ gram} = 1,000 \text{ milligrams} = 100 \text{ centigrams} = 10 \text{ decigrams}$$

$1 \text{ kilogram} = 10 \text{ hectograms} = 100 \text{ decagrams} = 1,000 \text{ grams}$

$1 \text{ metric ton} = 1,000 \text{ kilograms}$

3. English to Metric Conversions

The avoirdupois pound is defined as exactly 0.45359237 kg.

$1 \text{ pound} \cong 0.454 \text{ kilograms}$

$1 \text{ kilogram} \cong 2.205 \text{ pounds}$

$1 \text{ metric ton} \cong 1.102 \text{ tons (short)}$

E. Angular Measurement

In geometry, any horizontal or vertical angle is measured in degrees. These angles may be given in decimal degrees or degrees, minutes, and seconds.

$1 \text{ degree} = 60 \text{ minutes} = 3,600 \text{ seconds}$

e.g. $45.555\bar{5} \text{ degrees} = 45^{\circ}33'20''$

The radian is another unit of measure for angles. By definition, a full circle has 2π radians or 360 degrees.

$2\pi \text{ radians} = 360 \text{ degrees}$

$1 \text{ radian} = \frac{360}{2\pi} \text{ degrees} \cong 57.2958 \text{ degrees}$

F. Temperature

1. English Units

The Fahrenheit scale, or degrees Fahrenheit ($^{\circ}\text{F}$), is used in the United States to measure temperature. On the Fahrenheit scale, the freezing point of water is 32°F while the boiling point is 212°F at standard atmospheric pressure. The boiling and freezing points of water are exactly 180 degrees apart, making each degree Fahrenheit $1/180$ of the interval between the two points.

2. Metric Units

The Celsius scale, or degrees Celsius ($^{\circ}\text{C}$), is used the metric system to measure temperature. On the Celsius scale, the freezing point of water is 0°C while the boiling point is 100°C at standard atmospheric pressure. The boiling and freezing points of water are exactly 100

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degrees apart, making each degree Celsius 1/100 of the interval between the two points. Fahrenheit and Celsius scales converge at -40° (i.e. -40°F and -40°C are the same temperature).

$$(212 - 32)^\circ\text{F} = (100 - 0)^\circ\text{C}; \quad 180^\circ\text{F} = 100^\circ\text{C}$$

$$1^\circ\text{F} = \frac{100}{180}^\circ\text{C} = \frac{5}{9}^\circ\text{C}$$

$$1^\circ\text{C} = \frac{180}{100}^\circ\text{F} = \frac{9}{5}^\circ\text{F}$$

3. English to Metric Conversions

$$^\circ\text{F} = \frac{9}{5} * ^\circ\text{C} + 32$$

$$^\circ\text{C} = \frac{5}{9} * (^\circ\text{F} - 32)$$

G. Pressure

Atmospheric pressure is the force per unit area exerted against a surface by the weight of the Earth's atmosphere above that surface. Because there is less overlying atmospheric mass as elevation increases, pressure decreases with increasing elevation. The standard atmosphere (atm) is an international reference for pressure.

1. English Units

In the English system, air pressure is typically measured in inches mercury (inHg).

$$1 \text{ atm} = 29.2125 \text{ inHg}$$

2. Metric Units

Air pressure is typically measured in millimeters mercury (mmHg) or millibars (mbars) in the metric system but may also be measured in pascals or kilopascals.

$$1 \text{ atm} = 101,325 \text{ Pa} = 1013.25 \text{ mbars} = 760 \text{ mmHg}$$

3. English to Metric Conversions

$$1 \text{ inHg} / 12 \frac{\text{in}}{\text{ft}} * 0.3048 \frac{\text{m}}{\text{ft}} * 1,000 \text{ mm/m} = 25.40 \text{ mmHg}$$