Measurements in Power, Structural, and Technical Systems

DID YOU KNOW that in ancient times an inch was the width of a man's thumb, and a foot was the length of the average man's foot, 11 1/42 inches? A yard was initially the length of a man's belt. However, in the 12th century, King Henry I of England changed the yard to the distance from his nose to the thumb of his out-stretched arm, 36 inches. Measurements today are much more precise.

Objective:

Examine measurements in power, structural, and technical systems.

Key Terms:

area
International System of Units (SI)
length
mass
measurement
metric system
ruler
temperature
United States customary system of measurement
volume
weight

Measurement

Measurement is the act of determining the extent, dimension, or quantity of something. The use of accurate and exact measurements often is essential in agricultural power, structural, and technology systems applications.

Physical quantities or properties are measured or calculated numerically. Units of measurement are used for time, distance, mass, and temperature. From these, other measurement forms (e.g., volume, area, and weight) are derived.

SYSTEMS OF MEASUREMENT

The United States customary system and the International System of Units gauge these quantities by using different units. For example, the inch and the centimeter measure length, but they measure length with different units. Both systems of measurement are used in the United States.

FIGURE 1. Measuring is essential with structural systems.

United States Customary System of Measurement

General measuring in the United States is handled using the United States customary system, commonly known as the American system or English units. The **United States customary system of measurement** is a system of measure based on imperial units used in countries influenced by the British Empire. The United States has continued to use the United States customary system of measurement because of heavy use by citizens in everyday life and the preexisting system's strong incorporation into this country's products and government infrastructure.

- The system for measuring length in the United States customary system is based on the inch, foot, yard, and mile.
- The most widely used area units are the square foot and the acre.
- The cubic inch, cubic foot, and cubic yard are typically used for measuring volume.
- Fluid volume is measured by the fluid ounce, cup, pint, quart, and U.S. gallon.
- Dry volume is measured by the dry pint, dry quart, peck, and bushel.
- Units of weight include ounce, pound, and ton.
- Most nonscientific measurements of temperature are in Fahrenheit.

International System of Units (SI)

Countries other than the United States, Liberia, and Myanmar use the International System of Units (SI) for measuring length, volume, weight, and temperature. The **International System of Units (SI)** is a modern standardized form of the metric system that allows people worldwide to have a common measurement system to share information accurately.

The International System of Units (SI) has been the internationally recognized standard metric system since the 1960s. The abbreviation SI comes from the French name *le Systmé International d'Unités*.

The **metric system**, first adopted in 1791, is a decimal system of measurements in which all units are based on multiples of 10. Since the International System of Units is a metric system of measurement based on the powers of 10, its units can be easily converted between measurements.

The International System of Units (SI) consists of basic units, including the meter (length), liter (volume), and gram (weight). Names for larger and smaller units are made by adding prefixes to these basic units.

Length

Length is the distance from one point to another. The SI unit of length is the meter. In making measurements, it is often more convenient to report length in terms that signify a portion or combination of meters.

FIGURE 2. One side of this measuring stick is marked in inches and the other in centimeters.

Area

Area is distance based on measurements of length (i.e., length × width). The SI unit for area is the square meter (m^2). However, when measuring plots of land for agricultural purposes, the hectare (ha) is normally used instead of the square meter (1 hectare = 10,000 square meters).

Volume

Volume is the amount of space a substance occupies and is based on measurements of length (i.e., length × width × height). The SI unit of volume is the cubic meter (m^3). However, this measurement is too large for most scientific work, so scientists normally use the cubic decimeter $(0.1 \text{ of a meter})^3$ to measure volume. One thousand cubic centimeters (1,000 cm^3) is equal to 1 liter.

Weight

Weight is a measure of the pull of gravity on an object. The SI unit of weight is the Newton. However, the pull of gravity differs when a person leaves Earth, and many experiments are now conducted in space. Therefore, scientists commonly measure the mass of an object.

Mass

Mass is the amount of matter in an object. The SI unit of mass is the gram. The weight of an object changes, depending on the gravitational pull on the matter. Mass, however, remains

constant. For example, the moon's gravity is approximately one-sixth that of Earth. So someone who weighs 150 pounds on Earth would weigh 25 pounds on the moon.

Temperature

Temperature is the degree of hotness or coldness of an object or environment. The SI unit for measuring temperature is the Kelvin. However, the majority of people utilizing the International System of Units use degrees Celsius in everyday measurements. Celsius utilizes a system based on multiples of 10, in which there are 100 degrees from the temperature at which water freezes (0°) to the temperature at which water boils (100°).

The International System of Units makes use of prefixes in combination with units of measure. The prefixes are an international standard. A commonly used prefix is kilo, which is a multiple of 1,000. When used with meter, it forms the word kilometer and represents 1,000 meters. Similarly, a kilogram equals 1,000 grams, and a kilowatt equals 1,000 watts. In addition, a symbol is given to each prefix. The prefix symbol can be used in combination with the symbols for units of measure. The symbol for kilo is k. It can be used with the m symbol for meter to create km or with the g symbol for gram to make kg.

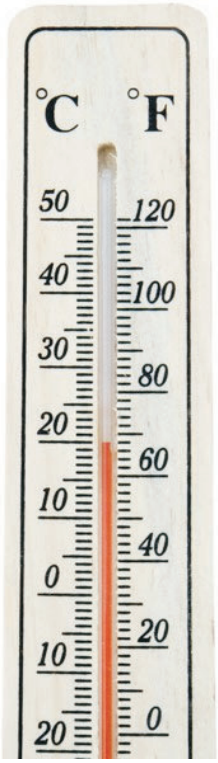

FIGURE 3. Celsius as compared to Fahrenheit.

TABLE 1. SI Prefixes

1000^m	10^n	Prefix	Symbol	Since	Short Scale	Long Scale	Decimal
1000^4	10^{12}	tera	T	1960	Trillion	Billion	1000000000000
1000^3	10^9	giga	G	1960	Billion	Milliard	1000000000
1000^2	10^6	mega	M	1960	Million		1000000
1000^1	10^3	kilo	k	1795	Thousand		1000
$1000^{2}/_{3}$	10^2	hecto	h	1795	Hundred		100
$1000^{1}/_{3}$	10^1	deca	da	1795	Ten		10
1000^0	10^0	*(none)*	*(none)*	NA	One		1
$1000^{-1}/_{3}$	10^{-1}	deci	d	1795	Tenth		0.1
$1000^{-2}/_{3}$	10^{-2}	centi	c	1795	Hundredth		0.01
1000^{-1}	10^{-3}	milli	m	1795	Thousandth		0.001
1000^{-2}	10^{-6}	micro	μ	1960	Millionth		0.000001
1000^{-3}	10^{-9}	nano	n	1960	Billionth	Milliardth	0.000000001
1000^{-4}	10^{-12}	pico	p	1960	Trillionth	Billionth	0.000000000001

MEASUREMENT CONVERSIONS

Numbers can be converted within the International System of Units by moving the decimal points accordingly.

Converting Numbers Between Units

To convert numbers between units, it is necessary to move the decimal points using the prefixes in front of the basic unit. When moving from a smaller unit to a larger unit, it is essential to move the decimal point to the left. When moving from a larger unit to a smaller unit, it is critical to move the decimal point to the right.

- Example 1: To change 3 centimeters to hectometers, move the decimal point four places to the left. The answer would be 0.0003 hectometer.
- Example 2: To convert 16 liters to milliliters, move the decimal point three places to the right. The answer would be 16,000 milliliters.
- Example 3: To change 2.62 grams to kilograms, move the decimal point three places to the left. The answer would be 0.00262 kilogram.

Conversions Between the United States Customary System and the International System of Units

Measurements can be converted between the U.S. customary system and the International System of Units. The key operation is to multiply or divide units, just like numbers. The strategy is to set up multiplication or division to get all unwanted units to cancel out. If all unwanted units do not cancel out, the problem has been set up incorrectly.

Example 1: 15 in. = _____ cm

STEP 1: The outcome unit is centimeters.

STEP 2: Structure the derived equation so the units cancel out, leaving only the desired outcome unit: in. × cm. / in. = cm.

STEP 3: Place the numbers into the derived equation using the learned equivalents. At least one volume, length, and weight equivalent should be committed to memory. The most commonly used equivalents are 1 gal. = 3.79 L, 1 in. = 2.54 cm, and 1 lb. = 0.45 kg. By knowing one equivalent conversion and understanding prefixes, it is possible to do any conversion.

$$15 \text{ in.} \times 2.54 \text{ cm} = 1 \text{ in.}$$

NOTE: Place the equivalent in the equation as a proportion.

STEP 4: Perform the mathematical task as indicated by the equation. *NOTE*: In mathematics, the term "per" refers to division, as 2.54 cm. per in.

$$15 \text{ in.} \times \frac{2.54 \text{ cm}}{1 \text{ in.}} = 38.1 \text{ cm}$$

Therefore, 15 in. = 38.1 cm

This method works equally as well within either system, as shown in the following two examples:

Example 2: 15 in. = _____ yd.

STEP 1: The outcome unit is yards.

STEP 2: Derive an equation that will yield the desired outcome unit.

$$\text{in.} \times \frac{\text{yd.}}{\text{in.}} = \text{yd.}$$

STEP 3: Put the numbers into the derived equation, placing the appropriate equivalent in the proportion position.

$$15 \text{ in.} \times \frac{1 \text{ yd.}}{36 \text{ in.}} = 0.42 \text{ yd. (rounded off to the nearest tenth)}$$

Example 3: 15 ft. = _____ cm

STEP 1: The outcome unit is centimeters.

STEP 2: Derive an equation that will yield the desired outcome unit. The derived equation will have two proportions in it this time.

$$\text{ft.} \times \frac{\text{in.}}{\text{ft.}} \times \frac{\text{cm}}{\text{in.}} = ? \text{ cm}$$

NOTE: The two proportions are inches to feet and centimeters to inches.

STEP 3: Place the numbers and equivalents into the equation.

$$15 \text{ ft.} \times \frac{12 \text{ in.}}{1 \text{ ft.}} \times \frac{2.54 \text{ cm}}{1 \text{ in.}} = 457.2 \text{ cm}$$

Therefore, 15 ft. = 457.2 cm

Example 4: A recent research report found a significant yield increase in corn when a certain micronutrient was added at the rate of 20 kilograms per hectare.

No gains were noted below this rate, and toxicity levels occurred at higher rates, thereby decreasing yields. Your fertilizer spreader is calibrated in pounds per acre. Can you make this conversion accurately?

STEP 1: The outcome units are pound and acre.

STEP 2: Derive equations that will yield the desired outcome units.

Equation 1:

$$\text{kg} \times \frac{\text{lb.}}{\text{kg}} = \text{lb.}$$

Equation 2:

$$\text{ha} \times \frac{\text{acre(s)}}{\text{ha}} = \text{acre(s)}$$

STEP 3: Place the numbers and equivalents in the equations.

Equation 1:

$$20\ \text{kg} \times \frac{1\ \text{lb.}}{0.45\ \text{kg}} = 44.4\ \text{lb.}$$

Equation 2:

$$1\ \text{ha} \times \frac{1\ \text{acre}}{0.4\ \text{ha}} = 2.5\ \text{acres}$$

Therefore, $\frac{20\ \text{kg}}{1\ \text{ha}} = \frac{44.4\ \text{lb.}}{2.5\ \text{acres}} = \frac{17.6\ \text{lb.}}{1\ \text{acre}}$

Example 5: 96°F = _____°C. The conversion formula is 5/9 (°F – 32).

Step 1: 5/9 (96° – 32) or 5/9 (64)

Step 2: 320/9

Step 3: 35.5°C

TABLE 2. Conversion Factors for Acceptable Units

To Convert Column 1 into Column 2 Multiply by	Column 1 Acceptable Unit	Column 2 SI Unit	To Convert Column 2 into Column 1 Multiply by
Length			
0.304	foot, ft.	meter, m	3.28
2.54	inch, in.	centimeter, cm (10–2 m)	0.394
25.4	inch, in.	millimeter, mm (10–3 m)	3.94 × 10–2
1.609	mile, mi.	kilometer, km (103 m)	0.621
0.914	yard, yd.	meter, m	1.094
Area			
0.405	acre	hectare, ha	2.47
4.05 × 103	acre	square meter, m^2	2.47 × 10–4
9.29 × 10–2	square foot, $ft.^2$	square meter, m^2	10.76
2.59	square mile, $mi.^2$	square kilometer, km^2 $(103\ m)^2$	0.386
Volume			
35.24	bushel (dry), bu.	liter, L	2.84 × 10–2
28.3	cubic foot, $ft.^3$	liter, L	3.53 × 10–2
2.83 × 10–2	cubic foot, $ft.^3$	cubic meter m^3	35.3
1.64 × 105	cubic inch, $in.^3$	cubic meter, m^3	6.10 × 104
3.78	gallon, gal.	liter, L	0.265
2.96 × 10–2	ounce (liquid), oz.	liter, L	33.78
Mass			
28.4	ounce, oz.	gram, g	3.52 × 10–2
454	pound, lb.	gram, g	2.20 × 10–3
0.454	pound, lb.	kilogram, kg	2.205
907	ton (2,000 lb.), ton	kilogram, kg	1.10 × 10–3
Yield and Rate			
35.84	32-lb. bushel per acre	kilogram per hectare	2.79 × 10–2
53.75	48-lb. bushel per acre	kilogram per hectare	1.86 × 10–2
62.71	56-lb. bushel per acre	kilogram per hectare	1.59 × 10–2
67.19	60-lb. bushel per acre	kilogram per hectare	1.49 × 10–2
9.35	gal. per acre	liter per hectare	0.107
1.12	lb. per acre	kilogram per hectare	0.893
Temperature			
5/9 (°F – 32)	Fahrenheit, °F	Celsius, °C	(9/5 °C) + 32

BROADENING AWARENESS...

AMAZING ASPECTS: Metric Money

As a whole, Americans have been reluctant to adopt the metric system in everyday life. The inch, foot, gallon, and pound are engrained in society. Although efforts to change have been made, little progress has resulted.

It makes it all that more astounding when looking at our monetary system. The Mint Act of 1792 resulted in the United States becoming the first country to use a decimal point currency. At that time, countries relied on different forms of currency. For example, England relied on the British pence/shilling/pound. Twelve pence equaled a shilling, and 20 schillings amounted to a pound. The notion of having 100 pennies equal a dollar was innovative for the time.

RULERS AND TAPE MEASURES

Most construction in this country is handled using **standard English measurement**, which is units in inches, feet, and yards. **Metric measurements** are units in millimeters, centimeters, and meters—used in many other countries.

Tape Measures

Linear distance is the amount of space between two points. It can be measured with a **tape measure**, which is a type of flexible ruler that rolls or winds up. The markings may differ, depending on their purpose. A measuring tape used in carpentry often uses a spring, which allows it to roll up. The metal hook on the end of the tape measure is called a **floating tang**. It is attached to the tape by loose rivets that allow the tape to be accurate when measuring from the inside or outside. A tape measure can range in size from 1 ft. to 300 ft. in length. The **100-foot wind-up tape** is a device useful in building layout work where distances of more than 30 feet must be measured. Little maintenance is required. However, bending a measuring tape can cause it to break or tear.

FIGURE 4. A tape measure is a type of flexible ruler that rolls or winds up.

An **electronic tape measure** is a tool that uses a laser to determine linear distance. It is accurate and displays a reading on a digital screen. Advantages of use over traditional tape measures include increased accuracy, ease of use, and increased range. These tools often display readings in multiple measurement units with the push of a button.

Rulers

A **ruler** is a thin strip of wood, metal, or plastic with a straight edge and markings in whole and fractional units of length (e.g., inches or centimeters) used in measuring length. Two types of scale rulers or scales are used in design work: the architect's scale and the engineer's scale.

The architect's scale is commonly used for architectural plans, landscape plans, and construction work. Its markings are similar to those found on rulers and tape measures. The architect's scale can be used easily for scale measurements of $^1/_{16}$, $^1/_8$, and $^1/_4$ inch. A ruler can be used to read the plan prepared with an architect's scale. The preferred scale for design work is $^1/_8$ or $^1/_4$. With $^1/_8$ scale, $^1/_8$ of an inch on the plan represents 1 foot. One inch on the plan represents 8 feet (1 inch equals 8 × $^1/_8$, or $^8/_8$). If the chosen scale is followed strictly, all measurements will be accurate.

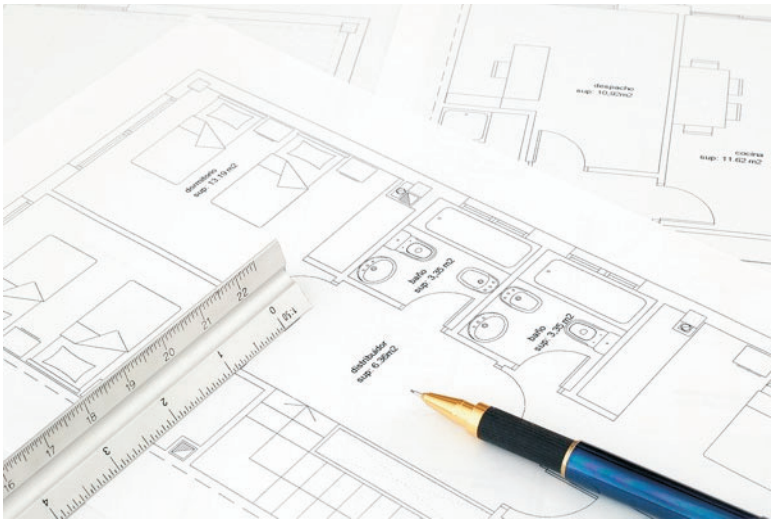

FIGURE 5. The architect's scale is commonly used for architectural and landscape plans and construction work.

The engineer's scale is used in surveying. It is divided into tenths and is used to produce $^1/_{10}$-, $^1/_{20}$-, $^1/_{50}$-, and $^1/_{100}$-scale drawings.

Summary:

Measurement is the act of determining the extent, dimension, or quantity of something. The United States customary system and the International System of Units gauge these quantities by using different units.

The United States customary system of measurement is a system of measure based on Imperial units used in countries influenced by the British Empire. The International System of Units (SI) is a modern standardized form of the metric system. The metric system is a decimal system of measurements in which all units are based on multiples of 10. Its units can be easily converted between measurements.

Most construction in this country is done using the United States customary system with units of inches, feet, and yards. Metric measurements using millimeters, centimeters, and meters are used in many other countries.

Linear distance can be measured with a tape measure. Two types of scale rulers or scales are the architect's scale and the engineer's scale.

Checking Your Knowledge:

1. How do the United States customary system of measurement and the International System of Units compare?
2. What are advantages to the International System of Units?
3. How are measurements converted between the United States customary system of measurement and the International System of Units?
4. How are tape measures used?
5. How do the architect's scale and the engineer's scale compare?

Expanding Your Knowledge:

Practice using the metric system around your house. Obtain yardsticks and meter sticks, and then measure a wide variety of items in your house. Compare the measurements. Look at food containers, and determine the volume and weight in both the English and metric systems. Convert your weight to kilograms. Use your imagination as to what to measure.

Web Links:

Metric and English Systems
http://mathbitsnotebook.com/Algebra1/Units/UNMetricEnglish.html

Metric System
http://www2.seminolestate.edu/rrapalje/Tech-Prep-Math/Metric%20System.htm

Metric
http://www.metric4us.com/

Conversion Charts and Practice Activities
http://www.aaamath.com/mea.html

Agricultural Career Profiles
http://www.mycaert.com/career-profiles