

MEASUREMENT SYSTEMS

Introduction

Measurements are used in business, industry, medicine and our daily lives. The system of measurement used throughout most of the world is the International System of Units (SI) and is commonly referred to as the metric system. Here, in the United States, a non-metric system is used. It's called the U.S. Customary or English System. In this unit we'll examine the principles and procedures common to both of these systems of measurement.

Metric System

The metric system uses fourteen prefixes that denote the size of the metric unit. These prefixes are: tera, giga, mega, kilo, hecto, deka, deci, centi, milli, micro, nano, pico, femto and atto. Rest easy though. The most commonly used ones and those you should know how to manipulate are the ones listed in Table M-1 below.

Table M-1 Metric Prefixes

<u>Prefix</u>	<u>Symbol</u>	<u>Power of Ten</u>
Kilo	k	$10^3 = 1000$
Hecto	h	$10^2 = 100$
Deka	da	$10^1 = 10$
Deci	d	$10^{-1} = \frac{1}{10}$
Centi	c	$10^{-2} = \frac{1}{100}$
Milli	m	$10^{-3} = \frac{1}{1000}$

The metric system is considered easy to learn and use because it is a decimal system in which all the units are related by powers of ten. That is, conversions from one unit to another are accomplished by multiplying or dividing by a power of ten. The basic units of measure used in the metric system along with their abbreviations are:

- Meter (m) – used for measuring length
- Liter (L) – used for measuring volume
- Gram (g) – used for measuring weight

In the tables that follow (Tables M-2, M-3, and M-4) each prefixed unit of measure is related to its respective basic unit. Note that in each instance the basic unit is multiplied or divided by a power of ten to produce the desired measure.

Table M-2 Meters

<u>Unit</u>	<u>Abbreviation</u>	<u>Number of Meters</u>
1 kilometer	1 km =	1000 meters (1000m)
1 hectometer	1 hm =	100 meters (100m)
1 dekameter	1 dam =	10 meters (10m)
1 meter	1 m =	1 meter 1m (the basic unit)
1 decimeter	1 dm =	$\frac{1}{10}$ of a meter $\left(\frac{1}{10}\text{m}\right)$
1 centimeter	1 cm =	$\frac{1}{100}$ of a meter $\left(\frac{1}{100}\text{m}\right)$
1 millimeter	1 mm =	$\frac{1}{1000}$ of a meter $\left(\frac{1}{1000}\text{m}\right)$

Table M-3 Liters

<u>Unit</u>	<u>Abbreviation</u>	<u>Number of Liters</u>
1 kiloliter	1 kl	1000 liters (1000l)
1 hectoliter	1 hl	100 liters (100l)
1 dekaliter	1 dal	10 liters (10l)
1 Liter	1 l	1 liter (the basic unit)
1 deciliter	1 dl	$\frac{1}{10}$ of a liter $\left(\frac{1}{10}\text{l}\right)$
1 centiliter	1 cl	$\frac{1}{100}$ of a liter $\left(\frac{1}{100}\text{l}\right)$
1 milliliter	1 ml	$\frac{1}{1000}$ of a liter $\left(\frac{1}{1000}\text{l}\right)$

Table M-4 Grams

<u>Unit</u>	<u>Abbreviation</u>	<u>Number of Grams</u>
1 kilogram	1 kg	1000 grams (1000g)
1 hectogram	1 hg	100 grams (100g)
1 dekagram	1 dag	10 grams (10g)
1 gram	1 g	1 gram (the basic unit)
1 decigram	1 dg	$\frac{1}{10}$ of a gram $\left(\frac{1}{10}\text{g}\right)$
1 centigram	1 cg	$\frac{1}{100}$ of a gram $\left(\frac{1}{100}\text{g}\right)$
1 milligram	1 mg	$\frac{1}{1000}$ of a gram $\left(\frac{1}{1000}\text{g}\right)$

Conversions Within the Metric System

When converting from one unit of metric measure to another similar unit of metric measure all that needs to be done is to shift the decimal point. Use figure 1 and the procedure we've outlined below.

kilo (k)	hecto (h)	deka (da)	meter (m) liter (l) gram (g)	deci (d)	centi (c)	milli (m)
1000	100	10	1	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$


Fig. 1

Converting Within the Metric System

1. Identify the location of the given unit of measure and mentally place the decimal point in that position.
2. Move the decimal point to the location of the desired unit of measure.
3. Count the number of places the decimal point was moved and move the decimal point in the number to be converted the same number of places, adding zeros as necessary.
4. When changing from square units to other square units (area) move the decimal point twice as many places as the number of places counted.
5. When changing from cubic units to other cubic units (volume), move the decimal point three times as many places as the number of places counted.


EXAMPLE 1: Change 2.37 grams to kilograms

Solution: Using figure 1 we see that the decimal point would have to be moved from grams to kilograms, a shift of 3 places to the left.

$$2.37 \text{ grams} = 002.37 = .00237 \text{ kilograms}$$


EXAMPLE 2: Change 1.5cm² (square centimeters) to mm² (square millimeters)

Solution: The movement of the decimal point is one place to the right, but because we're making a change involving area, we must double the number of places we move the decimal.

$$1.5\text{cm}^2 = 150 = 150\text{mm}^2$$


EXAMPLE 3: Convert 3.94m³ to mm³

Solution: The number of places we move the decimal must be tripled because we're dealing with volume.

$$3.94\text{m}^3 = 3940000 = 3,940,000\text{mm}^3$$

$3 \times 3 \text{ places} = 6 \text{ place shift}$



The U.S. Customary System

The system of measurement used in the United States is referred to as the U.S. Customary System. Sometimes referred to as the English system of measurement, it contains relationships for length, volume and weight just like the metric system. Although the United States is moving towards the adoption of a metric system of measurement as its standard, conversions between the metric and U.S. system are sometimes a necessity. Just as in the metric system, conversions within the U.S. Customary system are also completed.

Conversions Between Systems

When making conversions from one system to another we use conversion factors and a procedure commonly referred to as dimensional analysis. Table M-5 lists some of the most commonly used conversion factors. Dimensional analysis requires the multiplication of conversion factors in such a way that the units of measure to be changed cancel out. Making conversions of this kind is a little like following a road map. We must first identify our starting point and our destination. We then pick appropriate intermediate locations to pass through on our way to this destination.

Table M-5 Conversion Factors

U.S. Customary System		
Length	Volume	Weight
1 foot (ft) = 12 inches (in)	1 pint (pt) = 16 fluid ounces (oz.)	1 pound (lb) = 16 ounces (oz.)
1 yard (yd) = 3 feet (ft)	1 quart (qt) = 2 pints (pt)	1 ton = 2000 pounds (lb)
1 mile (mi) = 5280 feet (ft)	1 gallon (gal) = 4 quarts (qt)	
Metric System		
Length	Volume	Weight
1 meter = 39.37 in	1 ml = .03 fluid oz	1 gram = .04 oz
1 meter = 3.28 ft	1 l = 2.1 pints	1 kg = 2.20 lbs
1 meter = 1.09 yd	1 l = 1.06 qt	1 oz = 28.35 g
1 cm = .39 in	1 l = .26 gal	1 lb = .45 kg
1 mm = .04 in	1 fluid oz = 30 ml	
1 km = .62 mile	1 pt = .47 liter	
1 in = 25.4 mm	1 quart = .95 liter	
1 in = 2.54 cm	1 gallon = 3.8 liter	
1 in = .03 m		
1 ft = .30 m		
1 yd = .91 m		
1 mile = 1.61 km		
Time		
1 minute = 60 seconds		
1 hour = 60 minutes		
1 day = 24 hours		
1 week = 7 days		
1 year = 365 days		
1 year = 52 weeks		
1 year = 12 months		

Note: Slightly different values can be obtained when using different forms of conversion factors. For example: 1cm = .39in or 1 in = 2.54cm.

Mechanically, we follow the steps in this procedure.

Converting Between the Metric and English Systems

1. Set up the unit of measure to be converted as a fraction with the dimension to be changed in the numerator.
2. From Table M-5 select conversion factor(s) that contain the dimensions to be changed. Express these conversion factor(s) as unit fractions with the dimension to be eliminated in the denominator.
3. Cancel dimensions and multiply the remaining fractions to arrive at the desired value and unit of measure.

Note: Use this pattern when making these conversions.

$$\frac{\text{Units to be converted}}{1} \times \frac{\text{Conversion Factor}}{\text{Units to be converted that are equivalent to the conversion factor above.}}$$

EXAMPLE 4: Convert 13ft to inches

Solution:

$$\frac{\text{Units to be converted}}{1} \times \frac{\text{Conversion Factor}}{\text{Units to be converted that are equivalent to the conversion factor above.}}$$

$$\frac{13\cancel{\text{ft}}}{1} \times \frac{12 \text{ in}}{1\cancel{\text{ft}}} = 13 \times 12 \text{ in} = 156 \text{ in}$$

Remember that we are trying to cancel feet; thus, we selected the conversion factor 12 inches = 1 foot and place 1 ft in the denominator so that it cancels with the diagonal factor feet in 13 ft.

EXAMPLE 5: Convert 3.2 lbs to grams using Table M-5.

Solution: From Table M-5 we see that 1 pound = 16 ounces and 1 gram = 0.04 ounces. Multiply the following unit fractions so that the appropriate dimensions cancel and the desired dimension remains.

$$\frac{3.2 \cancel{\text{lbs}}}{1} \times \frac{16 \cancel{\text{oz}}}{1 \cancel{\text{lb}}} \times \frac{1 \text{ gram}}{.04 \cancel{\text{oz}}} = \frac{51.2 \text{ grams}}{.04} = 1280 \text{ grams}$$

EXAMPLE 6: Convert 72 inches to meters

Solution:
$$\frac{72 \cancel{\text{inches}}}{1} \times \frac{2.54 \cancel{\text{cm}}}{1 \cancel{\text{inch}}} \times \frac{1 \text{ meter}}{100 \cancel{\text{cm}}} = 1.8288 \text{ meters}$$

Combining Measurements

When adding or subtracting measurements, it is important to remember that only similar units can be combined. Use these steps when combining (adding or subtracting) measurements.

Combining Measurements

1. Arrange the numbers so that like units of measure are lined up in the same vertical column.
2. Add or subtract.
3. Simplify by making any necessary conversions.

EXAMPLE 7: Combine 13lbs 8ozs with 14lbs 9ozs

Solution:
$$\begin{array}{r} 13\text{lbs } 8\text{ozs} \\ 14\text{lbs } 9\text{ozs} \\ \hline 27\text{lbs } 17\text{ozs} \end{array}$$

Now convert 17ozs to 1lb 1oz and add to 27 lbs

$$\begin{array}{r} 27\text{lbs } 0\text{oz} \\ 1\text{lb } 1\text{oz} \\ \hline 28\text{lbs } 1\text{oz} \end{array}$$

EXAMPLE 8: Subtract 7ft 8in from 13ft 2in.

Solution:
$$\begin{array}{r} 13\text{ft } 2\text{in} \\ - 7\text{ft } 8\text{in} \\ \hline \end{array}$$

Here, we change 13ft to 12ft 12in. We add 2in to 12ft 12in to get 12ft 14 inches.

$$\begin{array}{r} 12\text{ft } 14\text{in} \\ - 7\text{ft } 8\text{in} \\ \hline 5\text{ft } 6\text{in} \end{array}$$

Multiplying or Dividing Measurements

Follow these steps when multiplying or dividing a measurement by a whole number.

Multiplying/Dividing Measurements

1. Multiply or divide each part of the measurement by the whole number.
2. Simplify by making any necessary conversions.

EXAMPLE 9: Multiply 5ft 3in by 4.

Solution:
$$\begin{array}{r} 5\text{ft} \quad 3\text{in} \\ \times \quad 4 \\ \hline 20\text{ft} \quad 12\text{in} \end{array}$$

Convert 12in to 1ft.
20ft + 1ft = 21ft

EXAMPLE 10: Divide 28lbs 14ozs by 7.

Solution:
$$\frac{28\text{lbs} \quad 14\text{ozs}}{7} = 4\text{lbs} \quad 2\text{ozs}$$

Applications

EXAMPLE 11: Diane purchases 4.5 meters of fabric while on vacation in Spain. She is wondering how many yards this would be equivalent to in the United States. Calculate the equivalent.

Solution: From Table M-5 we see that 1yd = .91 meter

We multiply

$$\frac{4.5\cancel{\text{meters}}}{1} \times \frac{1\text{yd}}{.91\cancel{\text{meter}}}$$

= approximately 4.9 yards

EXAMPLE 12: Neil purchases a stepladder with a load limit of 90kg. He is trying to determine what the load limit is in pounds. Determine the load limit.

Solution: From Table M-5 we see that 1 pound = .45 kilogram

We multiply

$$\frac{90\text{kg}}{1} \times \frac{1\text{lb}}{.45\text{kg}}$$

= 200 lbs

EXAMPLE 13: Tom travels for a total of 2hrs 36min making the trip to his brother's house for the holiday. His sister travels the same distance having left at exactly the same time. She arrives however, 27 minutes later. What was Tom's sister's driving time?

Solution: Add: 2hrs 36min + 0hrs 27min
= 2hrs 63 min
Since 63 min = 1hr 3min we add:
2hrs + 1hr 3min and get 3hrs 3min

EXERCISES SET A

Fill in the blanks.

- | | |
|---------------------------------------|--|
| 1) 1 kiloliter = _____ liters | 2) 1 centimeter = _____ meter |
| 3) 1 decigram = _____ gram | 4) $\frac{1}{1000}$ of a liter = _____ |
| 5) $\frac{1}{100}$ of a meter = _____ | 6) 10 grams = _____ dekagram |
| 7) 1000 meters = _____ | 8) 1 milliliter = _____ liter |

Identify the power of ten associated with each of the following prefixes.

- | | |
|-------------------|-------------------|
| 9) deci = _____ | 10) kilo = _____ |
| 11) milli = _____ | 12) deka = _____ |
| 13) hecto = _____ | 14) centi = _____ |

EXERCISE SET B

Perform the following conversions within the metric system.

- 15) 295 dekagrams = _____ decigrams
- 16) 5.53 cl = _____ L
- 17) .083hl = _____ dl
- 18) .795hm = _____ cm
- 19) .006711 = _____ kl
- 20) $2.76\text{cm}^2 =$ _____ mm^2
- 21) $426\text{cm}^2 =$ _____ m^2
- 22) $1.25\text{m}^3 =$ _____ mm^3
- 23) .095 cubic centimeters = _____ cubic millimeters
- 24) 12 grams = _____ mg
- 25) 14 km = _____ cm
- 26) 5 hectoliters = _____ ml

- 27) 37.9dam = _____ cm
 28) 1240l = _____ ml
 29) 0.014dg = _____ cg
 30) 0.051km = _____ cm

EXERCISE SET C

Perform the following conversions within the U.S. Customary System

- 31) 10yd = _____ ft
 32) 48in = _____ ft
 33) 48oz = _____ lbs
 34) 5 gallons = _____ qts
 35) 16pt = _____ qt
 36) 3lbs = _____ ozs
 37) $\frac{5}{8}$ lb = _____ oz
 38) $1\frac{5}{6}$ yds = _____ inches
 39) 120ft = _____ yds
 40) 17pt = _____ qt

EXERCISE SET D

Perform the following conversions using the dimensional analysis approach. Round answers to the nearest hundredth.

- 41) 100m = _____ yd
 42) 48km = _____ miles
 43) 30in = _____ cm
 44) .60lbs = _____ kg
 45) 20qts = _____ liters
 46) 1,400lbs = _____ kg
 47) 1.5yd = _____ cm
 48) 8oz = _____ kg
 49) 5ft = _____ m
 50) 12kg = _____ oz
 51) 4.2m = _____ ft
 52) 2.4l = _____ pt
 53) 16m = _____ inches
 54) 1.25l = _____ qt
 55) 10.6gallons = _____ liters

EXERCISE SET E

Combine the following. Simplify as necessary.

- 56) $(17\text{ft } 3\text{in}) + (5\text{ft } 2\text{in})$
- 57) $(8\text{ft } 3\text{in}) - (4\text{ft } 3\text{in})$
- 58) $(13\text{lb } 7\text{oz}) - (10\text{lb } 12\text{oz})$
- 59) $(9\text{lb } 10\text{oz}) + (2\text{lb } 10\text{oz}) + (7\text{lb } 12\text{oz})$
- 60) $(8\text{yd } 2\text{ft } 4\text{in}) + (2\text{yd } 1\text{ft } 8\text{in}) + (6\text{yd } 0\text{ft } 3\text{in})$

Multiply or divide as indicated. Simplify as necessary.

- 61) $(7\text{ft } 8\text{in}) \times 4$
- 62) $(16\text{yd } 5\text{ft}) \times 3$
- 63) $(19\text{lb } 15\text{oz}) \times 5$
- 64) $(27\text{gallons } 3\text{quarts}) \div 3$
- 65) $(18\text{yd } 2\text{ft}) \div 4$

EXERCISE SET F

- 66) Ronnie purchases a 40 fluid ounce bottle of vegetable oil, thinking it amounted to 2 quarts. How many fluid ounces less than 2 quarts is it?
- 67) A local youth center hosting a Halloween party estimates it needs 23 pounds of candy. Each bag it purchases weighs 12 ounces. How many bags should be purchased.
- 68) Karen rode her bicycle in a benefit race. She rode 24 miles according to an odometer she has mounted to her handlebars. The actual distance is reported in kilometers, however. How many kilometers did she ride?
- 69) How many liters of gas would be needed to fill an 18 gallon gas tank?
- 70) Shawn Carey swam a 200 meter race but wants to know how many yards this distance is. Calculate the equivalent distance in yards. Round the answer to the nearest whole yard.
- 71) A doctor's order is written ordering 1.25 liters of fluid. Express this amount in quarts.
- 72) A pill contains 60mg of a drug. Calculate the total number of grams in a bottle containing 200 pills.
- 73) Two yards of fabric must be trimmed with lace. The lace is measured in centimeters. Calculate how many centimeters must be purchased to complete the job.
- 74) A square-shaped room measures 9ft 7in on a side. Determine the total length of molding that must be purchased if it is to be installed on each side of the room.
- 75) A 38ft 6in length of pipe is to be divided into six equal parts. What is the length of each part?
- 76) Jody skied cross-country a distance of 12 miles in 2hrs 40 minutes. What was her average rate in miles per hour?
- 77) The dimensions of an L-shaped room are 6ft 4in; 8ft 3in; 14ft 6in; 20ft 9in; 8ft 2in; 12ft 6in. Calculate the total length of the six sides of the room.

