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ABSTRACT

After an introduction including a brief history of measurement, conversion of units within the customary system, within the metric system, and from customary to metric and vice versa a discussed. A fraction/multiplication system is introduced to teach correct alignment of units of measurement and to direct proper multiplication and division of conversion factors. A number of solved examples are given, as well as several problems to be solved by the reader. It is suggested that successful completion of the problems should increase confidence in the student's ability to convert between measurement systems. (Author/PK)

# HOW TO CONVERT UNITS OF LENGTH FROM THE CUSTOMARY SYSTEM TO THE METRIC SYSTEM AND BACK

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## Abstract

After an introduction including a brief history of measurement, the paper discusses conversion of units within the customary system, within the metric system, and from customary to metric and vice versa. A fraction/multiplication system is introduced to teach correct alignment of units of measurement and to direct proper multiplication and division of conversion factors. A number of solved examples are given, as well as several problems to be solved by the reader.

HOW TO CONVERT UNITS OF LENGTH FROM THE CUSTOMARY SYSTEM TO THE METRIC SYSTEM AND BACK

The United States is "going metric".

In December, 1975, President Gerald Ford signed the Metric Conversion Act which established a 17 member Metric Board delegated with the responsibility for devising and coordinating a plan to increase the use of the metric system of measurement in the United States, making this country the last technologically developed nation in the world to adopt the metric system. All other nations which are highly developed in scientific technology already had utilized metric measurement. Since the metric system has certain advantages over the customary system of measurement, and because international trade between the nations of the world is conducted predominantly in metric measures, it had become almost an economic necessity for the United States to begin using the metric system. Americans, therefore, have been faced with the task of learning to use a new system of measurement and how to convert from one system to another.

Some History of Measurement

Ever since man has been able to move from place to place and converse with his fellow man there has been the need for a method of expressing distance or length. In the trading of goods and services there arose needs for units of measure in weight (mass), volume (capacity), and in time.

For many years rather crude methods of measurement were used. Grain was measured by adding enough grain to a balance to equalize the weight of a given number of stones on the opposite arm. The distance from a man's elbow to the end of his fingers was called a cubit and was a standard unit of length or distance. A foot was the length of a man's foot. These methods were useful but not very precise. Not all stones weigh the same and the arms or feet of one man are not often equal in length to those of another. After a considerable number of fistfights and other expressions of disagreement, it was decided that trade relations would be more peaceful if standards were established. The King was selected as the standard. A yard was defined as the distance from the tip of the King's nose to the end of his outstretched hand with the arm fully extended in a horizontal position. This approach to measurement was an improvement, but still the standard varied from nation to nation and changed within the nation when a new king gained power.

In 1875, a laboratory known as the International Bureau of Weights and Measures was set up by international treaty for the purpose of preparing, measuring, and preserving the standards of the international metric system. The meter was selected to be the fundamental unit of length and was originally intended to be one ten-millionth of the distance from the equator to the North Pole along the Paris meridian. However, it was found to be easier and more precise to compare two meter bars with each other than to relate them to the meridian so the standard meter was defined as the distance between two parallel lines on a platinum-iridium bar which was preserved at the International Bureau of Weights and Measures.

This standard presented some problems because it was not indestructible. It was subject to alteration and damage if moved or used. A more stable standard was sought, and in 1960 the International

General Conference on Weights and Measures redefined the meter as 1,650,763.73 times the wavelength of orange light emitted by a pure isotope (atomic mass 86) of krypton. This standard permits measurement which is more precise than that allowed by the platinum-iridium bar and has the added advantage that it can be generated at any location where the necessary equipment is available.

## Converting Units within the Customary System

Almost all Americans are familiar with the units of length or distance commonly used in the customary system, i.e., the inch, the foot, the yard, and the mile. Furthermore, most individuals can perform conversions within the customary system. To illustrate this point, answer the following three questions:

1. How many inches are there in one foot?
2. How many feet are there in one yard?
3. How many inches are there in one yard?

In answering these three questions you have performed three conversions. The answers 12 inches, three feet, and 36 inches, respectively, are basic conversion factors with which most Americans are familiar. Not all conversions are quite this simple but they really are not very hard. Try these two:

4. How many inches are there in 3.5 yards?
5. How many yards are there in 126 inches?

Solving these two problems (126 inches and 3.5 yards, respectively) required the use of two important operations. First, you had to remember the conversion factor, 36 in/yd. Second you had to decide whether to multiply by 36 or divide by 36. In the two problems this choice was relatively easy because most persons frequently encounter these units and this type of conversion, and consequently remember how to perform the calculations. It is possible, though, for one to forget values of conversion factors and to make a mistake when deciding whether to multiply or divide, especially when converting from the customary system to the metric system and vice versa. For example, try the following conversion:

6. Convert 0.25 miles into inches.

Did you get 15,840 inches as an answer? If so, did you remember that there are 63,360 inches in one mile and solve it in this manner?

0.25 mi x 63360 in/mi = 15,840 in

Or did you solve the problem in a series of steps--perhaps in a way similar to this?

0.25 mi x 5280 ft/mi = 1320 ft

1320 ft x 12 in/ft = 15,840 in

Or like this?

0.25 mi x 1760 yd/mi = 440 yd

440 yd x 3 ft/yd = 1320 ft

1320 ft x 12 in/ft = 15,840 in

As you can see, there are several ways to perform the conversion, all of which give the correct answer. The conversion is rather easy and you may have solved it readily, even with a method different from those above. Nevertheless, it might take you a little longer to figure out how many square meters of carpet are needed in order to cover 1850 square feet of floor area. If you can solve this problem in two minutes or less, you probably don't need to read this paper (Answer: 172 square meters).

Earlier it was mentioned that it is possible to make a mistake in deciding whether to multiply or divide when converting units. Although such mistakes are occasionally made when working within the customary system, they occur much more frequently when converting from the customary to the metric system. Before proceeding to the metric system, let us practice using a method or approach which is designed to help us remember whether to multiply or divide.

Suppose your task is to convert 22,176 inches into miles. If you happen to remember that there are 63,360 inches in one mile, you can divide 22,176 by 63,360 and get the answer. Suppose, though, that you can't remember this particular conversion factor but can remember how many inches there are in one foot, how many feet per yard, and how many yards per mile. The following method will help you think your way through any conversion problem.

Step 1: Take the given distance and write it as a fraction by writing the given distance over a denominator of 1. Be sure to include the unit of measurement:

$$\frac{22{,}176 \text{ in}}{1}$$

Remember, dividing a number by 1 does not change its value. Therefore, the above process did not change the distance.

Step 2: Write a multiplication sign following the fraction formed in step 1, draw a line to form another fraction, and write the units of measure which appear in the original fraction ("in") in the denominator of the second fraction:

$$\frac{22{,}176 \text{ in}}{1} \times \frac{\phantom{mi}}{\text{in}}$$

Step 3: Decide what unit you wish to convert to and write the symbol for this unit in the numerator. If you happen to remember the factor for converting directly from the units given into the units desired, the conversion may be completed in one multiplication or division operation. For the sample problem, write:

$$\frac{22{,}176 \text{ in}}{1} \times \frac{\text{mi}}{\text{in}}$$

Step 4: Insert the numerical values of the conversion factor into the fraction and complete the multiplication. In the example being used, note that the conversion factor is 63,360 inches in one mile. Reading this correctly is important because it tells you to put 63,360 by the inches (in the denominator), and the number 1 by miles (in the numerator).

$$\frac{22{,}176 \text{ in}}{1} \times \frac{1 \text{ mi}}{63{,}360 \text{ in}} = 0.35 \text{ mi}$$

Note that the units cancel, i.e., inches cancel inches, leaving only miles, and the answer is expressed in miles. This also is very important because all units should cancel except the units for the final answer. If all units except the final units do not cancel out, then the problem is set up incorrectly.

Suppose that you do not remember the factor for converting inches into miles and vice versa. You may still get the answer by following another route. The example given above may be solved in other ways:

<u>Solution No. 1</u>:

Step 1: $\frac{22{,}176 \text{ in}}{1}$

Step 2: $\frac{22{,}176 \text{ in}}{1} \times \frac{\text{ft}}{\text{in}}$

Step 3: $\frac{\text{22,176 in}}{1} \times \frac{\text{1 ft}}{\text{12 in}}$

Step 4: $\frac{\text{22,176 in}}{1} \times \frac{\text{1 ft}}{\text{12 in}} \times \frac{\underline{\qquad}\ \text{mi}}{\text{ft}}$

Step 5: $\frac{\text{22,176 in}}{1} \times \frac{\text{1 ft}}{\text{12 in}} \times \frac{\text{1 mi}}{\text{5280 ft}}$

Step 6: $\frac{\text{22,176 in}}{1} \times \frac{\text{1 ft}}{\text{12 in}} \times \frac{\text{1 mi}}{\text{5280 ft}} = \frac{\text{22,176 mi}}{\text{63,360}} = 0.35\ \text{mi}$

Solution No. 2: (omitting the steps)

$$\frac{\text{22,176 in}}{1} \times \frac{\text{1 ft}}{\text{12 in}} \times \frac{\text{1 yd}}{\text{3 ft}} \times \frac{\text{1 mi}}{\text{1760 yd}} = 0.35\ \text{mi}$$

Solution No. 3: (omitting the steps)

$$\frac{\text{22,176 in}}{1} \times \frac{\text{1 yd}}{\text{36 in}} \times \frac{\text{1 mi}}{\text{1760 yd}} = 0.35\ \text{mi}$$

The solutions shown above illustrate that it is possible to use different routes (conversion factors) to solve a conversion problem. You know from using a road map that there are many ways to travel from New York to Los Angeles. Likewise, if you learn to use the technique of expressing conversion problems as a series of multiplications of fractions, then there are many different ways to solve the problem. Note that if the procedure above is followed, there will be no trouble deciding whether to divide or multiply. If the problem is "set up" correctly, the fractions indicate whether one should multiply or divide by the conversion factor.

## The Metric System

So far the discussion has dealt largely with the customary system. Because most people are familiar with this system, it was used for illustration. However, working with the metric system requires you to learn a new set of conversion factors. Fortunately, this task is easierthan might be expected, since all conversion factors are in multiples of ten, making the arithmetic easier. The prefixes most commonly used, their symbols, and their values are included in the following table:

Table 1

| | | | |
|---|---|---|---|
| deci | = d | = 0.1 | or $\frac{1}{10}$ |
| centi | = c | = 0.01 | or $\frac{1}{100}$ |
| milli | = m | = 0.001 | or $\frac{1}{1000}$ |
| deka | = dk | = 10 | |
| hecto | = h | = 100 | |
| kilo | = k | = 1000 | |

These six prefixes occur so often in metric measurement that they should be memorized. There are other prefixes in the metric system but they are used predominantly by scientists who deal with very large or very small numbers. It is less important that these be remembered but for the curious or needy they are presented in Table 2.

Table 2

| | | | | |
|---|---|---|---|---|
| Micro- | = | 0.000001 | = | $10^{-6}$ |
| Nano- | = | 0.000000001 | = | $10^{-9}$ |
| Pico- | = | 0.000000000001 | = | $10^{-12}$ |
| Mega- | = | 1,000,000 | = | $10^{6}$ |
| Giga- | = G = | 1,000,000,000 | = | $10^{9}$ |
| Tera- | = T = | 1,000,000,000,000 | = | $10^{12}$ |

Now you need to know the various conversion units. Close examination should convince you that what you really need to know is the basic unit of measure and the meaning of the prefixes. For practice why not build your own conversion table? Refer to Table 1 if you need and fill in the values for the following table:

Table 3

| | | |
|---|---|---|
| 1 meter (m) | = | ____________dm |
| 1 meter | = | ____________cm |
| 1 meter | = | ____________mm |
| 1 meter | = | ____________dkm |
| 1 meter | = | ____________hm |
| 1 meter | = | ____________km |

Does your table look like this?

Table 4

| | | |
|---|---|---|
| 1 meter (m) | = | 10 dm |
| 1 m | = | 100 cm |
| 1 m | = | 1000 mm |
| 1 m | = | 0.1 dkm |
| 1 m | = | 0.01 hm |
| 1 m | = | 0.001 km |

Perhaps you expressed the fractions as common fractions. If so, this is all right, but why not get in the habit of using decimals? It's easier and more convenient in the metric system.

Now we are ready to perform conversions within the metric system. Try the following conversion:

7. Change 3.5 kilometers into centimeters:

If you had any trouble with this conversion, try using the fraction/multiplication approach described earlier.

Step 1: $\frac{3.5 \text{ km}}{1}$

Step 2: $\frac{3.5 \text{ km}}{1} \times \frac{\_\_\_\_ \text{ m}}{\text{km}}$

Step 3: $\frac{3.5 \text{ km}}{1} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{100 \text{ cm}}{1 \text{ m}}$

Step 4: $\frac{3.5 \text{ km}}{1} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{100 \text{ cm}}{1 \text{ m}} = 350{,}000 \text{ cm}$

Try this problem:

8. Change 3500 mm into meters:

Did your solution look like this?

$$\frac{3500 \text{ mm}}{1} \times \frac{1 \text{ m}}{1000 \text{ mm}} = 3.5\text{m}$$

Or like this?

$$\frac{3500 \text{ mm}}{1} \times \frac{1 \text{ cm}}{10 \text{ mm}} \times \frac{1 \text{ m}}{100 \text{ cm}} = 3.5\text{m}$$

Have you noticed that in the metric system conversions always seem to require that one multiply or divide by 10 or by some number which is a power of ten (i.e., 100, 1000, or 0.01, 0.001)? This is one of the characteristics which make the metric system superior to the customary system. Our number system is based upon ten digits. A system of measurement in which the units differ by some power of ten makes the calculations much easier. Note that to multiply by 10 one needs only to move the decimal point one place to the right; to multiply by 100, move the decimal two places to the right; and to multiply by 1000, move the decimal point three places. To divide by these same numbers the decimal is moved a like number of places to the left. With a little practice, one can become quite adept at performing mentally conversions within the system, thus eliminating the need for pencil calculations. Try mental conversions in the customary system. Can you convert 8720 yards into miles mentally and feel really sure about the answer (1.65 mi)? Try converting 8720 meters into kilometers. By simply moving the decimal three places to the left you have the answer (8.72 k

## Converting from Customary to Metric and Vice Versa

Now comes the task of converting from one system to another. Except for the fact that the process involves the use of some "oddball" conversion factors (which one must either remember or look up in a book), the process is the same as that for converting within either system. The following table shows the equivalents between certain units of distance or length in the metric system and those in the customary system.

Table 5

| | | | |
|---|---|---|---|
| 1 | cm | = | 2.54 in |
| 1 | ft | = | .3048 m |
| 1 | m | = | 1.09361 yd |
| 1 | m | = | 39.37 in |
| 1 | km | = | 0.621372 mi |

Using the fraction/multiplication system and the information in Table 5, let us try a sample problem:

Convert 20 inches into centimeters.

Step 1: $\frac{20 \text{ in}}{1} \quad X \quad \frac{\_\_ \text{ cm}}{\text{in}}$

Step 2: $\frac{20 \text{ in}}{1} \quad X \quad \frac{2.54 \text{ cm}}{1 \text{ in}}$

Step 3: $\frac{20 \text{ in}}{1} \quad X \quad \frac{2.54 \text{ cm}}{1 \text{ in}} = 50.8 \text{ cm}$

Try performing the following conversions using the fraction/multiplication method and the conversion factors from Table 5:

9. Change 4.3 ft into meters:

10. Change 1760 yards into meters:

11. Change 2.5 meters into inches:

Do your solutions and rounded answers look like this?

$$\frac{4.3\text{ ft}}{1} \times \frac{0.3048\text{ m}}{1\text{ ft}} = 1.31\text{ m}$$

$$\frac{1760\text{ yd}}{1} \times \frac{1\text{ m}}{1.09361\text{ yd}} = 1609.35\text{ m}$$

$$\frac{2.5\text{ m}}{1} \times \frac{39.37\text{ in}}{1\text{ m}} = 93.43\text{ in}$$

Suppose you are faced with the task of converting 125 miles into kilometers and you can't remember the factor for converting miles into kilometers. If you remember your customary units and your metric prefixes and just one distance factor for converting from the customary to the metric system you can probably solve the problem. Suppose you do remember that one inch equals 2.54 centimeters. Why not convert the miles into inches, inches into centimeters, and then centimeters into kilometers?

$$\frac{125\text{ mi}}{1} \times \frac{5280\text{ ft}}{1\text{ mi}} \times \frac{12\text{ in}}{1\text{ ft}} \times \frac{2.54\text{ cm}}{1\text{ in}} \times \frac{1\text{ m}}{100\text{ cm}} \times \frac{1\text{ km}}{1000\text{ m}} = 201.17\text{ km}$$

Try performing the three previous conversions using the fact that one inch equals exactly 2.54 centimeters.

12. Change 4.3 ft into meters:

13. Change 1760 yards into meters:

14. Change 2.5 meters into inches:

Do your solutions and answers look like this?

$$\frac{4.3\ \text{ft}}{1} \times \frac{12\ \text{in}}{1\ \text{ft}} \times \frac{2.54\ \text{cm}}{1\ \text{in}} \times \frac{1\ \text{m}}{100\ \text{cm}} = 1.31\ \text{m}$$

$$\frac{1760\ \text{yd}}{1} \times \frac{3\ \text{ft}}{1\ \text{yd}} \times \frac{12\ \text{in}}{1\ \text{ft}} \times \frac{2.54\ \text{cm}}{1\ \text{in}} \times \frac{1\ \text{m}}{100\ \text{cm}} = 1609.34\ \text{m}$$

$$\frac{2.5\ \text{m}}{1} \times \frac{100\ \text{cm}}{1\ \text{m}} \times \frac{1\ \text{in}}{2.54\ \text{cm}} = 98.43\ \text{in}$$

Note that the answer to question 13 is slightly different from the answer to question 10 because the conversion factors in Table 5 are not exact as is the 2.54 cm per inch conversion factor.

Now that you have successfully completed these problems, you can feel satisfied that you can convert from the customary to the metric system and back as well as within these measurement systems. By using the fraction/multiplication system, you should be able to set up conversion problems correctly and should have no trouble performing multiplications and divisions of the units. With these skills, you can be an active participant in going metric.