# Measurement Systems

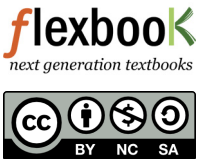
CK12 Editor

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-content, web-based collaborative model termed the **FlexBook®**, CK-12 intends to pioneer the generation and distribution of high-quality educational content that will serve both as core text as well as provide an adaptive environment for learning, powered through the **FlexBook Platform®**.



Printed: July 17, 2012







**AUTHORS**
CK12 Editor

# CONCEPT 1 Measurement Systems

## Lesson Objectives

The student will:

- state an advantage of using the metric system over the United States customary system.
- state the different prefixes used in the metric system.

## Vocabulary

**base unit** a unit that cannot be expressed in terms of other units, such as the gram (base unit of mass), the meter (base unit of length), and the liter (base unit of volume)

**metric system** an international decimal-based system of measurement

## Introduction

Even in ancient times, humans needed measurement systems for commerce. Land ownership required measurements of length, and the sale of food and other commodities required measurements of mass. The first elementary efforts in measurement required convenient objects to be used as standards, such as the human body. Inch and foot are examples of measurement units that are based on parts of the human body. The inch is based on the width of a man's thumb, and the foot speaks for itself. The grain is a unit of mass measurement that is based upon the mass of a single grain of wheat. Because grains of wheat are fairly consistent in mass, the quantity of meat purchased could be balanced against some number of grains of wheat on a merchant's balance.

It should be apparent that measuring the foot of two different people would lead to different results. One way to achieve greater consistency was for everyone to use the foot of one person, such as the king, as the standard. The length of the king's foot could be marked on pieces of wood, and everyone who needed to measure length could have a copy. Of course, this standard would change when a new king was crowned.

What were needed were objects that could be safely stored without changing over time to serve as standards of measurement. Copies of these objects could then be made and distributed so that everyone was using the exact same units of measure. This was especially important when the requirements of science necessitated accurate, reproducible measurements.

## The Metric System

The **metric system** is an international decimal-based system of measurement. Because the metric system is a decimal system, making conversions between different units of the metric system are always done with factors of ten. To understand why this makes the metric system so useful and easy to manipulate, let's consider the United

States customary system – that is, the measurement system commonly used in the US. For instance, if you need to know how many inches are in a foot, you need to remember: 12 inches = 1 foot. Now imagine that you now need to know how many feet are in a mile. What happens if you have never memorized this fact before? Of course, you can find this conversion online or elsewhere, but the point is that this information must be given to you, as there is no way for you to derive it by yourself. This is true about all parts of the United States customary system: you have to memorize all the facts that are needed for different measurements.

## Metric Prefixes and Equivalents

The metric system uses a number of prefixes along with the base units. A **base unit** is one that cannot be expressed in terms of other units. The base unit of mass is the gram (g), that of length is the meter (m), and that of volume is the liter (L). Each base unit can be combined with different prefixes to define smaller and larger quantities. When the prefix "centi-" is placed in front of gram, as in centigram, the unit is now $\frac{1}{100}$ of a gram. When "milli-" is placed in front of meter, as in millimeter, the unit is now $\frac{1}{1{,}000}$ of a meter. Common prefixes are shown in **Table** 1.1.

**TABLE 1.1: Common Prefixes**

| Prefix | Meaning | Symbol |
|---|---|---|
| pico- | $10^{-12}$ | p |
| nano- | $10^{-9}$ | n |
| micro- | $10^{-6}$ | $\mu$ (pronounced *mu*) |
| milli- | $10^{-3}$ | m |
| centi- | $10^{-2}$ | c |
| deci- | $10^{-1}$ | d |
| kilo- | $10^{3}$ | k |

Common metric units, their symbols, and their relationships to a base unit are shown below:

$$\begin{aligned} 1.00 \text{ picogram} &= 1.00 \text{ pg} = 1.00 \times 10^{-12} \text{ g} \\ 1.00 \text{ nanosecond} &= 1.00 \text{ ns} = 1.00 \times 10^{-9} \text{ g} \\ 1.00 \text{ micrometer} &= 1.00 \ \mu\text{m} = 1.00 \times 10^{-6} \text{ m} \\ 1.00 \text{ centimeter} &= 1.00 \text{ cm} = 1.00 \times 10^{-2} \text{ m} \\ 1.00 \text{ deciliter} &= 1.00 \text{ dL} = 1.00 \times 10^{-1} \text{ L} \\ 1.00 \text{ kilogram} &= 1.00 \text{ kg} = 1.00 \times 10^{3} \text{ g} \end{aligned}$$

You can express a given measurement in more than one unit. If you express a measured quantity in two different metric units, then the two measurements are metric equivalents. Common metric equivalents are shown below.

- Length:

$$\begin{aligned} 1{,}000 \text{ millimeters} &= 1 \text{ meter} \\ 100 \text{ centimeters} &= 1 \text{ meter} \\ 10 \text{ millimeters} &= 1 \text{ centimeter} \end{aligned}$$

- Mass:

$$\begin{aligned} 1{,}000 \text{ milligrams} &= 1 \text{ gram} \\ 1{,}000 \text{ grams} &= 1 \text{ kilogram} \end{aligned}$$

- Volume:

$$1 \text{ liter} = 1{,}000 \text{ milliliters}$$

## Lesson Summary

- The metric system is an international decimal-based system of measurement.
- The metric system uses a number of prefixes along with the base units.
- The prefixes in the metric system are multiples of 10.
- A base unit is one that cannot be expressed in terms of other units
- If you express a measured quantity in two different metric units, then the two measurements are metric equivalents.

## Further Reading / Supplemental Links

The following website provides more information about the metric system and measurements in chemistry.

- http://www.chemistry24.com/teach_chemistry/measurement-and-math-in-chemistry.html

## Review Questions

Fill in the blanks in **Table** 1.2.

**TABLE 1.2: Table for Review Question**

| **Prefix** | **Meaning** | **Symbol** |
|---|---|---|
| pico- | $10^{-12}$ | p |
| nano- | **?** | n |
| **?** | $10^{-6}$ | $\mu$ |
| milli- | $10^{-3}$ | **?** |
| centi- | **?** | c |
| deci- | $10^{-1}$ | **?** |
| **?** | $10^{3}$ | k |