

APPENDIX A

Systems of Measurement

Twelve inches make one foot; three feet, a yard. Five and a half yards are one rod; 40 rods equal a furlong; eight furlongs give us a mile; and three miles equal one league. So when the submarine in Jules Verne's famous novel dove to 20,000 leagues beneath the sea, it was 60,000 miles; 480,000 furlongs; 16,200,000 rods; 89,100,000 yards; 267,300,000 feet; or 3,207,600,000 inches below the ocean surface. Unless, of course, the submarine's crew was measuring its depth in marine leagues, which equal three nautical miles. The nautical mile is defined as 10 cable lengths. Unfortunately, the cable length has three values, depending on whether you are using the U.S. Navy, British Navy, or ordinary definitions.

Situations like this may seem somewhat absurd, and they are! However, they are also very real. Units of measurement vary from country to country and from one application to another. With many different systems of measurements communication is, at best, difficult. Thus, science (and most commerce in the world) relies on the metric system.

In the metric system units have been carefully defined and agreed upon by international convention. For example, lengths are measured in meters. A meter is defined in terms of the wavelength of one color of light emitted by a cesium atom. Thus units of measure can be agreed upon by people at any location.

More importantly, the units are related to one another by factors of ten: $1 \text{ m} = 100 \text{ centimeters} = 1000 \text{ millimeters} = 0.001 \text{ kilometers}$. The conversion to different units of length is just a matter of moving the decimal. The same is true for other units in the metric system. We simply move the decimal

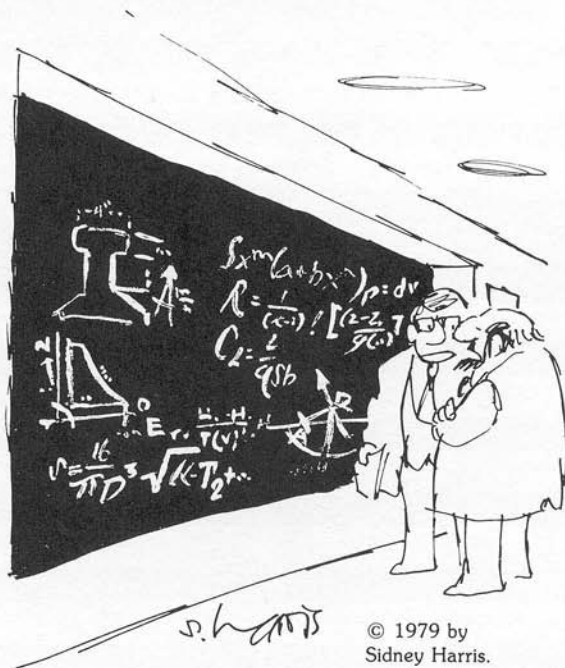
point to change from one unit to another. As shown in the table, the prefix tells us the relation between the basic unit and other derived units.

Prefix	Relation to Basic Unit
Micro	0.000001
Milli	0.001
Centi	0.01
Kilo	1,000
Mega	1,000,000

Thus, a millimeter is one-thousandth of a meter; a kilogram is 1000 grams. The basic unit for the most common physical quantities are listed below.

Measurement	Metric Unit
Length	meter (m)
Mass	gram (g)
Force	newton (N)
Energy	joule (J)
Power	watt (W)
Electric charge	coulomb (C)
Electric current	ampere (A)
Potential difference	volt (V)
Electrical resistance	ohm (Ω)
Temperature	degrees Celsius or Kelvin ($^{\circ}\text{C}$ or K)

The one unit of measurement that has never been converted to one based on tens is the basic unit of time. The second, minute, and hour are used universally, even though conversion among them is somewhat cumbersome.



"ALL RIGHT—NOW CONVERT
THE WHOLE THING TO METRIC."

You have probably studied the metric system, but since you may not use it every day, some of the units may seem a little unfamiliar. To help you become more comfortable with them, we list the comparison between metric units and the traditional English units.

1 centimeter	= 0.3937 inches
1 meter	= 1.09 yards = 3.28 feet = 39.37 inches
1 kilometer	= 3,280 feet = 0.621 miles
1 kilogram	= 0.0685 slugs (See note below)
1 newton	= 0.22 pounds
1 joule	= 0.24 calories = 0.00024 (food) Calories = 0.00095 BTU
1 meter/second	= 3.28 feet/second = 2.2 miles/hour
1 kilometer/hour	= 0.621 miles/hour

Note: The differences between metric and U. S. measures become particularly muddled when one attempts to describe mass—the amount of matter present. In the metric system, mass is commonly described in kilograms. The corresponding English unit, the slug, is seldom mentioned. In the United States, we usually express mass in terms of weight (a force of gravity on a particular mass), given in pounds. On earth, a mass of 1 kilogram (0.0685 slugs) has a weight of 2.2 pounds.