Units and Numbers

Measuring and Uncertainty

Today's Lecture

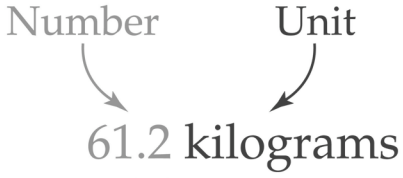
Units

- ►Why they Matter
- ►SI units
  - •Length
  - •Volume
  - •Mass (difference between mass and weight)

- ►Numbers

2.1 Physical Quantities

Physical properties such as height, volume, and temperature that can be measured are called **physical quantities**. Both a number and a unit of defined size is required to describe physical quantity.



About Numbers

- ►A number without a unit is meaningless.
  - What would it mean if I said that my height was 65? (You would probably guess that I mean inches, but it would not be clear.)
  - How about if I said my daughter was 14? Do I mean 14 years, 14 months or 14 weeks?
- ►To avoid confusion, we use units.
  - My height is 65 inches?
  - My daughters is 14 years old. (In this case we often leave the units off.)

About Units

We can units to describe what we are measuring, the type of measurement and the size of what we measured.

- Distance or length – inches, centimeters, yards, meters, miles
- Volume – teaspoons, milliliters, drams, liters, quarts, gallons
- Temperature – degrees fahrenheit, degrees celsius, degrees centigrade
- Time – seconds, half hours, days, years, light years
- Energy – calories, ergs, joules, kilowatts hour

About Units

To avoid confusion, scientists have agreed on a standard set of units. Scientists use SI, or the closely related metric units.

- Distance or length – ~~inches~~, centimeters, ~~yards~~, meters, ~~miles~~
- Volume – ~~teaspoons~~, milliliters, ~~drams~~, liters, ~~quarts~~, ~~gallons~~
- Temperature – ~~degrees fahrenheit~~, degrees celsius, degrees centigrade~~,~~ kelvin
- Time – seconds, ~~half hours~~, ~~days~~, ~~years~~, ~~light years~~
- Energy – ~~calories~~, ~~ergs~~, joules, kilowatts hour

About Units

In SI system and in the metric system prefixes are used to indicate the relative size of units.

Prefix	Example	Abbreviation	Symbol	factor	
				standard	scientific notation
Mega	megameter	Mm	M	1000,000	10
Kilo	kilometer	Km	K	1,000	10
(none)	meter	m	m	1	10^0
Deci	decimeter	dm	d	0.1	10^{-1}
Centi	centimeter	cm	c	0.01	10^{-2}
milli	millimeter	mm	m	0.001	10^{-3}
micro	micrometer	μm	μ	0.000001	10^{-6}

Prefixes and Meters

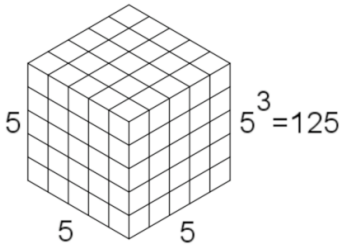
The meter (m) is the standard measure of length or distance in both the SI and the metric system.

- ► The length of a table 2.2 meters.
- ► The distance between Boston and Framingham is 34,400 meters. Kilometers? 34.4 kilometers
- ► The circumference of a baby's head is 0.16 meters. Centimeters? 16 centimeters
- ► One iron atom has a radius of 0.000000000126 meters. Picometers? 126 picometers

8

Volume

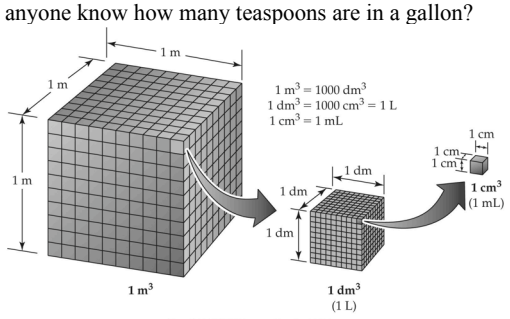
Volume is the amount of space occupied by an object. A volume can be described as a length^3.



Volume and Prefixes

- The SI unit for volume is the cubic meter (m^3). One cubic yard is about ¾ the size of a cubic meter.
- It is more common in chemistry to use a cubic centimeter (cm^3), which is the same as a milliliter.
- Liters are also commonly used in chemistry. A liter is a cubic decimeter. How many milliliters are there in a liter? 1000 milliliters in 1 liter
- We will save the question how many milliliters are in a cubic meter until later. (There are 1 million milliliters in a cubic meter.)

The metric system is based on factors of 10 and is much easier to use than common U.S. units. Does anyone know how many teaspoons are in a gallon?



Mass and Weight

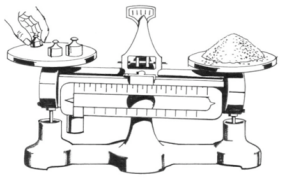
Mass is a measure of the amount of matter in an object. It is not the same thing as weight. **Weight** is related to mass, but you would weigh less on the moon than you do on earth, even though your mass is the same both places.

Mass and Weight

Weight measure of the gravitational force acting on an object. Weight depends on location. Mass does not depend on location.

A scale responds to weight.

A balance measures mass. (At the same location, two objects with identical masses have identical weights.)



Grams, Kilograms and Such

► The SI units for mass is a kilogram. What sort of things are typically measured in kilograms?

►In a chemistry lab small amounts are typically measured. Grams and milligrams are most often used.

- How many milligrams are in 1 gram?
- How many micrograms are in 1 gram?

Accuracy and Precision

►In day to day life we tend to use these two words as though they mean the same thing. In the sciences the differences between them matters.

►Accuracy describes how close a measurement is to the measurement that would be made if the ruler was perfect.

►Precision precision is concerned with how the measurement will change between different measurements with the same measuring tool.

Accuracy

►What if you had a measuring tape that was just a little off at the 1 centimeter mark. Everything that you measured with the measuring tape would be off by about the same amount.

►For example if this tape had mistakenly been fastened to the ends such that there was only 0.64 cm between the end of the tape measure and the 1.0 cm mark. The measuring tape would not be very accurate. You could measure a board over and over with it and still not get the correct value.

Precision

Strangely, measurements made with this bad tape measure would be considered precise as long as the measurements were consistent with each other.

- Consider a board that is156.25 meters. If the tape measure mentioned before was used, its possible that the tape measure consistently gave 156.61 cm when the board was measured. The measurements are precise in this case, even though they are wrong.

Uncertainty

- Uncertainty in a measurement can occur because of errors in precision and in accuracy.
- You can only trust numbers to there level of uncertainty in the numbers.

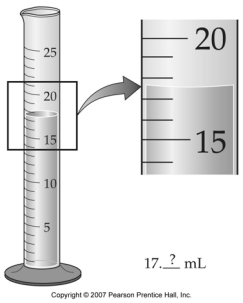
Often a medicine will say that 1 teaspoon should be used. You would expect to have different uncertainty in the doses given depending on whether you used a table spoon and guessed how much was a teaspoon, or if you used a measuring spoon. Part of the problem would be accuracy and part precision.

Uncertainty

- What factors do you think matter in the two ways of measuring the medicine? Which would seem to be a matter of precision and which a matter of accuracy?

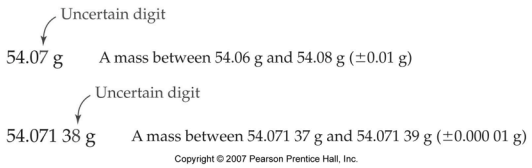
2.4 Measurement and Significant Figures

- Every experimental measurement has a degree of uncertainty.
- The volume, V, at right is certain in the 10's place, 10mL<V<20mL
- The 1's digit is also certain, 17mL<V<18mL
- A best guess is needed for the tenths place.



- To indicate the precision of a measurement, the value recorded should use all the digits known with certainty, plus one additional estimated digit that usually is considered uncertain by plus or minus 1.
- No further insignificant digits should be recorded.
- The total number of digits used to express such a measurement is called the number of **significant figures**.
- All but one of the significant figures are known with certainty. The last significant figure is only the best possible estimate.

Below are two measurements of the mass of the same object. The same quantity is being described at two different levels of precision or certainty.



- When reading a measured value, all nonzero digits should be counted as significant. There is a set of rules for determining if a zero in a measurement is significant or not.
- **RULE 1.** Zeros in the middle of a number are like any other digit; they are always significant. Thus, 94.072 g has five significant figures.
- **RULE 2.** Zeros at the beginning of a number are not significant; they act only to locate the decimal point. Thus, 0.0834 cm has three significant figures, and 0.029 07 mL has four.

- **RULE 3.** Zeros at the end of a number and *after* the decimal point are significant. It is assumed that these zeros would not be shown unless they were significant. 138.200 m has six significant figures. If the value were known to only four significant figures, we would write 138.2 m.
- **RULE 4.** Zeros at the end of a number and *before* an implied decimal point may or may not be significant. We cannot tell whether they are part of the measurement or whether they act only to locate the unwritten but implied decimal point.

2.5 Scientific Notation

- **Scientific notation** is a convenient way to write a very small or a very large number.
- Numbers are written as a product of a number between 1 and 10, times the number 10 raised to power.
- 215 is written in scientific notation as:

$215 = 2.15 \times 100 = 2.15 \times (10 \times 10) = 2.15 \times 10^2$

Two examples of converting standard notation to scientific notation are shown below.

$$215. = 2.15 \times 10^2$$

Decimal point is moved two places to the left, so exponent is 2.

$$0.002\,15 = 2.15 \times \frac{1}{1000} = 2.15 \times \frac{1}{10 \times 10 \times 10} = 2.15 \times \frac{1}{10^3} = 2.15 \times 10^{-3}$$

$$0.002\,15 = 2.15 \times 10^{-3}$$

Decimal point is moved three places to the right, so exponent is -3.

Two examples of converting scientific notation back to standard notation are shown below.

$$3.7962 \times 10^4 = 37{,}962.$$

Positive exponent of 4, so decimal point is moved to the right four places.

$$1.56 \times 10^{-8} = 0.000\,000\,015\,6$$

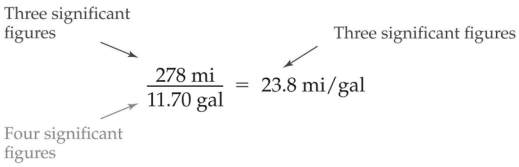
Negative exponent of -8, so decimal point is moved to the left eight places.

- Scientific notation is helpful for indicating how many significant figures are present in a number that has zeros at the end but to the left of a decimal point.
- The distance from the Earth to the Sun is 150,000,000 km. Written in standard notation this number could have anywhere from 2 to 9 significant figures.
- Scientific notation can indicate how many digits are significant. Writing 150,000,000 as 1.5×10^8 indicates 2 and writing it as 1.500×10^8 indicates 4.
- Scientific notation can make doing arithmetic easier. Rules for doing arithmetic with numbers written in scientific notation are reviewed in Appendix A.

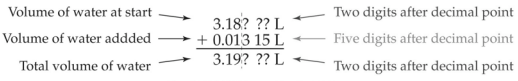
2.6 Rounding Off Numbers

- Often when doing arithmetic on a pocket calculator, the answer is displayed with more significant figures than are really justified.
- How do you decide how many digits to keep?
- Simple rules exist to tell you how.

RULE 1. In carrying out a multiplication or division, the answer cannot have more significant figures than either of the original numbers.



►**RULE 2.** In carrying out an addition or subtraction, the answer cannot have more digits after the decimal point than either of the original numbers.



- Once you decide how many digits to retain, the rules for rounding off numbers are straightforward:
- **RULE 1.** If the first digit you remove is 4 or less, drop it and all following digits. 2.4271 becomes 2.4 when rounded off to two significant figures because the first dropped digit (a 2) is 4 or less.
- **RULE 2.** If the first digit removed is 5 or greater, round up by adding 1 to the last digit kept. 4.5832 is 4.6 when rounded off to 2 significant figures since the first dropped digit (an 8) is 5 or greater.
- If a calculation has several steps, it is best to round off at the end.