Office Hours: M 1:30pm – 3:00pm
(in Park 169) W 11:00am – 12:00pm
or by appointment (email me)
or just email me with questions!

TA Hours: TBD

Q-center: https://www.brynmawr.edu/inside/offices-services/q-center/q-center-schedule

Measurements, Uncertainty, and Unit Conversion

9/2/2026

Achieve HW #1 due Wednesday 9/9 at 10:00am

Quiz #1 in Recitation next Friday (9/11)

We need to take attendance today for registration reasons…..

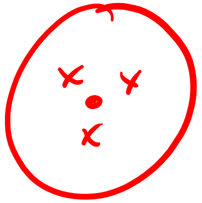
Learning Objectives

- Express quantities in scientific notation
- Explain the process of measurement
- Identify the three basic parts of a quantity
- Describe the properties and units of length, mass, volume, density, temperature, and time
- Perform basic unit calculations and conversions in the metric and other unit systems
- Define accuracy and precision and be able to explain whether a dataset is precise and/or accurate
- Distinguish exact and uncertain numbers
- Distinguish extensive vs intensive properties
- Correctly represent uncertainty in quantities using significant figures
- Apply proper rounding rules to computed quantities
- Explain the dimensional analysis (factor label) approach to mathematical calculations involving quantities
- Use dimensional analysis to carry out unit conversions for a given property and computations involving two or more properties

Accuracy vs Precision

Accuracy is a measure of closeness to "true" value

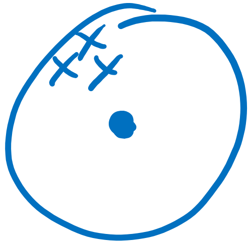
accurate - close to bullseye



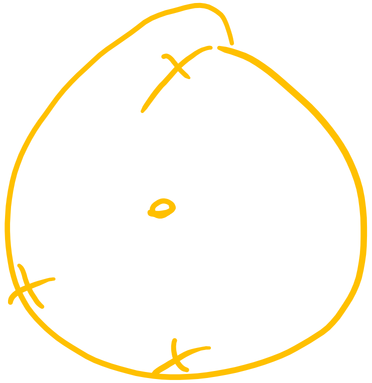
accurate + precise

Precision is a measure of reproducibility

precise - values are close together

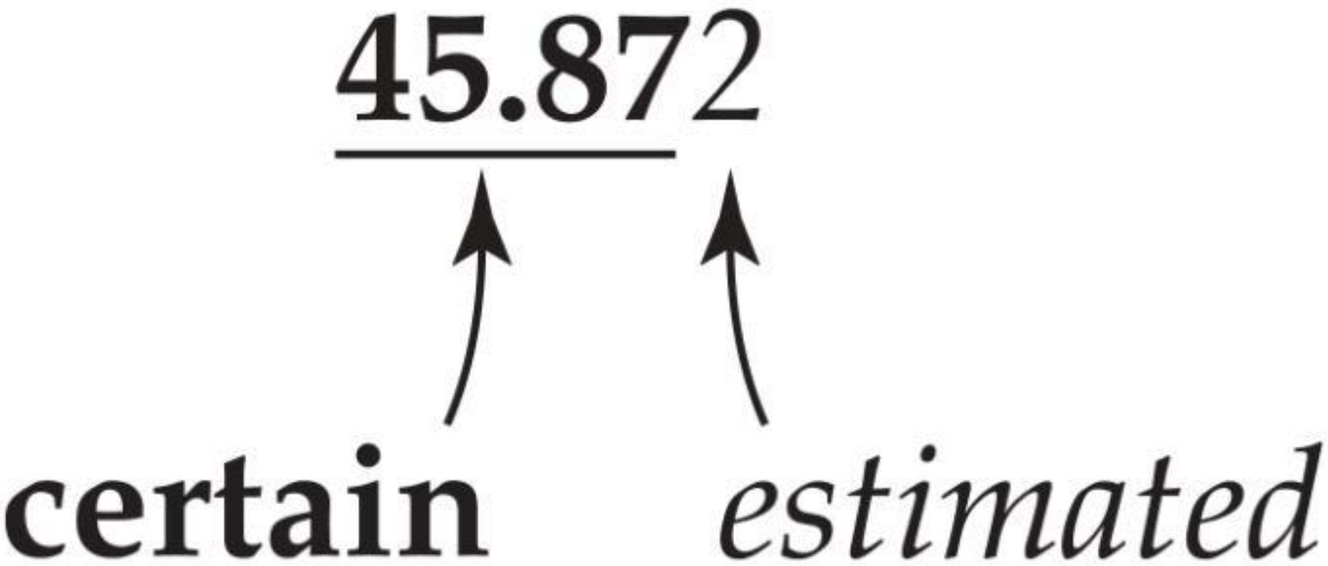


precise, not accurate



not accurate or precise.

Reporting Uncertainty in Measurements



The first four digits are certain; the last digit is estimated.

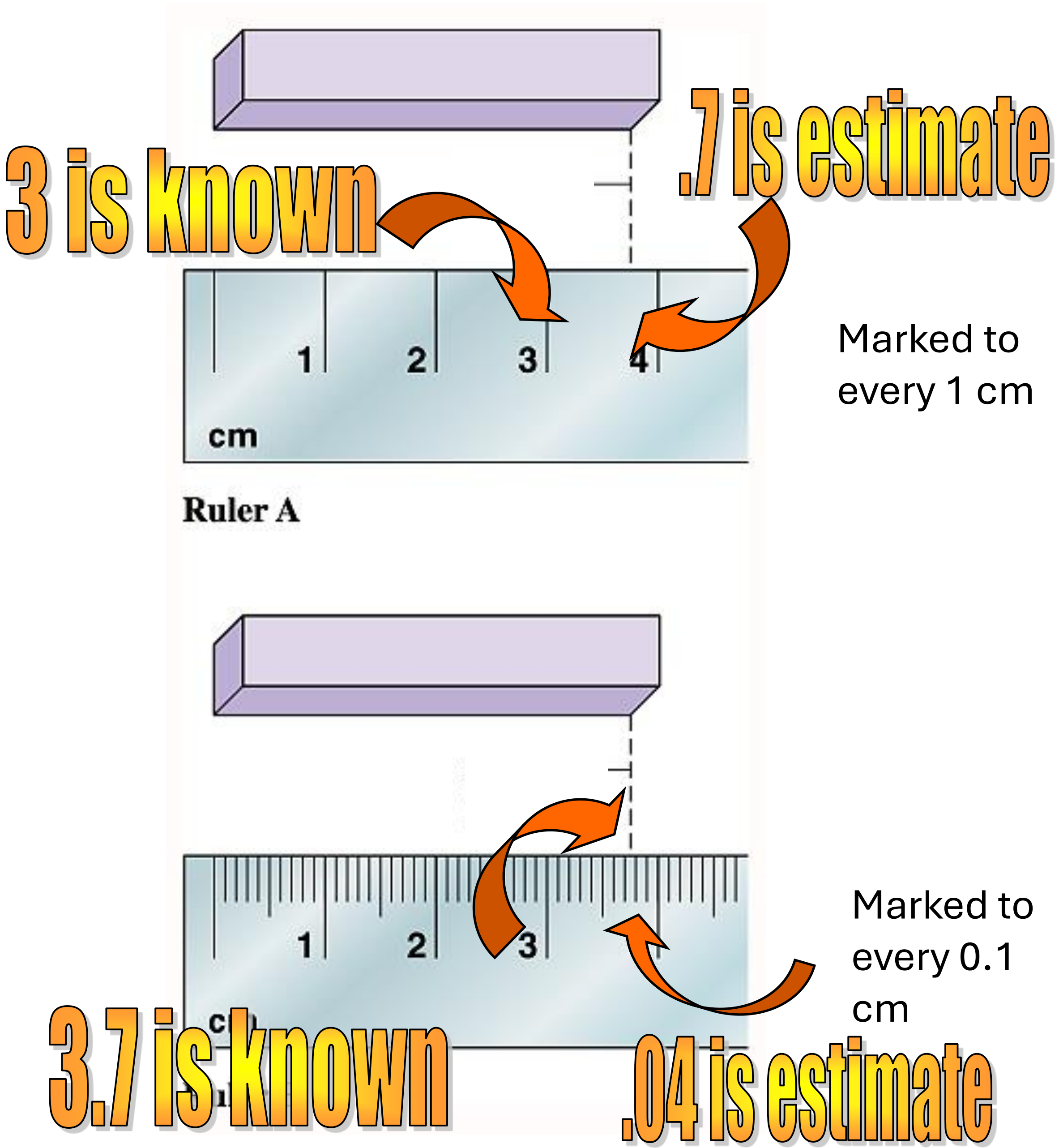
The greater the precision of the measurement, the greater the number of “significant figures.”

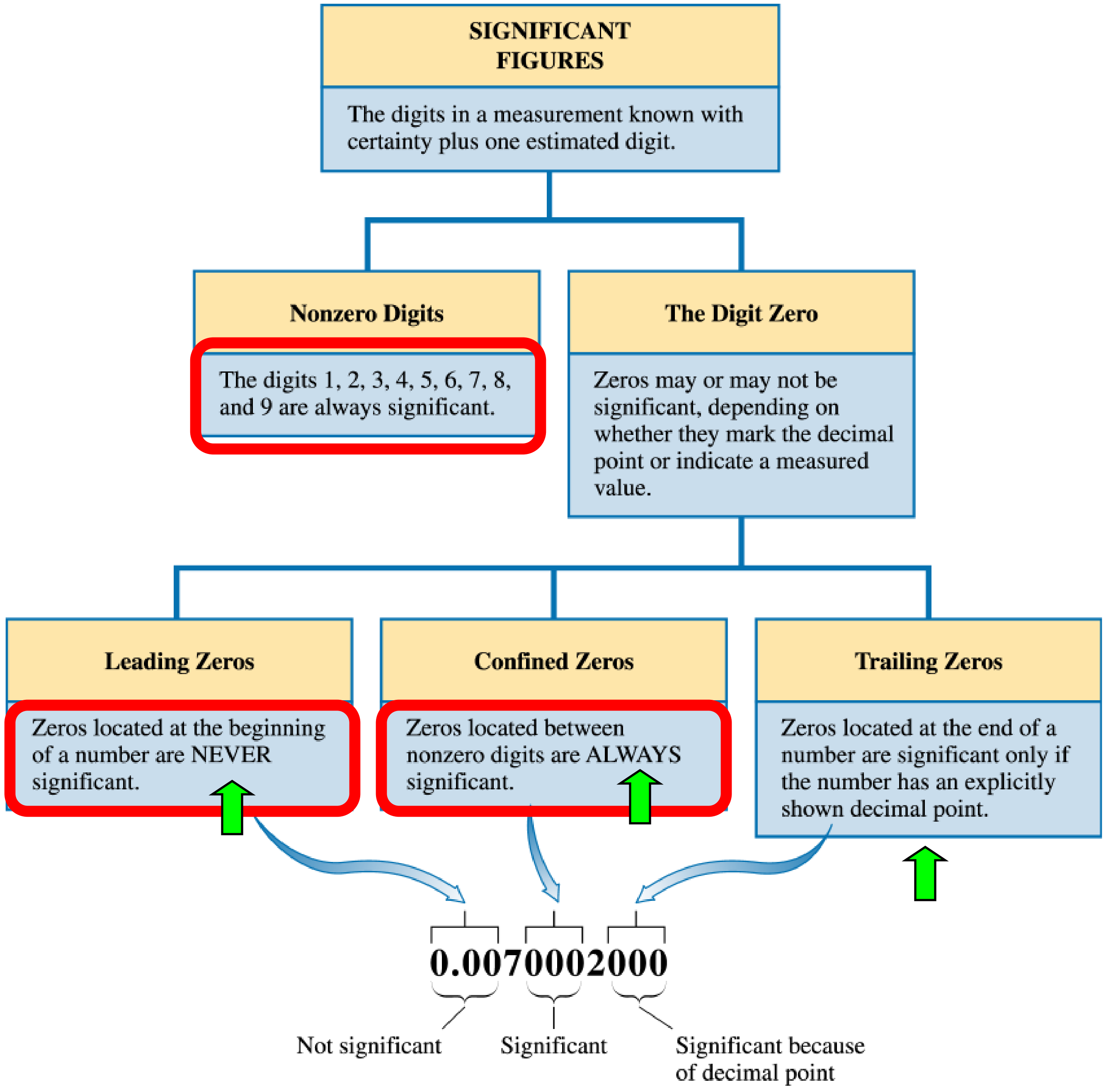
Significant figures are important!! They communicate the precision of a measurement!!

Measurement =

known digits

+ 1 estimated digit





Which digits are significant in 0.0830 ?

Identifying “Exact” Numbers

“Exact” numbers have unlimited significant figures.

- Exact counting of discrete objects

  Ex: 7 apples

- Integer numbers (whole numbers) that are part of an equation

  Ex: Radius = Diameter/2

- Defined quantities
  - *Some conversion factors are defined quantities, while others are not.*
  - *Treat conversion factors as defined quantities unless specified otherwise.*

  1 in = 2.54 cm exact

Counting Significant Figures

How many significant figures are in each number?

0.0035
1.080
2371
2.97×10^5
1 dozen = 12
100.00
100,000
2500

Significant Figures in Calculations

Rules for Rounding:

- When numbers are used in a calculation, the result is rounded to reflect the significant figures of the *data*.
- For calculations involving multiple steps, round only the final answer— ***do not round between steps.***
- Use only the *leftmost digit being dropped* to decide in which direction to round —ignore all digits to the right of it.
- Round down if the last digit dropped is 4 or less;
  round up if the last digit dropped is **5 or more**.

Accuracy vs Precision

Accuracy is a measure of closeness to the true value

Precision is a measure of reproducibility

We use significant figures so that the least precise measurement is reflected in a calculation

- Final answer can only be as precise as the weakest link!

Multiplication and Division Rule

In multiplication or division, the result has the same number of *significant figures* as the quantity with the fewest *significant figures*.

Multiplication

$$5.02 \times 89.665 \times 0.10 = 45.0118$$

Division

$$5.892 \div 6.10 = 0.96590 =$$

Addition and Subtraction Rule

For addition or subtraction, the answer has the same number of **decimal places** as the quantity with the fewest **decimal places**.

$$
\begin{array}{r}
2.345 \\
0.07 \\
+\ 2.9975 \\
\hline
5.4125
\end{array}
\ =
$$

Rules for Rounding:

- When rounding to the correct number of significant figures,
  - Round down if the leftmost digit being dropped is four or less.
  - Round up if the leftmost digit being dropped is five or more.

Round to two significant figures:

5.37 rounds to 5.4
5.34 rounds to
5.35 rounds to
5.349 rounds to

Both Multiplication/Division and Addition/Subtraction

$3.489 \times (5.67 - 2.3)$

Use the subtraction rule to determine that the intermediate answer has only one significant decimal place.

$5.67 - 2.3 = 3.\underline{3}7$

Use the multiplication rule to significant figures

$3.489 \times 3.\underline{3}7 = 1\underline{1}.758 =$

The Basic Units of Measurement

The unit system for science measurements, based on the metric system, is called the **International System of Units** (*Système International d'Unités*) or ***SI* units**.

Base Units of the SI System

Property Measured	**Name of Unit**	**Symbol of Unit**
length	meter	m
mass	kilogram	kg
time	second	s
temperature	kelvin	K
electric current	ampere	A
amount of substance	mole	mol
luminous intensity	candela	cd

Intensive vs Extensive Properties

Intensive properties do **not** ___________ ______ ____________ of substance in a sample.

Extensive properties do.

Weight vs. Mass

- The kilogram is a measure of mass, which is different from weight.
- The **mass** of an object is a measure of the quantity of **matter** within it.
- The weight of an object is a measure of the gravitational pull on that matter.
- **Weight** depends on **gravity** while mass does not.

Unit Prefixes

Prefixes are used to scale units up or down by powers of 10.

Example: kilograms (kg) 1 kg = 1000 grams

Prefix	Symbol	Factor	Example
femto	f	10^{-15}	1 femtosecond (fs) = 1×10^{-15} s (0.000000000000001 s)
pico	p	10^{-12}	1 picometer (pm) = 1×10^{-12} m (0.000000000001 m)
nano	n	10^{-9}	4 nanograms (ng) = 4×10^{-9} g (0.000000004 g)
micro	μ	10^{-6}	1 microliter (μL) = 1×10^{-6} L (0.000001 L)
milli	m	10^{-3}	2 millimoles (mmol) = 2×10^{-3} mol (0.002 mol)
centi	c	10^{-2}	7 centimeters (cm) = 7×10^{-2} m (0.07 m)
deci	d	10^{-1}	1 deciliter (dL) = 1×10^{-1} L (0.1 L)
kilo	k	10^{3}	1 kilometer (km) = 1×10^{3} m (1000 m)

Derived Units

A derived unit is formed from other units.

Many units of **volume,** a measure of 3D space, are derived units.

Any unit of length, when cubed (raised to the third power), becomes a unit of volume.

- Cubic meters (m^3), cubic centimeters (cm^3), and cubic millimeters (mm^3) are all units of volume.

Unit Conversion

Given one or more quantities, convert them into different units.

Units are multiplied, divided, and canceled like any other algebraic quantities.

Always write every number with its associated unit!!! No shortcuts!!

Some conversion factors

Length	1 km = 0.6214 mi 1 m = 39.37 in = 1.094 yd 1 ft = 30.48 cm 1 in = 2.54 cm	Mass	1 kg = 2.205 lb 1 lb = 453.59 g 1 oz = 28.35 g
Volume	1 L = 1000 mL = 1000 cm^3 1 L = 1.057 qt 1 gal = 3.785 L		

You will always be provided with any unit conversion factors needed for a problem.

You **do not** need to memorize unit conversion factors. (i.e. 1 kg = 2.205 lb)

You **do** need to memorize conversion factors for the unit *prefixes* (i.e. 1 kg = 10^3 g) indicated a few slides ago.

Problem Solving Using the Factor-Label Method

Conversion factor: A term that converts a quantity in one unit to a quantity in another unit.

$$\boxed{\text{original quantity}} \times \boxed{\text{conversion factor}} = \boxed{\text{desired quantity}}$$

Conversion factors are usually written as equalities.

2.21 lb = 1 kg

To use them, they must be written as fractions.

Solving Problems Using Conversion Factors

Factor-label method: Using conversion factors to manage a complex problem involving many units. Also called Dimensional Analysis.

- units are treated like numbers
- make sure all unwanted units cancel
- ***all*** quantities in the calculation have units **labeled**!

To convert 130 lb into kilograms:

$$1.3\times10^{2}\ \text{lb} \times \boxed{\text{conversion factor}} = ?\ \text{kg}$$

original quantity — desired quantity

How many kg in 1.3×10^2 lb ?

$2.21 \text{ lb} = 1 \text{ kg}$

$$1.3 \times 10^2 \text{ lb} \quad \times \quad \boxed{\frac{2.21 \text{ lb}}{1 \text{ kg}}} \text{ or } \boxed{\frac{1 \text{ kg}}{2.21 \text{ lb}}} \quad = \quad 59 \text{ kg}$$

Set up the conversion factor with original unit in the <u>bottom</u> of the fraction.

- The unwanted unit lb cancels.
- The desired unit kg does not cancel, and is on the <u>**top**</u> of the fraction
  → final unit is kg

Solving Multistep Unit Conversion Problems

Each step should have a conversion factor set up to cancel the units of the previous step

Example: How many km are there in 1.2×10^4 ft?

1 foot = 0.3048 m

Conversion with Units Raised to a Power

Example: converting cm^3 to in^3

1 in = 2.54 cm

Must cube both sides of the equality to obtain the proper conversion factor.

How many cubic inches in 251 cm^3?

Density

The density of a substance is the ratio of its mass to its volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad \text{or} \quad d = \frac{m}{V}$$

Water has a density of 1.0 g/mL (or 1.0 g/cm^3)

Things that are less dense (like oil) will float in water.
Things that are more dense (like CH_2Cl_2) will sink.

Calculating Density

<u>Example:</u> a sample of liquid has a volume of 22.5 mL and a mass of 27.2 g.

Assuming this liquid is not *miscible* with water (that is, they will separate like oil and water and not mix), will this liquid float or sink in water?

Density as a Conversion Factor

We can use the density of a substance as a conversion factor between the mass of the substance and its volume.

For a liquid substance with a density of 1.32 g/cm^3, what volume in liters should be measured to deliver a mass of 68.4 g?

A 23.5 kg sample of ethanol is needed for a large scale reaction. What volume in liters of ethanol should be used? The density of ethanol is 0.789 g/cm^3.

Conversion factors: 1 cm^3 = 1 mL

Convert 2.6 lb/in^3 to g/ml .

Mass	1 kg = 2.205 lb 1 lb = 453.59 g 1 oz = 28.35 g
Length	1 km = 0.6214 mi 1 m = 39.37 in = 1.094 yd 1 ft = 30.48 cm 1 in = 2.54 cm