Uncertainty in Measurements

- Two kinds of numbers
  - Exact
    - counted values
      - 2 dogs
      - 26 letters
      - 3 brothers
    - defined numbers
      - 12 inches per foot
      - 1000 g per kilogram
      - 2.54 cm per inch

Metric Practice

- 34.5 cm to m
- 56.7 L to mL
- 2.34 m to mm
- 355 ml to L
- 3456 mm to cm
- 5602 mm to m
- 1.2 km to m
- 100 g to cg

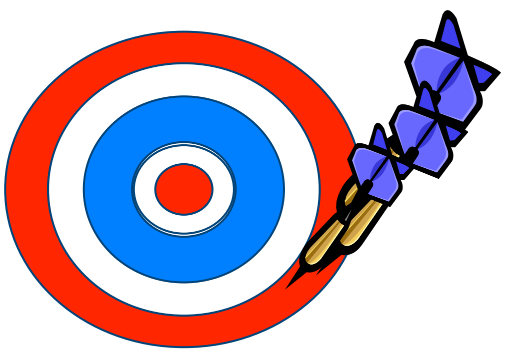
- 0.345 m
- 56700 mL
- 2340 mm
- 0.355L
- 345.6 cm
- 5.602 m
- 1200 m
- 10000 cg

Uncertainty in Measurements

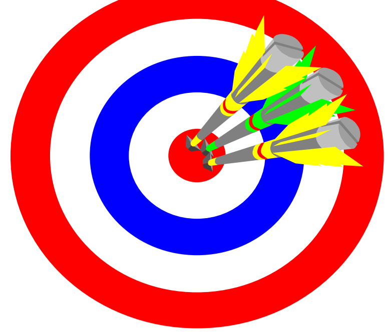
- Two kinds of numbers:
  - Inexact Numbers
    - Numbers obtained by measurements
    - Some degree of uncertainty in the number
      - Equipment limitations
      - Human "error"
    - Examples:
      - Length
      - Mass
      - Density

Precision vs. Accuracy (chapter 3)

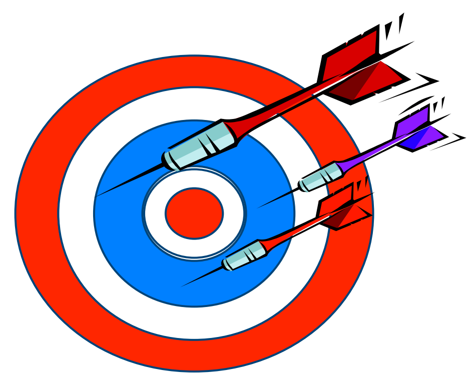
- Precision
  - how closely individual measurements agree with each other
- Accuracy
  - how closely individual measurements agree with the correct or true value



Good precision



Good accuracy and precision



Neither

Significant Figures

- All measuring devices have limitations
- Balances may read to the nearest :
  - 0.1 g (125.6 ± 0.1 g)
    - Uncertainty in the tenths place
  - 0.01 g (23.04 ± 0.01 g)
    - Uncertainty in the hundredths place
  - 0.001 g (118.906 ± 0.001 g)
    - Uncertainty in the thousandths place

Significant Figures

- Scientists drop the ± notation and assume that an uncertainty of at least 1 unit exists in the final digit.
    - All digits, including the final one, are called significant figures.

Rules for Significant Figures

- Nonzero digits are always significant.
  - 12.11 (4 significant figures)
  - 12345 (5 significant figures)

- Zeros between nonzero digits are always significant.
  - 10.1 (3 significant figures)
  - 19.06 (4 significant figures)
  - 100.005 (6 significant figures)

Rules for Significant Figures

- Zeros at the beginning of a number are never significant.
  - 0.0003 (1 significant figure)
  - 0.00105 (3 significant figures)

- Zeros that follow a non-zero digit AND are to the right of the decimal point are significant.
  - 1.10 (3 significant figures)
  - 0.009000 (4 significant figures)

Rules for Significant Figures

- Assume that zeros located at the end of numbers that do not have a decimal point are not significant.
  - 200 (1 significant figure)
  - 105000 (3 significant figures)

Scientific Notation and Significant Figures

- Use scientific notation to remove ambiguity
- 10,100 meters
  - 1.01×10^4
    - measured to the nearest 100 meters
    - 3 sig fig
  - 1.010×10^4
    - Measured to the nearest 10 meters
    - 4 sig fig
  - 1.0100×10^4
    - Measured to the nearest 1 meter
    - 5 sig fig

Significant Figures in Calculations

- Consider only measured numbers when determining the number of significant figures in an answer.
  - Ignore counted numbers
  - Ignore defined numbers

- Multiplication and Division (least most)
  - The result must have the same # of significant figures as the measurement with the fewest significant figures.

Significant Figures in Calculations

Example: What is the density of a liquid with a volume of 3.0 mL and a mass of 5.057g?

$$D = \frac{\text{mass}}{\text{volume}} = \frac{5.057\ g}{3.0\ mL} = 1.685666\ g/mL$$

↓

1.7 g/mL

Rules for Rounding

- If the digit to the right of the last significant digit is < 5, leave the last significant digit alone.

  1.743 → 1.7

- If the digit to the right of the last significant digit is $\geq$ 5, round up.

  1.5449 → 1.545

  0.075 → 0.08

Rules for Rounding

- You cannot change the magnitude of the number when rounding!!
  - 102,433 rounded to 3 sig fig.
  - 395,952 rounded to 1 sig fig.
  - 926 rounded to 2 sig fig.

Rules for Rounding

- You cannot change the magnitude of the number when rounding!!
  - 102,433 rounded to 3 sig fig. = 102,000
    not 102
  - 395,952 rounded to 1 sig fig. = 400,000
    not 4
  - 926 rounded to 2 sig fig. = 930
    not 93

Rules for Addition & Subtraction

- The answer obtained from addition or subtraction must have the same number of decimal places as the measurement which contains the <u>fewest number of decimal places.</u>
  - The total number of significant figures in the answer can be greater or less than the number of significant figures in any of the measurements.

Rules for Addition & Subtraction

- Do the addition or subtraction as indicated in the problem.
- Find the measurement that has the fewest decimal places.
- Count the number of decimal places in that measurement.
- Round the answer off so that the answer has the same number of decimal places.

Rules for Addition & Subtraction

Example: Add the following masses.

120.15 g		2 decimal places
83 g		0 decimal places
+ 0.530 g		3 decimal places
203.680 g		

Round answer to 0 decimal places → **204 g**

Unit Analysis

- Unit Analysis
  - A systematic method for solving problems in which units are carried thru the entire problem
    - units are multiplied together, divided into each other, or cancelled
  - Helps communicate your thinking
  - Helps ensure that solutions have the proper units
  - Uses conversion factors

Conversion Factors

- Conversion Factor
  - a fraction whose numerator and denominator are the same quantity expressed in different units
  - used to change from one unit to another

Conversion Factors

- Examples of Conversion Factors

12 in = 1 ft → $\frac{12 \text{ in}}{1 \text{ ft}}$ or $\frac{1 \text{ ft}}{12 \text{ in}}$

100 cm = 1 m → $\frac{100 \text{ cm}}{1 \text{ m}}$ or $\frac{1 \text{ m}}{100 \text{ cm}}$

Every relationship can give two conversion factors that are the inverses of each other. The value is the same.

Unit Analysis - One Conversion Factor

Example: A lab bench is 175 inches long. What is its length in feet?

Dimensional Analysis - One Conversion Factor

Example: A lab bench is 175 inches long. What is its length in feet?

Given: 175 in.

Find: Length (ft)

Conversion factor:

$$\frac{12 \text{ in}}{1 \text{ ft}} \quad \text{or} \quad \frac{1 \text{ ft}}{12 \text{ in.}}$$

$$\text{ft} = 175 \cancel{\text{in}} \times \frac{1 \text{ ft}}{12 \cancel{\text{in}}} = 14.583333 \text{ ft} = 14.6 \text{ ft}$$

Dimensional Analysis - One Conversion Factor

Example: A marble rolled 50.0 mm. How many meters did it roll?

Dimensional Analysis - One Conversion Factor

Example: A marble rolled 50.0 mm. How many meters did it roll?

Given: 50.0 mm

Find: dist. (m)

Conversion factor:

$\frac{1000\ \text{mm}}{1\ \text{m}}$ or $\frac{1\ \text{m}}{1000\ \text{mm}}$

$$\text{m} = 50.0\ \cancel{\text{mm}} \times \frac{1\ \text{m}}{1000\ \cancel{\text{mm}}} = 0.05\ \text{m} = 0.0500\ \text{m}$$

Dimensional Analysis - One Conversion Factor

Example: In Germany, a salesman I was with drove at 185 km/hr. What was our speed in mi/hr?

Unit Analysis - One Conversion Factor

Example: In Germany, a salesman I was with drove at 185 km/hr. What was our speed in mi/hr?

Given: 185 km/hr

Find: mi/hr

Conversion factor:

$$\frac{1.609\ \text{km}}{1\ \text{mi}} \quad \text{or} \quad \frac{1\ \text{mi}}{1.609\ \text{km}}$$

$$\frac{\text{mi}}{\text{hr}} = \frac{185\ \cancel{\text{km}}}{\text{hr}} \times \frac{1\ \text{mi}}{1.609\ \cancel{\text{km}}} = 114.97825\ \frac{\text{mi}}{\text{hr}}$$

Speed = 115 mi/hr