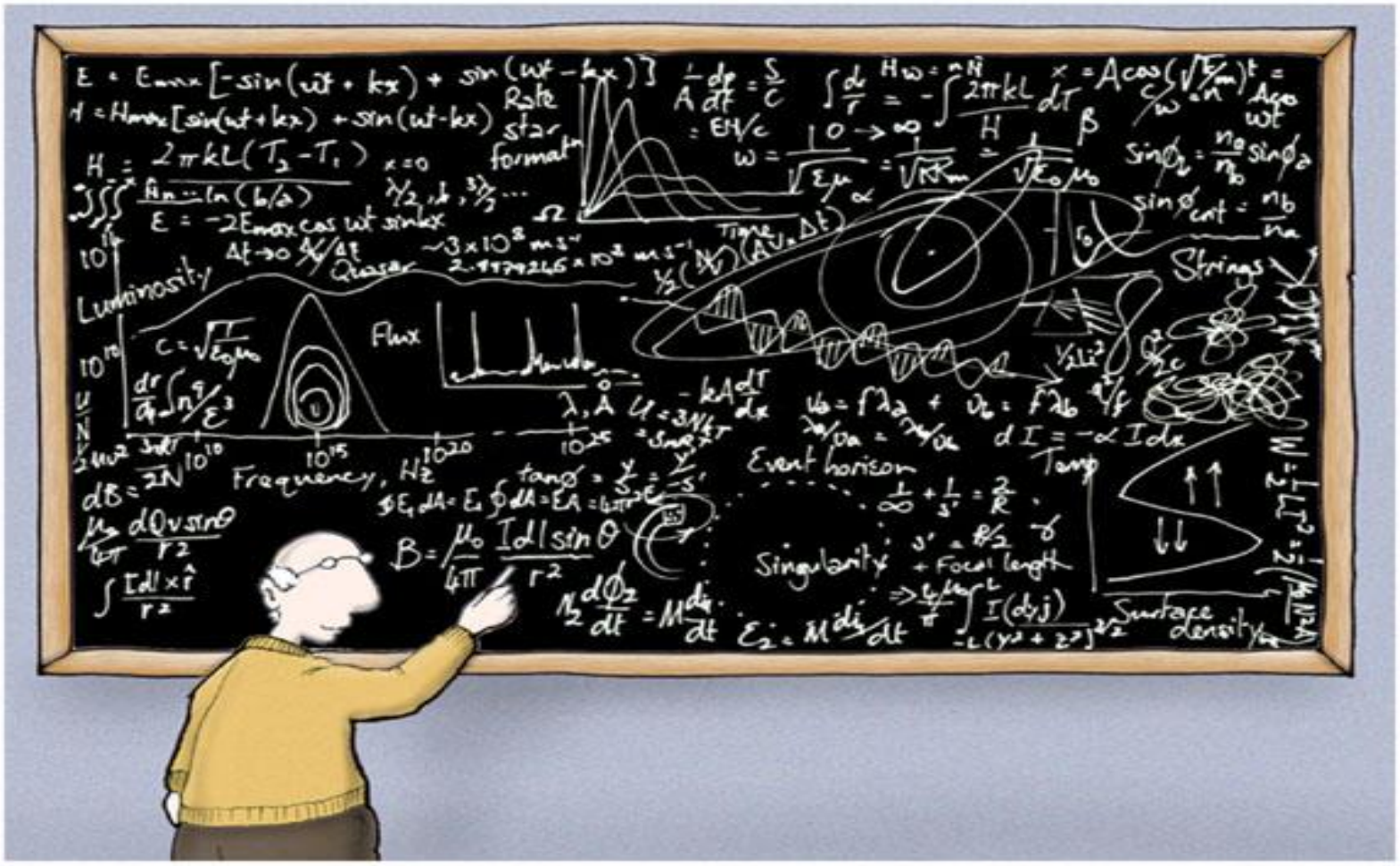
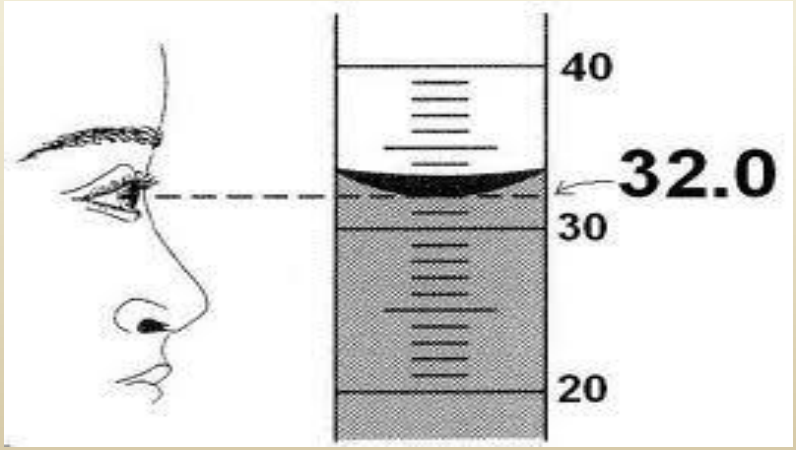
Uncertainty and Significant Figures

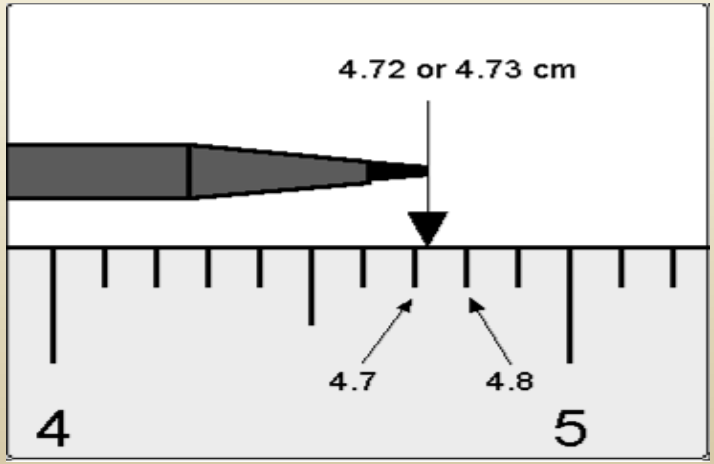


Cartoon courtesy of Lab-initio.com

Uncertainty in Measurement

A digit that must be **estimated** is called **uncertain**. A **measurement** always has some degree of uncertainty.





Why Is there Uncertainty?

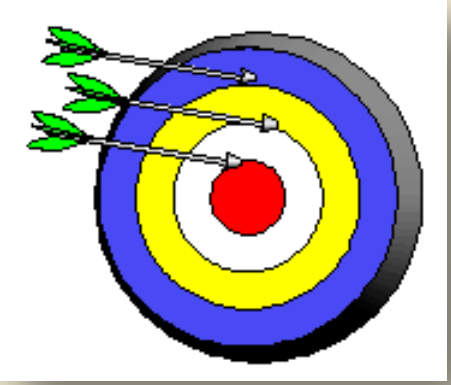
- Measurements are performed with instruments
- No instrument can read to an infinite number of decimal places

Which of these balances has the greatest uncertainty in measurement?

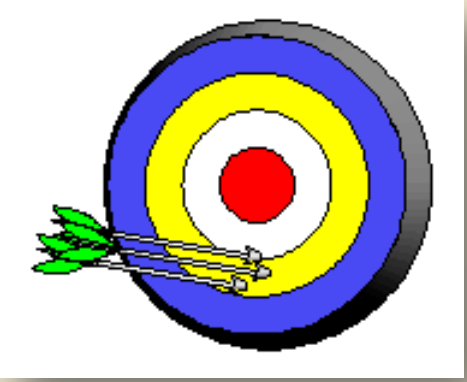
Precision and Accuracy

Accuracy refers to the agreement of a particular value with the true value.

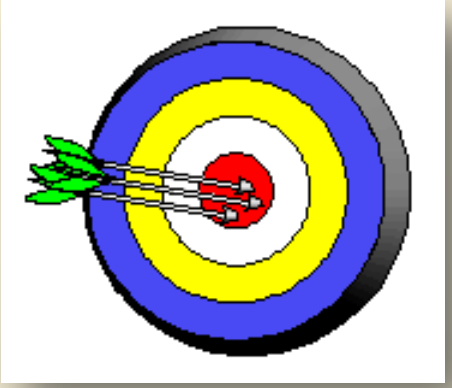
Precision refers to the degree of agreement among several measurements made in the same manner.



Neither accurate nor precise



Precise but not accurate



Precise AND accurate

Types of Error

Random Error (Indeterminate Error) - measurement has an equal probability of being high or low.

Systematic Error (Determinate Error) - Occurs in the same direction each time (high or low), often resulting from poor technique or incorrect calibration.

Percent Error

Percent error: is calculated by subtracting the experimental value from the accepted value, then dividing the difference from the accepted value, and multiplying by 100.

$$\text{Percent error} = \frac{\text{Value}_{\text{accepted}} - \text{Value}_{\text{experimental}}}{\text{Value}_{\text{accepted}}} \times 100$$

Example #1

Example 1. What is the percent error for a mass measurement of 17.7g, given that the correct value is 21.2g?

$$\text{Percent error} = \frac{\text{Value}_{\text{accepted}} - \text{Value}_{\text{experimental}}}{\text{Value}_{\text{accepted}}} \times 100$$

$$\text{Percent error} = \frac{21.2\text{g} - 17.7\text{g}}{21.2\text{g}} \times 100$$

Percent error = 16.5%

Rules for Counting Significant Figures - Details

Nonzero integers always count as significant figures.

3456 has

4 significant figures

Rules for Counting Significant Figures - Details

Zeros

- **Leading zeros** do not count as significant figures.

0.0486 has

3 significant figures

Rules for Counting Significant Figures - Details

Zeros

- **Captive zeros** always count as significant figures.

16.07 has

4 significant figures

Rules for Counting Significant Figures - Details

Zeros

Trailing zeros are significant only if the number contains a decimal point.

9.300 has

4 significant figures

Rules for Counting Significant Figures - Details

Exact numbers have an *infinite* number of significant figures.

1 inch = 2.54 cm, exactly

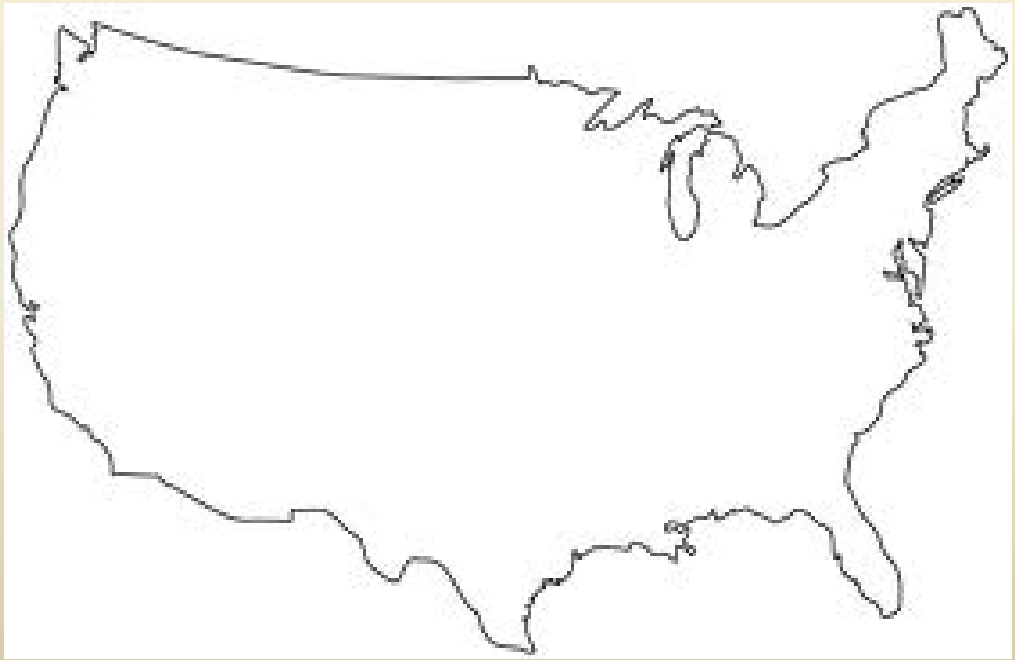
Scientific Notation - all of the numbers on front of the x10 are significant.

6.022×10^{23} = **4** significant figures.

Identifying & Counting Significant Figures:

Use the *Atlantic-Pacific Rule*! If the decimal point is *absent* approach the number from the *Atlantic* side, go to your first non-zero number, and count all the way through. If the decimal point is *present* approach the number from the *Pacific* side go to your first non-zero number, and count all the way through.

Pacific Ocean



Atlantic Ocean

Sig Fig Practice #1

How many significant figures in each of the following?

1.0070 m → 5 sig figs

17.10 kg → 4 sig figs

100,890 L → 5 sig figs

3.29×10^3 s → 3 sig figs

0.0054 cm → 2 sig figs

3,200,000 → 2 sig figs

Rules for Significant Figures in Mathematical Operations

Multiplication and Division: # sig figs in the result equals the number in the least precise measurement used in the calculation.

$$6.38 \times 2.0 =$$

$$12.76 \rightarrow 13 \text{ (2 sig figs)}$$

Sig Fig Practice #2

Calculation	Calculator says:	Answer
3.24 m x 7.0 m	22.68 m^2	23 m^2
100.0 g ÷ 23.7 cm^3	4.219409283 g/cm^3	4.22 g/cm^3
0.02 cm x 2.371 cm	0.04742 cm^2	0.05 cm^2
710 m ÷ 3.0 s	236.6666667 m/s	240 m/s
1818.2 lb x 3.23 ft	5872.786 lb·ft	5870 lb·ft
1.030 g ÷ 2.87 mL	2.9561 g/mL	2.96 g/mL

Rules for Significant Figures in Mathematical Operations

Addition and Subtraction: The number of decimal places in the result equals the number of decimal places in the least precise measurement.

$$6.8 + 11.934 =$$

$$18.734 \rightarrow 18.7 \text{ (3 sig figs)}$$

Sig Fig Practice #3

Calculation	Calculator says:	Answer
3.24 m + 7.0 m	10.24 m	10.2 m
100.0 g - 23.73 g	76.27 g	76.3 g
0.02 cm + 2.371 cm	2.391 cm	2.39 cm
713.1 L - 3.872 L	709.228 L	709.2 L
1818.2 lb + 3.37 lb	1821.57 lb	1821.6 lb
2.030 mL - 1.870 mL	0.16 mL	0.160 mL