ABE 20100

Lecture 1

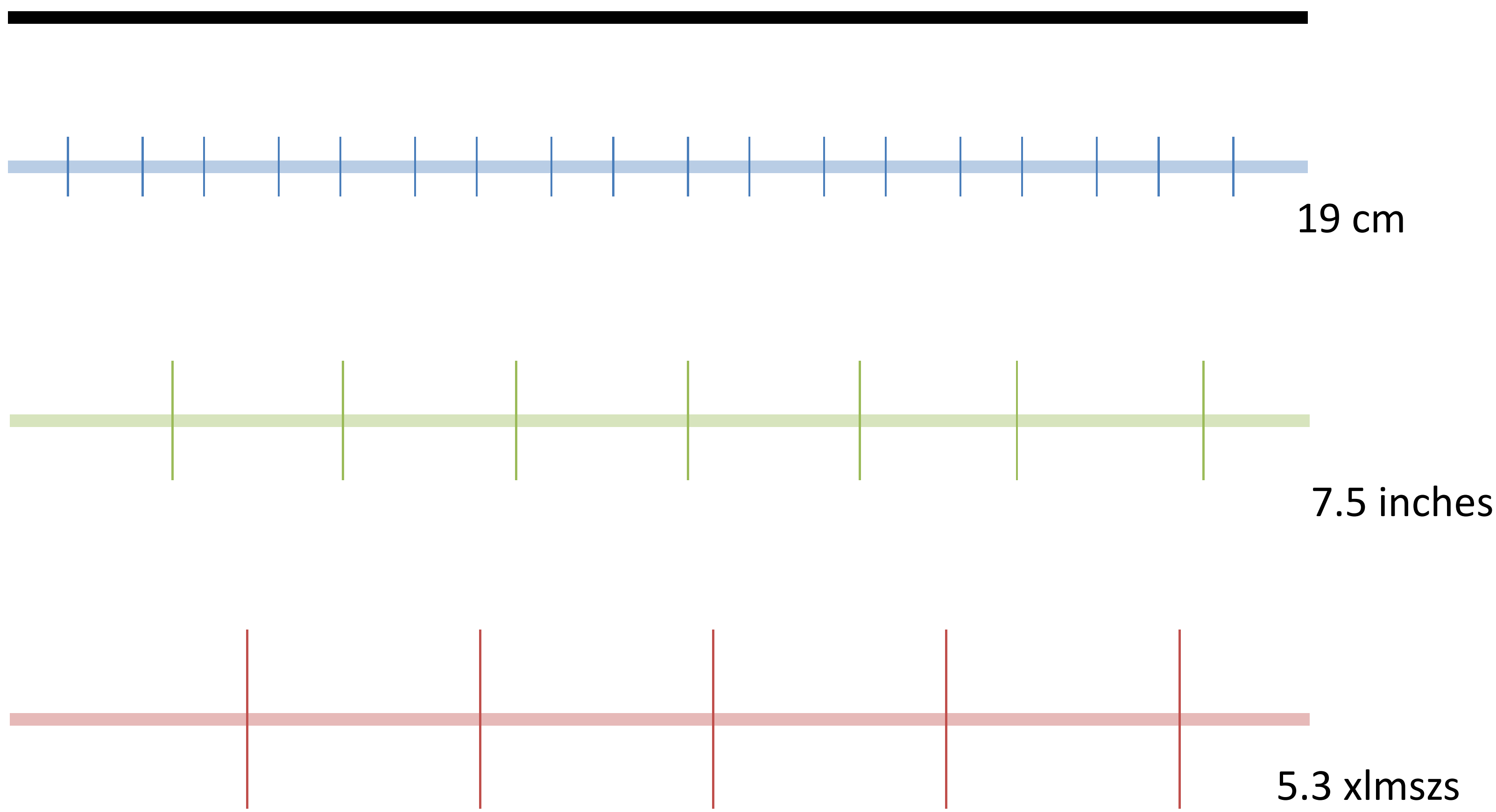
Units, Precision, Accuracy, and Significant Figures

Today’s Topics

- Dimensions
  – A property that can be measured (mass, time, etc.)
- Unit Conversion
  – How do you convert between lb and kg?
  – How do you convert between C and F?
- Precision vs Accuracy vs Reproducibility
  – Can we trust our measurements of a system?

Dimensions versus Units

- Dimension is a property that can be measured
- Dimensions have 2 parts: value and unit
  - Value is a number: 3.57
  - Unit describes the number: kg, sec., C
- Numerical values can only be added, subtracted, multiplied, or divided **<u>if</u>** they have the same units


19 cm
7.5 inches
5.3 xlmszs

Unit Conversion

- Convert each unit separately!
  - Some units are compound (force) and must be broken into constituent units
    - N to lbf
  - Some conversion tables have conversions for common compound units

Unit Conversion

- Watch your dimensions!

$$2.44\frac{\cancel{kJ}}{\cancel{min}} * \frac{1000\ \cancel{J}}{1\ \cancel{kJ}} * \frac{9.486\cdot 10^{-4}\ BTU}{1\ \cancel{J}} * \frac{60\ sec}{1\ min}$$

$$2.44\frac{\cancel{kJ}}{\cancel{min}} * \frac{1000\ \cancel{J}}{1\ \cancel{kJ}} * \frac{9.486\cdot 10^{-4}\ BTU}{1\ \cancel{J}} * \frac{1\ \cancel{min}}{60\ sec}$$

0.0386 BTU/sec

Force vs. Mass

- How do you convert from mass to force?

F= ma

SI Units: $$\mathrm{N} = \mathrm{kg} \cdot \frac{\mathrm{m}}{\mathrm{s}^2}$$

English Units: $$\mathrm{F} = \frac{\mathrm{m} \cdot \mathrm{a}}{\mathrm{g_c}} \qquad g_c = 32.2 \frac{\mathrm{lbm} \cdot \mathrm{ft}}{\mathrm{lbf} \cdot \mathrm{s}^2}$$

The Ambiguous Pound

- Pounds are Units of Mass
- Pounds are Units of Force

1 lbm exerts 1 lbf when accelerated by earth’s gravity

The Ambiguous Pound

1 lbm exerts 1 lbf when accelerated by earth's gravity

$$\mathrm{F} = \mathrm{m} \cdot \mathrm{g}$$

$$1\ \mathrm{lbf} \neq 1\ \mathrm{lbm} \cdot 32.2\ \frac{\mathrm{ft}}{\mathrm{s}^2}$$

$$1\ \mathrm{lbf} = \frac{1\ \cancel{\mathrm{lbm}} \cdot 32.2\ \cancel{\frac{\mathrm{ft}}{\mathrm{s}^2}}}{32.2 \frac{\cancel{\mathrm{lbm}} \cdot \cancel{\mathrm{ft}}}{\mathrm{lbf} \cdot \cancel{\mathrm{s}^2}}}$$

$$\mathrm{g}_c = 32.2 \frac{\mathrm{lbm} \cdot \mathrm{ft}}{\mathrm{lbf} \cdot \mathrm{s}^2}$$

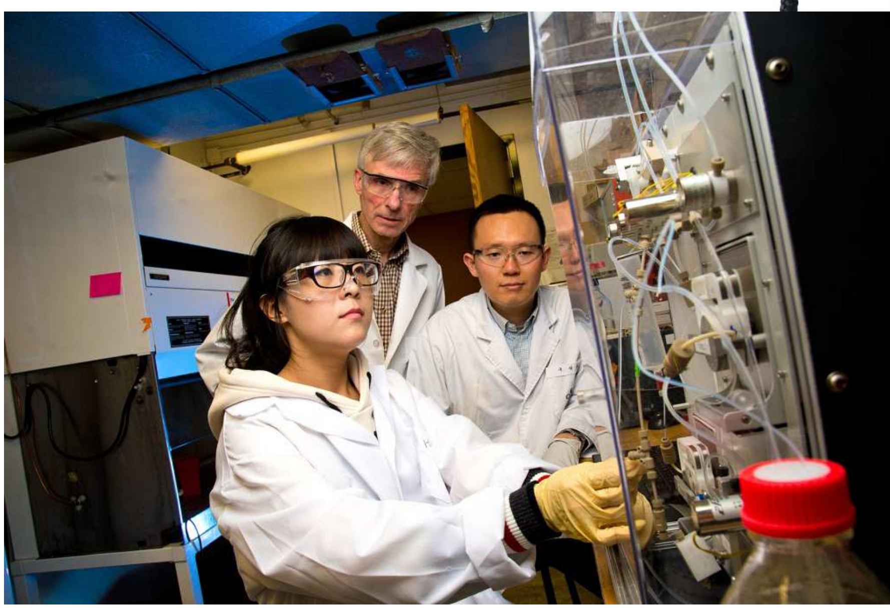
Moral of the story….

Calculate in SI units and convert final answer to US/English units!

Use:
kg for mass
m for length
s for time

Measuring Dimensions

Instruments



Accuracy vs Precision vs Reproducibility

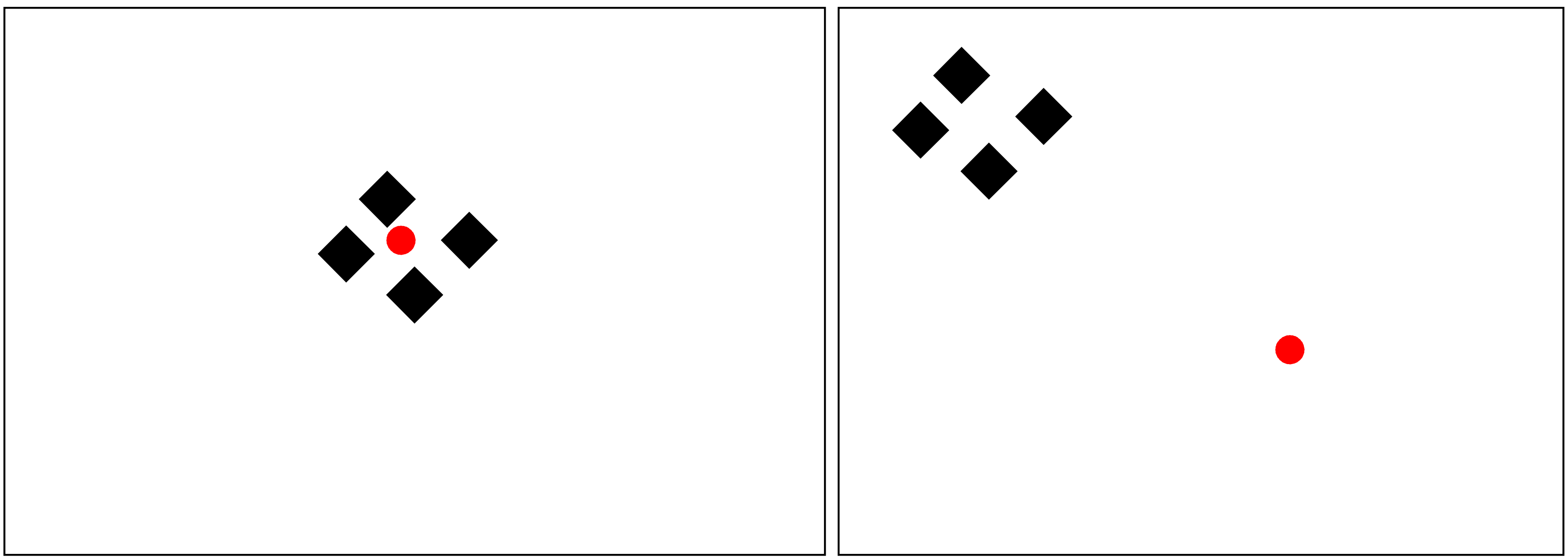
- Accuracy: How close is a measured value to the true value?

- Precision: How many significant digits can you measure?

- Reproducibility: Do you get the same value each time you measure something?

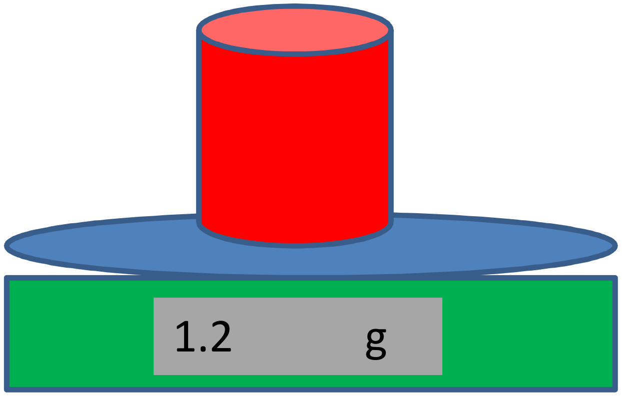
Accuracy

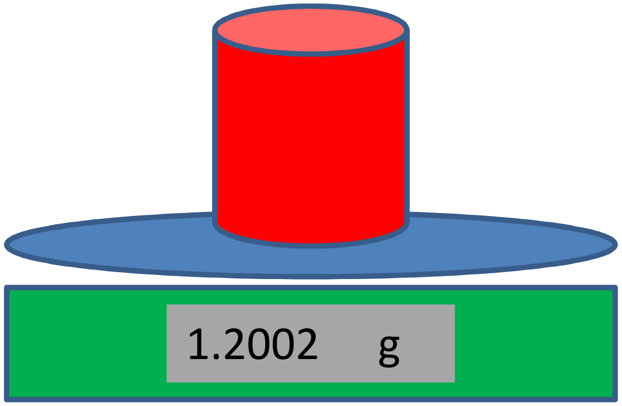
- Do your measurements match the “true” value or are they skewed?
- The **<u>mean</u>** value of multiple measurements determines accuracy



Precision

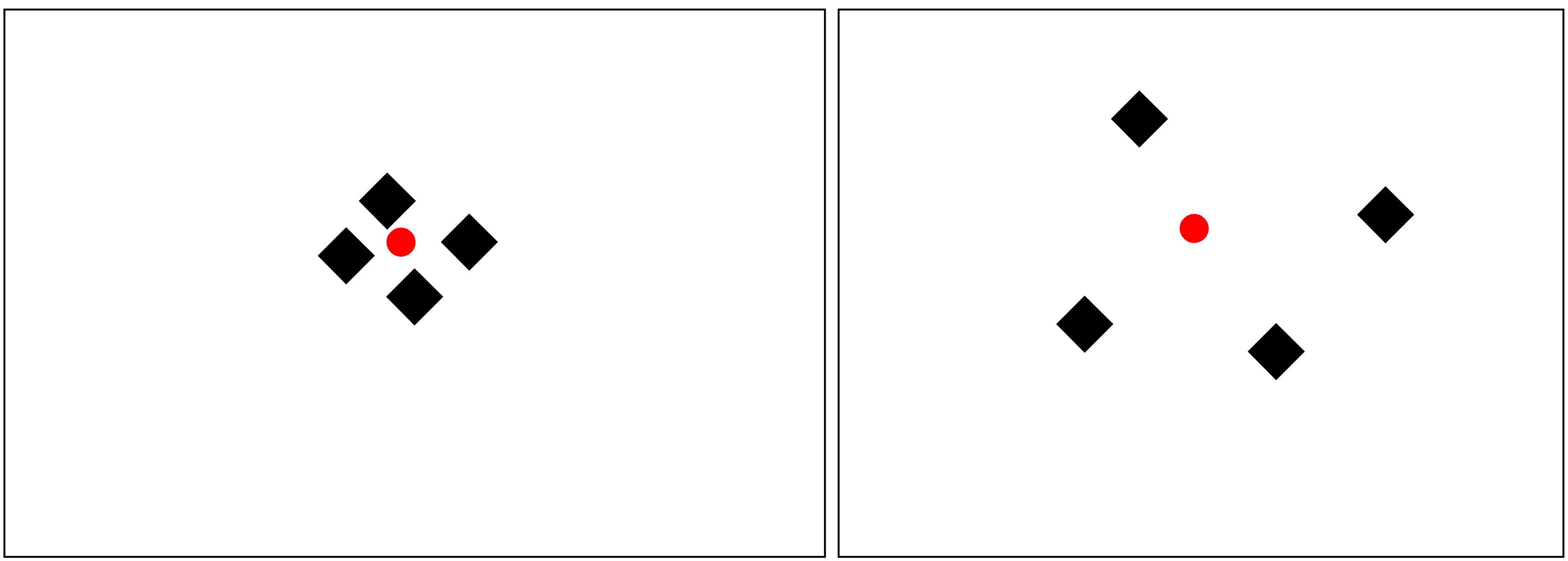
- How many significant digits?

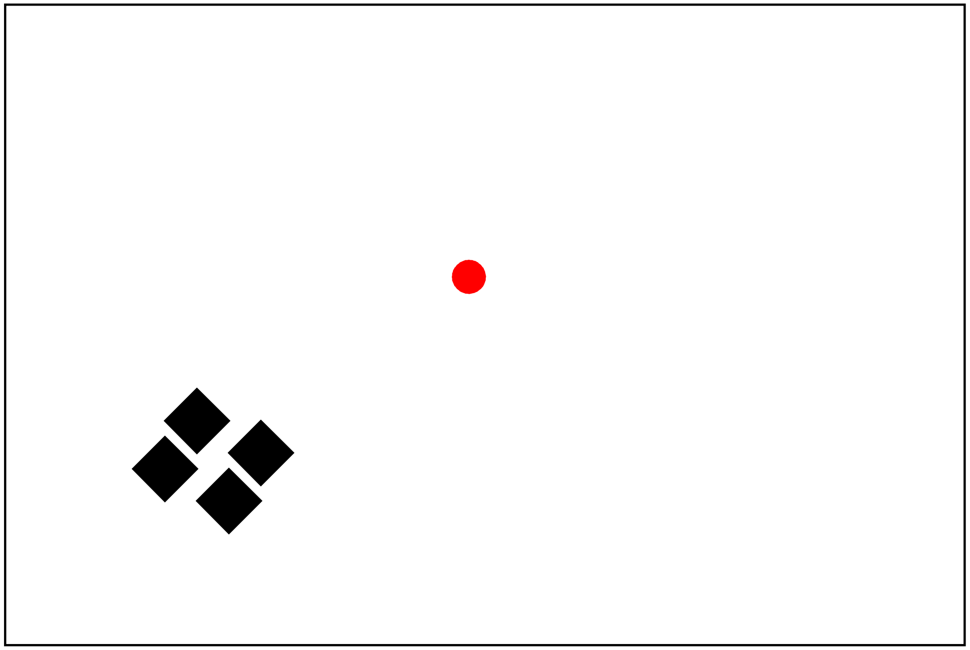




Reproducibility

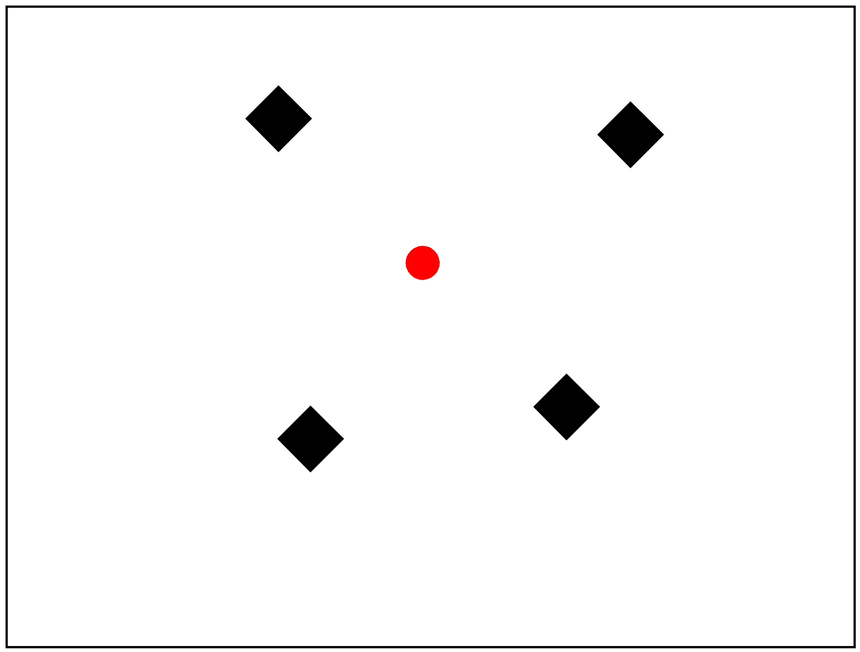
- Are your measurements repeatable?
- The <u>**standard deviation**</u> of multiple measurements determines precision

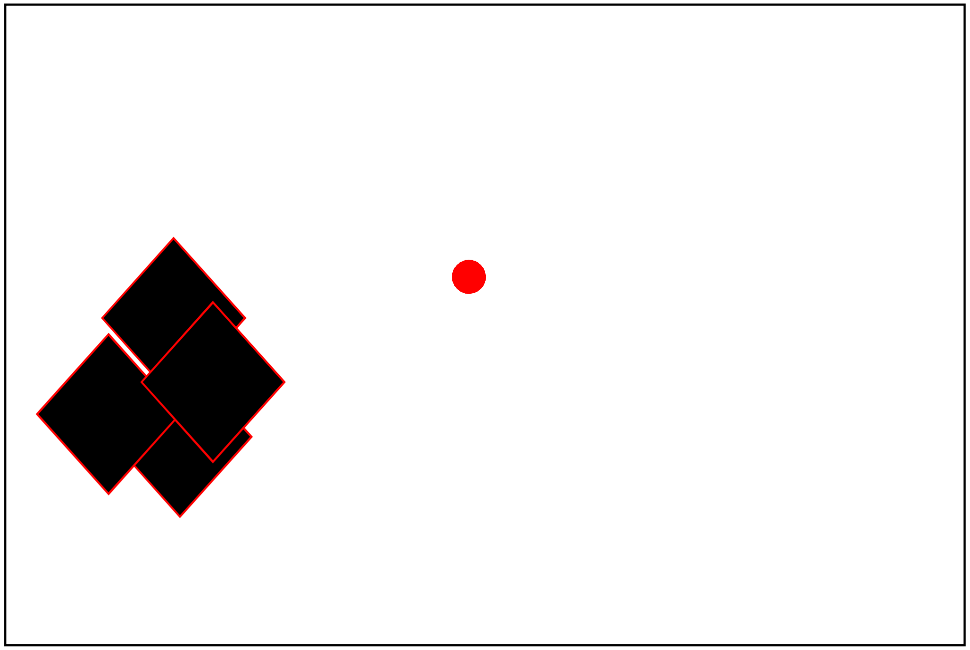




Reproducible but not accurate

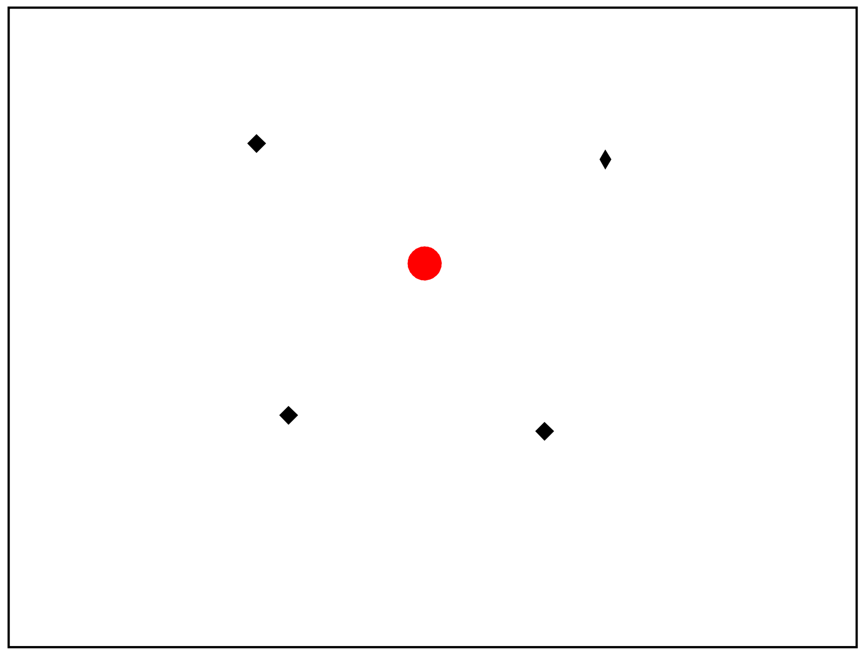
Accurate but not reproducible





Reproducible but not precise

Not reproducible but precise



Correcting for Poor Accuracy and Reproducibility

- Poor Accuracy – calibration
  - If your thermometer consistently measures 3 degrees below the true temperature, simply add 3 degrees to your measurements
- Poor Reproducibility – multiple samples
  - If your individual pressure measurements vary +/- 5 psi, take 25 measurements and compute average.
- Poor Precision
  - You need a more precise instrument!

Significant Figures

- Significant figures: 100, 100.3, 100.300

  1.47*3.0926 = 4.54612 correct?

- 147 + 23.5 = 170.5 correct?

Why Are Significant Figures Important?

- Measurements always involve a comparison.
- The comparison always involves some uncertainty.

1.92 cm

Rules of Thumb for Significant Figures

- All nonzero digits are significant:

  1.234 g has 4 significant figures,
  1.2 g has 2 significant figures.

- Zeroes between nonzero digits are significant:

  1002 kg has 4 significant figures,
  3.07 mL has 3 significant figures.

- Trailing zeroes that are also to the right of a decimal point in a number are significant:

  0.0230 mL has 3 significant figures,
  0.20 g has 2 significant figures.

Rules of Thumb for Significant Figures

- Leading zeroes and ending zeroes may or may not be significant:

  0.012 g may have 2, 3, or 4 significant figures.

  50,600 miles may be 3, 4, or 5 significant figures.

- Use scientific notation to eliminate confusion:

  5.06×10^4 calories (3 significant figures)
  5.060×10^4 calories (4 significant figures), or
  5.0600×10^4 calories (5 significant figures).

- Integers (counting numbers) have <u>infinite</u> significant figures

  "5 women" has infinite significant figures

Calculations Using Significant Figures

- The significant figures in a calculated result is no more than the significant figures of the smallest value involved in the calculation.

  $3.0 \times 12.60 = 38$

- In a long calculation involving mixed operations, carry as many digits as possible through the entire set of calculations and then round the <u>final result</u> appropriately.

  Rounding intermediate results introduces <u>errors!</u>

1.92 cm

16 pennies =
7/8” = 0.875 in.

Volume = $\pi * D^2/4 * H$

$= 3.14159 * (1.92\ cm)^2 / 4 * 0.875\ in / 16 * (0.393701\ cm/in)$

$= 0.062337095\ cm^3$

3.14159	6 sig. fig.
1.92 cm	3 sig. fig.
4	Infinite sig. fig.
0.875 in	3 sig. fig.
16	Infinite sig. fig.
0.393701 cm/in	6 sig. fig.

Volume = $6.23 \times 10^{-2}\ cm^3$

Summary

- Dimensions are properties that can be measured (mass, time, etc.)
- Units are scales for measuring dimensions and can be interconverted.
- Instruments are used to measure the physical world and have three inherent properties

  Precision = significant figures

  Accuracy = conformity to standard of measurement

  Reproducibility = give same answer for repeated measurements