2.2 Measurement Uncertainties

Comparing Results:

disregard this section

Accuracy and Precision

- degree of exactness of a measurement (like a *tight* grouping of arrows shot at a target) (getting basically the same results)
- depends on instrument used (it's divisions)

generally, If an instrument (meterstick) measures to the nearest millimeter (mm) you would estimate and list the measurement to within at least 0.5 mm. An instrument like a micrometer can measure to 0.01 mm and you can estimate within at least 0.005 mm, therfore, it is more precise than the meterstick.

Accuracy and Precision

- agreement of a measurement with a standard value (hitting the *bulls-eye*)

two-point calibration: checks the accuracy of an insturment by 1) seeing if the instrument reads "0" when it should and 2) do it then also give the correct reading of an accepted standard.

Techniques of good measurement

avoid parallax
control outside sources of error (heat, excess pressure)

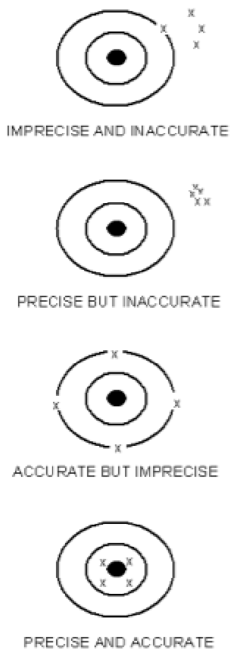
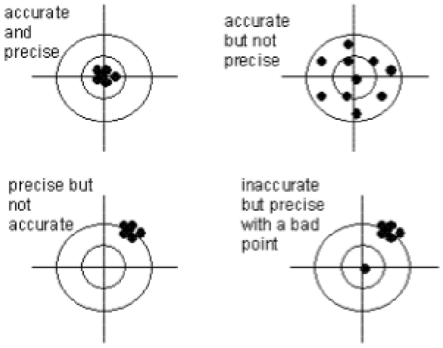


FIGURE 1. Accuracy versus precision (after Kelley et al 1992).



Significant Digits

Significant digits include *all* valid digits. This includes all digits up to the smallest increment of the instrument and then one estimated place further. You dicide how many divisions you can estimate between the smallest increment.

example: If you used a meterstick to measure the length your book it would be about 0.2835 m (28.35 cm). The "3 digit in the smallest increment of the meterstick (the "mm" and the "5" represents the estimated value between the smallest increment. The estimated diget is valid so this measurement has 4 valid digits and therefore 4 sig. figs.

repeat

Significant Digits

Significant digits include *all* valid digits. This includes all digits up to the smallest increment of the instrument and then one estimated place further. You dicide how many divisions you can estimate between the smallest increment.

How you estimate is called *Uncertainty of a Measurement* and is indicated by a +/- following the listing of the measurement showing how many divisions you divided the smallest increment into. If you thought you could divide the millimeter increment into 10 estimated divisions you would list your textbook length measurement as 0.2835 ± .0001 m. The ± .0001 m states you divided the mm increment into 10 divisions are are confident the length is no smaller than 0.2834 m and no larger than 0.2836 m

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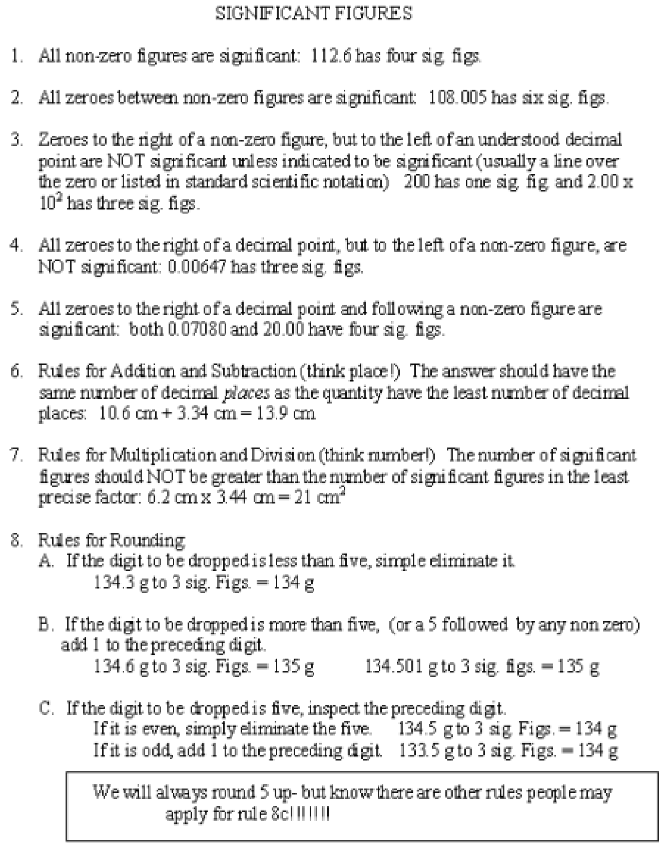
Are all zeros significant?

1) All nonzero digits are significant
2) All final zeros after the decimal point are significant
3) Zeros between any two nozero digits are significant
4) Zeros used soeley as placeholders are not significant



SIGNIFICANT FIGURES

1. All non-zero figures are significant: 112.6 has four sig. figs.
2. All zeroes between non-zero figures are significant: 108.005 has six sig. figs.
3. Zeroes to the right of a non-zero figure, but to the left of an understood decimal point are NOT significant unless indicated to be significant (usually a line over the zero or listed in standard scientific notation) 200 has one sig. fig. and 2.00 x 10^2 has three sig. figs.
4. All zeroes to the right of a decimal point, but to the left of a non-zero figure, are NOT significant: 0.00647 has three sig. figs.
5. All zeroes to the right of a decimal point and following a non-zero figure are significant: both 0.07080 and 20.00 have four sig. figs.
6. Rules for Addition and Subtraction (think place!) The answer should have the same number of decimal *places* as the quantity have the least number of decimal places: 10.6 cm + 3.34 cm = 13.9 cm
7. Rules for Multiplication and Division (think number!) The number of significant figures should NOT be greater than the number of significant figures in the least precise factor: 6.2 cm x 3.44 cm = 21 cm^2
8. Rules for Rounding
   A. If the digit to be dropped is less than five, simple eliminate it.
      134.3 g to 3 sig. Figs. = 134 g

   B. If the digit to be dropped is more than five, (or a 5 followed by any non zero) add 1 to the preceding digit.
      134.6 g to 3 sig. Figs. = 135 g   134.501 g to 3 sig. figs. = 135 g

   C. If the digit to be dropped is five, inspect the preceding digit.
      If it is even, simply eliminate the five.   134.5 g to 3 sig. Figs. = 134 g
      If it is odd, add 1 to the preceding digit.   133.5 g to 3 sig. Figs. = 134 g

We will always round 5 up- but know there are other rules people may apply for rule 8c!!!!!!

Arithmetic with Significant Digits

When you use your measurements to calculate additional characteristics/properties by adding, subtracting or multiplying/dividing you have to remember that your results can not be more precise than your measurements.

When you add/subtract in a calculation the *place* of significant digits in the measurements determines the place of significance in the answer.

$\pm$ place

$\times \div$ # of s.f.

$$\begin{array}{r} 1.2\ \ \text{mm} \\ +\ 2.33\ \text{mm} \\ \hline 3.53\ \text{mm} \end{array} = 3.5\ \text{mm}$$

$$\begin{array}{r} 1.\underline{2}\ \ \text{mm} \\ +\ 2.3\underline{3}\ \text{mm} \\ \hline 3.5\underline{3}\ \text{mm} \end{array} = 3.\underline{5}\ \text{mm}$$

the leftmost place of significance in the addends determine the rightmost place of significance in the answer

When you multiply/divide in a calculation the *number* of significant digits in the measurements determines the number of significant digits in the answer.

2.2 m — 2 sig. figs.

x 1.24 m — 3 sig. figs

$$2.728\ \text{m}^2 = 2.7\text{m}^2$$

answer has to have the least (2)

Aug 30 - 11:13 PM

Jon has 5 dimes. How many pennies is that?

1) $$5\ \text{dimes}\left(\qquad \right) = \underline{\qquad}\ \text{pennies}$$

units you have

units you want

1) write out the problem with the units you have on the left and the units you want on the right...(leave room for the conversion factor)

2) determine the conversion factor that is the *identify* of the two units (pennies/dimes)- if you put a "1" in front of the largest unit (dimes), then the other unit (pennies) will always be larger than "1" (10 pennies/1dime)

2) $$5\ \text{dimes}\left(\frac{10\ \text{pennies}}{1\ \text{dimes}}\right) = \underline{\qquad}\ \text{pennies}$$

Aug 31-12:36 PM

Jon has 5 dimes. How many pennies is that? *continued*

$$5\ \cancel{\text{dimes}}\left(\frac{10\ \text{pennies}}{1\ \cancel{\text{dimes}}}\right) = \_\_\_\_\_\ \text{pennies}$$

3) arrange the units in the conversion factor so the *units you have* are on the bottom and the *units you want* are on the top

4) the units you have now cancel (dimes on top cancel with dimes on the bottom) and pennies remain

5) multiply the units you have by the conversion factor (5 x 10= 50.....
50 ÷ 1 = 50)

5 dimes = 50 pennies

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23 cm = ________________ m

$$23\ \text{cm}\left(\frac{\overset{\text{units you want}}{1\ \text{m}}}{\underset{\text{units you have}}{100\ \text{cm}}}\right) = .23\ \text{m}$$

$$23\ \cancel{\text{cm}}\left(\frac{1\ \text{m}}{100\ \cancel{\text{cm}}}\right) = .23\ \text{m}$$

23 x 1 = 23......... 23 ÷ 100 = .23........or $\frac{23 \times 1}{100}$ = .23

review

1) have/want

2) conversion factor- identity

3) range, "1" by biggest unit

Sep 4-10:27 AM

$$750\ \text{pm} = \underline{\hspace{3cm}}\ \text{Mm}$$

7.5×10^2

$$750\ \text{pm}\left(\frac{1\ \text{Mm}}{10^{18}\ \text{pm}}\right) = \underline{7.5 \times 10^{-16}}\ \text{Mm}$$

$\text{Mm} = 10^6$

$\text{pm} = 10^{-12}$

range 10^{18}

Sep 4-10:54 AM

$$1100\,ft/s = \underline{\qquad\qquad}\ m/s$$

$$1100\,\cancel{ft}/s\left(\frac{1\ m}{3{,}28\ \cancel{ft}}\right) = \underline{335}\ m/s$$

Sep 4-10:58 AM

$$770\,\frac{miles}{hr} = \underline{\qquad\qquad}\ m/s$$

$$770\,\frac{\cancel{miles}}{\cancel{hr}}\left(\frac{1610\ m}{1\ \cancel{miles}}\right)\left(\frac{1\ \cancel{hr}}{3600\ s}\right) = \underline{344}\ m/s$$

Sep 4-11:02 AM

ex

$980\,nm = \_\_\_\_\_\_\ Mm$

9.8×10^{2}

$980\,nm \left(\frac{1\ Mm}{10^{15}\ nm} \right) = \frac{9.8 \times 10^{-13}}{\_\_\_\_\_\_}\ Mm$

$Mm = 10^{6}$
$nm = 10^{-9}$
$range = 10^{15}$

Sep 4-10:09 AM

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ex

$.0067\ Gm = \_\_\_\_\_\_\ \mu m$

6.7×10^{-3}

$.0067\,Gm \left(\frac{10^{15}\ \mu m}{1\ Gm} \right) = \frac{6.7 \times 10^{12}}{\_\_\_\_\_\_}\ \mu m$

$Gm = 10^{9}$
$\mu m = 10^{-6}$
$range = 10^{15}$

Sep 4-10:12 AM