Significant Figures

- When using our calculators we must determine the correct answer; our calculators are mindless drones and don't know the correct answer.
- There are 2 different types of numbers
  - Exact
  - Measured
- Exact numbers are infinitely important
- Measured number = they are measured with a measuring device (name all 4) so these numbers have ERROR.
- When you use your calculator your answer can only be as accurate as your worst measurement...Doohoo ☺

Exact Numbers

An exact number is obtained when you count objects or use a defined relationship.

Counting objects are always exact
- 2 soccer balls
- 4 pizzas

Exact relationships, predefined values, not measured
- 1 foot = 12 inches
- 1 meter = 100 cm

For instance is 1 foot = 12.000000000001 inches? No
1 ft is EXACTLY 12 inches.

Learning Check

A. Exact numbers are obtained by
1. using a measuring tool
2. counting
3. definition

B. Measured numbers are obtained by
1. using a measuring tool
2. counting
3. definition

Learning Check

Classify each of the following as an exact or a measured number.

1 yard = 3 feet

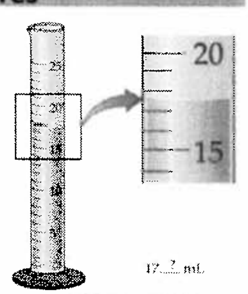
The diameter of a red blood cell is 6×10^{-4} cm.

There are 6 hats on the shelf.

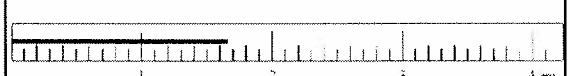
Gold melts at 1064°C.

2.4 Measurement and Significant Figures

- Every experimental measurement has a degree of uncertainty.
- The volume, V, at right is certain in the 10's place, 10mL<V<20mL
- The 1's digit is also certain, 17mL<V<18mL
- A best guess is needed for the tenths place.

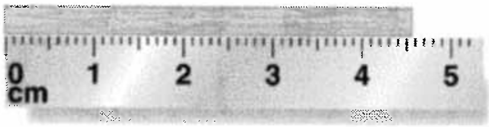


What is the Length?



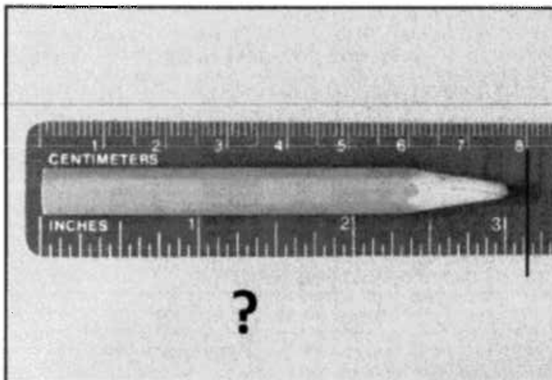
- We can see the markings between 1.6-1.7cm
- We can't see the markings between the .6-.7
- We must guess between .6 & .7
- We record 1.67 cm as our measurement
- The last digit an 7 was our guess...stop there

Learning Check



What is the length of the wooden stick?

1) 4.5 cm
2) 4.54 cm
3) 4.547 cm



Measured Numbers

- Do you see why Measured Numbers have error…you have to make that Guess!
- All but one of the significant figures are known with certainty. The last significant figure is only the best possible estimate.
- To indicate the precision of a measurement, the value recorded should use all the digits known with certainty.

Below are two measurements of the mass of the same object. The same quantity is being described at two different levels of precision or certainty.

Uncertain digit

54.07 g — A mass between 54.06 g and 54.08 g (±0.01 g)

Uncertain digit

54.071 38 g — A mass between 54.071 37 g and 54.071 39 g (±0.000 01 g)

Note the 4 rules

When reading a measured value, all nonzero digits should be counted as significant. There is a set of rules for determining if a zero in a measurement is significant or not.

- **RULE 1.** Zeros in the middle of a number are like any other digit; they are always significant. Thus, 94.072 g has five significant figures.
- **RULE 2.** Zeros at the beginning of a number are not significant; they act only to locate the decimal point. Thus, 0.0834 cm has three significant figures, and 0.029 07 mL has four.

- **RULE 3.** Zeros at the end of a number and *after* the decimal point are significant. It is assumed that these zeros would not be shown unless they were significant. 138.200 m has six significant figures. If the value were known to only four significant figures, we would write 138.2 m.
- **RULE 4.** Zeros at the end of a number and *before* an implied decimal point may or may not be significant. We cannot tell whether they are part of the measurement or whether they act only to locate the unwritten but implied decimal point.

Practice Rule #1 Zeros

45.8736

.000239

.00023900

48000.

48000

3.982×10^6

1.00040

2.5 Scientific Notation

- **Scientific notation** is a convenient way to write a very small or a very large number.
- Numbers are written as a product of a number between 1 and 10, times the number 10 raised to power.
- 215 is written in scientific notation as:

$215 = 2.15 \times 100 = 2.15 \times (10 \times 10) = 2.15 \times 10^2$

Two examples of converting standard notation to scientific notation are shown below.

$$215. = 2.15 \times 10^2$$

Decimal point is moved two places to the left, so exponent is 2.

$$0.002\,15 = 2.15 \times \frac{1}{1000} = 2.15 \times \frac{1}{10 \times 10 \times 10} = 2.15 \times \frac{1}{10^3} = 2.15 \times 10^{-3}$$

$$0.002\,15 = 2.15 \times 10^{-3}$$

Decimal point is moved three places to the right, so exponent is −3.

Two examples of converting scientific notation back to standard notation are shown below.

$$3.7962 \times 10^4 = 37{,}962$$

Positive exponent of 4, so decimal point is moved to the right four places.

$$1.56 \times 10^{-8} = 0.000\,000\,015\,6$$

Negative exponent of −8, so decimal point is moved to the left eight places.

- Scientific notation is helpful for indicating how many significant figures are present in a number that has zeros at the end but to the left of a decimal point.
- The distance from the Earth to the Sun is 150,000,000 km. Written in standard notation this number could have anywhere from 2 to 9 significant figures.
- Scientific notation can indicate how many digits are significant. Writing 150,000,000 as 1.5×10^8 indicates 2 and writing it as 1.500×10^8 indicates 4.
- Scientific notation can make doing arithmetic easier. Rules for doing arithmetic with numbers written in scientific notation are reviewed in Appendix A.

2.6 Rounding Off Numbers

- Often when doing arithmetic on a pocket calculator, the answer is displayed with more significant figures than are really justified.
- How do you decide how many digits to keep?
- Simple rules exist to tell you how.

- Once you decide how many digits to retain, the rules for rounding off numbers are straightforward:
- **RULE 1.** If the first digit you remove is 4 or less, drop it and all following digits. 2.4271 becomes 2.4 when rounded off to two significant figures because the first dropped digit (a 2) is 4 or less.
- **RULE 2.** If the first digit removed is 5 or greater, round up by adding 1 to the last digit kept. 4.5832 is 4.6 when rounded off to 2 significant figures since the first dropped digit (an 8) is 5 or greater.
- If a calculation has several steps, it is best to round off at the end.

Practice Rule #2 Rounding

Make the following into a 3 Sig Fig number

1.5587

.0037421

1367

128,522

1.6683×10^{6}

Examples of Rounding

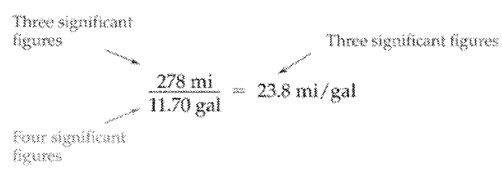
For example you want a 4 Sig Fig number

4965.03

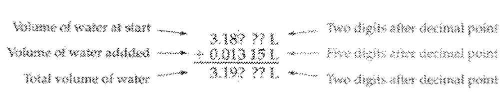
780,582

1999.5

RULE 1. In carrying out a multiplication or division, the answer cannot have more significant figures than either of the original numbers.



- **RULE 2.** In carrying out an addition or subtraction, the answer cannot have more digits after the decimal point than either of the original numbers.



Multiplication and division

$32.27 \times 1.54 = 49.6958$

$3.68 \div .07925 = 46.4353312$

$1.750 \times .0342000 = 0.05985$

$3.2650\times10^{6} \times 4.858 = 1.586137 \times 10^{7}$

$6.022\times10^{23} \times 1.661\times10^{-24} = 1.000000$

Addition/Subtraction

25.5	32.72	320
+34.270	- 0.0049	+ 12.5

Addition and Subtraction

.56 + .153 = .713

82000 + 5.32 = 82005.32

10.0 - 9.8742 = .12580

10 – 9.8742 = .12580

Look for the last important digit

Mixed Order of Operation

8.52 + 4.1586 × 18.73 + 153.2 =

= 8.52 + 77.89 + 153.2 = 239.61 =

(8.52 + 4.1586) × (18.73 + 153.2) =

= 12.68 × 171.9 = 2179.692 =