Measurement

(1) Pick the right device.

(2) Read the scale
  (a) digital .....

  (b) analog: read the value and then estimate last digit. Generally one can estimate to 10% of the smallest scale increment.
  Since the last digit is estimated there is error associated with it. Unless stated otherwise the
  error is assumed to be ±1 (the smallest increment)
  e.g.
  3.45 g means 3.45 ± 0.01 g

  79.5 g means 79.5 ± 0.1 g

Reporting measurements

1. Units: do not forget the units. Additionally, include names when appropriate.
   do not simply write 3.19 g, but 3.19 g $CuSO_4$

2. Significant Figures tell how precisely the measurement was made.
   A student uses a 4 decimal place balance to determine the mass of a sample of NaCl. Should the mass be reported as 5 g, or 5.0000 g?

   5.0000 g is the correct answer. If one were to write 5 g of NaCl the assumption is that the error is ±1 g when the actual measurement is precise to ±0.0001 g.

Using Significant figures

Two important steps with sigfigs...

(1) determining the number of significant figures in a measurement.

a. All non-zero numbers are significant

b. zero's are significant if

i. they are between two non-zero numbers

ii. they occur before and after the decimal point of a number whose absolute value is > 1

e.g. In 850.0 and 85.0 the zero's are significant, but in 850 the zero is not significant.

iii. they occur after a non-zero number in a number whose absolute value is < 1

e.g. In 0.0450 only the last zero is significant, the other zeros are place holders.

(2) determining the number of significant figures that should remain after performing mathematical manipulations with the numbers

a. addition/subtraction

the result of adding two numbers together should be precise to the place that corresponds to the least precise measurement

b. multiplication/division

the result of multiplying two numbers should have the same number of significant figures as the number with the fewest significant figures.

Some examples of mathematical operations with significant figures.

(a) Addition

3.4	could be	3.5	or	3.3
<u>5.33</u>	could be	<u>5.34</u>	or	<u>5.32</u>
8.7		8.84		8.62

An answer of 8.73 would mean that the sum of the measurements could be 8.74 to 8.72. Obviously the sum can be outside this small range due to the error associated with the measurement 3.4. To ensure that the result falls within the real window of uncertainty the answer is 8.7.

(b) Multiplication

2.5	could be	2.6	or 2.4
x <u>5</u>	could be	x <u>6</u>	or x <u>4</u>
10		15.6	9.6

Once again using to many significant figures in the answer would be misleading. The result "13" means from 12 to 14, or worse using 12.5 implies a range from 12.4 to 12.6. The actual possibilities are outside of both ranges. To ensure that the result does not imply more precision than is warranted, the result must be reported as 10, which implies that the number could be anywhere from 0 to 20.

Combining Mathematical operations

Losing Significant Figures

Because you are on a long automobile trip and you are bored, you decide to determine your average velocity in miles per second. The only instruments available are your odometer, and your wrist watch.

You start the timer on your wrist watch when the odometer reads 135,356.7 miles (did I mention that you are driving an old car?) and you stop the timer when the odometer reads 135,359.2 mile. Your stopwatch indicates that 159.5 seconds have elapsed.

average speed equals distance traveled divided be elapsed time.

$$\frac{\text{135,359.2 - 135.356.7 miles}}{\text{159.5 s}} = \text{0.0156739811 mile/s}$$

So, how many significant figures should be used in your answer?

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Why?

$$\frac{\text{135,359.2 - 135.356.7 miles}}{\text{159.5 s}} = \frac{\text{2.5 mile}}{\text{159.5 s}}$$

The difference is 2.5 and this number is the number that limits the number of significant figures the answer can contain.....so

0.016 mile/s (Incidentally, you are travelling 56 mph.)

Exact numbers

- Exact numbers never limit the number of significant figures.

- Exact numbers have as many significant figures as the problem requires.

- Exact numbers are numbers that are defined to be a certain value.

For example

12 inches = 1 foot these are definitions
5280 feet = 1 mile
2.54 cm = 1 inch
1 km = 1000 m

- Exact numbers are things that can be counted. (This statement must be applied cautiously. Every several years the United States attempts to count the number of people in the country. Clearly the population determined by the Census Bureau is not an exact number.)

For Example

Three measurements were made of the length of my office.

5.0 feet, 5.1 feet, and 5.2 feet. Determine the average length.

$$\frac{5.0 + 5.1 + 5.2}{3} = 5.1 \text{ feet}$$

5.1 feet is correct. The “3” is an exact number so it does not limit the number of significant figures contained in the result.