# Tutorial 2: Expressing Uncertainty (Sig Figs, Scientific Notation and Rounding)

Goals:

- ✓ To be able to convert quantities from one unit to another.
- ✓ To be able to express measurements and answers to the correct number of significant figures.
- ✓ To be able to use scientific notation when necessary to reflect the correct significant figures.

# Uncertainty in Measurements

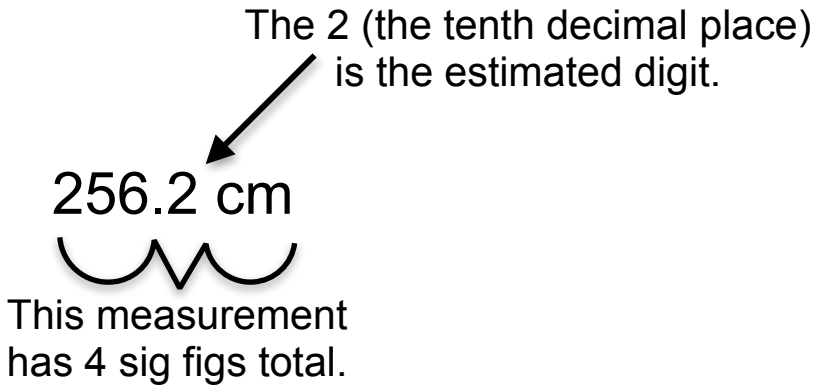
- **Exact numbers:** numbers that have a definite value.
  - All metric conversions are exact; for example, there are exactly 1000 g in 1 kg.
  - All counted numbers such as the number of people in a room or the number of quarters in a purse are exact.

- **Inexact numbers:** numbers that do not have a definite value and contain some uncertainty.
  - All measured quantities contain uncertainty due to estimating, so all measurements are inexact!

# Significant Figures

- All digits in a measured quantity are considered significant. The last digit of a measured quantity contains uncertainty because it is the estimated digit.

**Example:**



# Rules for Sig Figs

1) All nonzero digits are significant.
   - 457 cm has 3 sig figs
   - 2.5 g has 2 sig figs

2) Zeros between nonzero digits are significant.
   - 1007 kg has 4 sig figs
   - 1.033 g has 4 sig figs

3) Zeros to the left of the first nonzero digit are not significant. They are not actually measured, but are place holders.
   - 0.0022 g has 2 sig figs
   - 2.2 mg has 2 sig fig

4) Zeros at the end of a number and to the right of a decimal are significant. They are assumed to be measured numbers.
   - 0.002200 g has 4 sig figs
   - 0.20 has 2 sig figs
   - 7.000 has 4 sig figs

5) When a number ends in zero but contains no decimal place, the zeros may or may not be significant. We use scientific (aka exponential) notation to specify.
   - 7000 kg may have 1, 2, 3 or 4 sig figs!

# Scientific Notation

- Move the decimal behind the first nonzero digit (this will make the number between 1 and 10).

- Multiply the number by 10 to the appropriate power.

**Examples:**

1) 0.0001 cm = $1 \times 10^{-4}$ cm
2) 10,000 m (expressed to 2 sig fig ) = $1.0 \times 10^{4}$ m
3) 13,333 g = $1.3333 \times 10^{4}$ g
4) 10,000 m (expressed to 4 sig figs) = $1.000 \times 10^{4}$ m

**NOTE:** All zeros after the decimal are significant.

**NOTE:** The exponent is not counted as a sig fig.

# Sig Figs In Calculations

- **Multiplying and Dividing:** Answer must contain the same number of sig figs as there are in the measurement with the least number of sig figs.

- **Adding and Subtracting:** Round answer to the same number of decimal places as there are in the measurement with the fewest decimal places.

# Rounding Calculations

- If the left-most digit to be removed is less than 5, do not round up. If the left-most digit to be removed is greater than or equal to 5, round up.

**Examples:**

(6.221 cm)(5.2 cm) = 32.3492 $cm^2$ = 32 $cm^2$

(6.221 cm)(5.200 cm) = 32.3492 $cm^2$ = 32.35 $cm^2$

**NOTE:** Do not round until the last calculation has been performed. Rounding at each step introduces more error.

**NOTE:** Exact numbers (not measured numbers) are indefinitely precise and have indefinite sig figs, thus they do not ever determine the number of sig figs in a final answer! All metric conversions are exact.

**NOTE:** If a problem requires both addition/subtraction and multiplication/ division then each rule is applied separately.

# Dimensional Analysis (Factor-Labeled Method)

- **Conversion Factor:** A conversion factor is a fraction with a numerator and a denominator that are equal quantities with different units. Thus, a conversion factor is equal to 1! We use conversion factors to convert one type of units to another.

**Example:**

$$\frac{1000\ g}{1\ kg}$$