

## 1.9: Rounding Off Numbers

### Learning Objectives

- Use significant figures correctly in arithmetical operations.

### Rounding

Before dealing with the specifics of the rules for determining the significant figures in a calculated result, we need to be able to round numbers correctly. To **round** a number, first decide how many significant figures the number should have. Once you know that, round to that many digits, starting from the left. If the number immediately to the right of the last significant digit is less than 5, it is dropped and the value of the last significant digit remains the same. If the number immediately to the right of the last significant digit is greater than or equal to 5, the last significant digit is increased by 1.

Consider the measurement 207.518 m. Right now, the measurement contains six significant figures. How would we successively round it to fewer and fewer significant figures? Follow the process as outlined in Table 1.9.1.

Table 1.9.1: Rounding examples

Number of Significant Figures	Rounded Value	Reasoning
6	207.518	All digits are significant
5	207.52	8 rounds the 1 up to 2
4	207.5	2 is dropped
3	208	5 rounds the 7 up to 8
2	210	8 is replaced by a 0 and rounds the 0 up to 1
1	200	1 is replaced by a 0

Notice that the more rounding that is done, the less reliable the figure is. An approximate value may be sufficient for some purposes, but scientific work requires a much higher level of detail.

It is important to be aware of significant figures when you are mathematically manipulating numbers. For example, dividing 125 by 307 on a calculator gives 0.4071661238... to an infinite number of digits. But do the digits in this answer have any practical meaning, especially when you are starting with numbers that have only three significant figures each? When performing mathematical operations, there are two rules for limiting the number of significant figures in an answer—one rule is for addition and subtraction, and one rule is for multiplication and division.

*In operations involving significant figures, the answer is reported in such a way that it reflects the reliability of the **least precise** operation. An answer is no more precise than the least precise number used to get the answer.*

### Rules for Calculations With Measured Numbers

How are significant figures handled in calculations? It depends on what type of calculation is being performed.

#### Multiplication and Division

For multiplication or division, the rule is to count the number of significant figures in each number being multiplied or divided and then limit the significant figures in the answer to the lowest count. An example is as follows:

$$\underbrace{38.65}_{4 \text{ sig figs}} \times \underbrace{105.93}_{5 \text{ sig figs}} = \underbrace{4,094.1945}_{\text{reduce to 4 sig figs}}$$

38.65 times 105.93 equals 4094.1954, which should be rounded to 4 sig figs since the lowest count in the numbers being multiplied is 4 sig figs

The final answer, limited to four significant figures, is 4,094. The first digit dropped is 1, so we do not round up.

Scientific notation provides a way of communicating significant figures without ambiguity. You simply include all the significant figures in the leading number. For example, the number 450 has two significant figures and would be written in scientific notation as  $4.5 \times 10^2$ , whereas 450.0 has four significant figures and would be written as  $4.500 \times 10^2$ . In scientific notation, all significant figures are listed explicitly.

### ✓ Example 1.9.1

Write the answer for each expression using scientific notation with the appropriate number of significant figures.

- a.  $23.096 \times 90.300$   
 b.  $125 \times 9.000$

#### Solution

a

Solution to (a) in example question.

Explanation	Answer
The calculator answer is 2,085.5688, but we need to round it to five significant figures. Because the first digit to be dropped (in the tenths place) is greater than 5, we round up to 2,085.6.	$2.0856 \times 10^3$

b

Solution to (b) in example question.

Explanation	Answer
The calculator gives 1,125 as the answer, but we limit it to three significant figures.	$1.13 \times 10^3$

### Addition and Subtraction

If the calculation is an addition or a subtraction, the rule is as follows: limit the reported answer to the rightmost column that all numbers have significant figures in common. For example, if you were to add 1.2 and 4.71, we note that the first number stops its significant figures in the tenths column, while the second number stops its significant figures in the hundredths column. We therefore limit our answer to the tenths column.

$$\begin{array}{r}
 1.2 \\
 \underline{4.71} \\
 5.91 \\
 \uparrow \text{limit final answer to the tenths column: } 5.9
 \end{array}$$

We drop the last digit—the 1—because it is not significant to the final answer.

The dropping of positions in sums and differences brings up the topic of rounding. Although there are several conventions, in this text we will adopt the following rule: the final answer should be rounded up if the first dropped digit is 5 or greater and rounded down if the first dropped digit is less than 5.

$$\begin{array}{r}
 77.2 \\
 \underline{10.46} \\
 87.66 \\
 \uparrow \text{limit final answer to the tenths column and round up: } 87.7
 \end{array}$$

✓ Example 1.9.2

- a.  $13.77 + 908.226$   
 b.  $1,027 + 611 + 363.06$

**Solution**

a

Solution to (a) in example question.

Explanation	Answer
The calculator answer is 921.996, but because 13.77 has its farthest-right significant figure in the hundredths place we need to round the final answer to the hundredths position. Because the first digit to be dropped (in the thousandths place) is greater than 5, we round up to 922.00	$922.00 = 9.2200 \times 10^2$

b

Solution to (b) in example question.

Explanation	Answer
The calculator gives 2,001.06 as the answer, but because 611 and 1027 has its farthest-right significant figure in the ones place, the final answer must be limited to the ones position.	$2,001.06 = 2.001 \times 10^3$

? Exercise 1.9.2

Write the answer for each expression using scientific notation with the appropriate number of significant figures.

- a.  $217 \div 903$   
 b.  $13.77 + 908.226 + 515$   
 c.  $255.0 - 99$   
 d.  $0.00666 \times 321$

**Answer a:**

$$0.240 = 2.40 \times 10^{-1}$$

**Answer b:**

$$1,437 = 1.437 \times 10^3$$

**Answer c:**

$$156 = 1.56 \times 10^2$$

**Answer d:**

$$2.14 = 2.14 \times 10^0$$

Remember that calculators do not understand significant figures. *You* are the one who must apply the rules of significant figures to a result from your calculator

✓ Example 1.9.3

- a.  $2(1.008\text{g}) + 15.99\text{ g}$   
 b.  $137.3\text{ s} + 2(35.45\text{ s})$   
 c.  $\frac{118.7\text{g}}{2} - 35.5\text{g}$

**Solution**

a

Solution to (a) in example question.

Explanation	Answer
$2(1.008\text{g}) + 15.99\text{ g} =$ <b>Perform multiplication first.</b> $2 (1.008\text{g } 4 \text{ sig figs}) = 2.016\text{ g } 4 \text{ sig figs}$ The number with the least number of significant figures is 1.008g; <i>the number 2 is an exact number and therefore has infinite number of significant figures.</i> <b>Then, perform the addition.</b> $2.016\text{ g } \textit{thousandths place} + 15.99\text{ g } \textit{hundredths place (least precise)} = 18.006\text{ g}$ <b>Round the final answer.</b> Round the final answer to the hundredths place since 15.99 has its farthest right significant figure in the hundredths place (least precise).	18.01 g (rounding up)

b

Solution to (b) in example question.

Explanation	Answer
$137.3\text{ s} + 2 (35.45\text{ s}) =$ <b>Perform multiplication first.</b> $2 (35.45\text{ s } 4 \text{ sig figs}) = 70.90\text{ s } 4 \text{ sig figs}$ The number with the least number of significant figures is 35.45; <i>the number 2 is an exact number and therefore has infinite number of significant figures.</i> <b>Then, perform the addition.</b> $137.3\text{ s } \textit{tenths place (least precise)} + 70.90\text{ s } \textit{hundredths place} = 208.20\text{ s}$ <b>Round the final answer.</b> Round the final answer to the tenths place based on 137.3 s.	208.2 s

c

Solution to (c) in example question.

Explanation	Answer

$$\frac{118.7g}{2} - 35.5g =$$

**Perform division first.**

$$\frac{118.7g}{2} \text{ 4 sig figs} = 59.35 \text{ g 4 sig figs}$$

The number with the least number of significant figures is 118.7g; the number 2 is an exact number and therefore has infinite number of significant figures.

**Perform subtraction next.**

$$59.35 \text{ g hundredths place} - 35.5 \text{ g tenths place (least precise)} = 23.85 \text{ g}$$

**Round the final answer.**

Round the final answer to the tenths place based on 35.5 g.

23.9 g (rounding up)

### ? Exercise 1.9.3

Complete the calculations and report your answers using the correct number of significant figures.

- $5(1.008s) - 10.66 \text{ s}$
- $99.0 \text{ cm} + 2(5.56 \text{ cm})$

**Answer a**

-5.62 s

**Answer b**

110.2 cm

## Summary

- Rounding
  - If the number to be dropped is greater than or equal to 5, increase the number to its left by 1. e.g. 2.9699 rounded to three significant figures is 2.97
  - If the number to be dropped is less than 5, there is no change. e.g. 4.00443 rounded to four sig. figs. is 4.004
- The rule in multiplication and division is that the final answer should have the same number of significant figures as there are in the number with the fewest significant figures.
- The rule in addition and subtraction is that the answer is given the same number of decimal places as the term with the fewest decimal places.

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