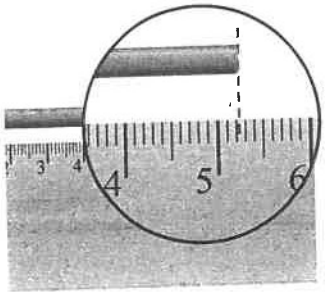
Working with Significant Digits

Measurement and Accuracy

You might think that a measurement can be an exact quantity. But in fact, whenever you take a measurement, you are only making an estimate. **Accuracy** is the difference between a measurement and its true value. No measuring device is 100 percent accurate. For example, the illustration below shows a ruler measuring the length of a rod. The ruler can give a quite accurate reading, as it is divided into millimetre marks. But the end of the rod falls between two marks. There is still uncertainty in the measurement.



Significant Digits

Significant digits are used to represent the amount of uncertainty in a measurement. The significant digits in a measured quantity include all the certain digits plus the first uncertain digit. In the example above, the length of the rod is between 5.2 cm and 5.3 cm. We must estimate the distance between the 2 mm and 3 mm marks. Suppose we estimate the length to be 5.23 cm. The first two digits (5 and 2) are certain (we can see those marks), but the last digit (0.03) was estimated. The measurement 5.23 cm has three significant digits.

Determining the Number of Significant Digits

The following rules will help you determine the number of significant digits in a given measurement.

1. All non-zero digits (1–9) are considered significant.

   Examples:
   - 123 m – three significant digits
   - 23.56 km – four significant digits

2. Zeros between non-zero digits are also significant.

   Examples:
   - 1207 m – four significant digits
   - 120.5 km/h – four significant digits

3. Any zero that follows a non-zero digit *and* is to the right of the decimal point is significant.

   Examples:
   - 12.50 m/s^2 – four significant digits
   - 6.0 km – two significant digits

4. Zeros used to indicate the position of the decimal are *not* significant. These zeros are sometimes called spacers.

   Examples:
   - 500 km – one significant digit (the decimal point is assumed to be after the final zero)
   - 0.325 m – three significant digits
   - 0.000 34 km – two significant digits

5. All counting numbers have an infinite number of significant digits.

   Examples:
   - 6 apples – infinite number of significant digits
   - 125 people – infinite number of significant digits

How Many Significant Digits?

Determine the number of significant digits in each measurement.

(a) 25 g
(b) 584 mL
(c) 0.003 56 km
(d) 505.2 m
(e) 1.030 L
(f) 12 000 cm
(g) 0.0070 kg

Using Significant Digits in Mathematical Operations

When you use measured values in mathematical operations, the calculated answer cannot be more certain than the measurements on which it is based. Often the answer on your calculator will have to be rounded to the correct number of significant digits.

Rules for rounding

1. When the first digit to be dropped is less than 5, the preceding digit is not changed.

   Example:

   6.723 m rounded to two significant digits is 6.7 m. The digit after the 7 is less than 5, so the 7 does not change.

2. When the first digit to be dropped is 5 or greater, the preceding digit is increased by one.

   Example:

   7.237 m rounded to three significant digits is 7.24 m. The digit after the 3 is greater than 5, so the 3 is increased by one.

Adding or subtracting measurements

Perform the mathematical operation, and then round off the answer to the value having the fewest decimal places.

Example:

Add the following measured lengths and express the answer to the correct number of significant digits.

$x = 2.3 \text{ cm} + 6.47 \text{ cm} + 13.689 \text{ cm}$
$= 22.459 \text{ cm}$
$= 22.5 \text{ cm}$

Since 2.3 cm has only one decimal place, the answer can have only one decimal place.

Multiplying or dividing measurements

Perform the mathematical operation, and then round off the answer to the least number of significant digits of the data values.

Example:

Multiply the following measured lengths and express the answer to the correct number of significant digits.

$x = (2.342 \text{ m})(0.063 \text{ m})(306 \text{ m})$
$= 45.149\,076 \text{ m}^3$
$= 45 \text{ m}^3$

Since 0.063 m has only two significant digits, the final answer must also have two significant digits.

Calculations with Significant Digits

Perform the following calculations, rounding off your answer to the correct number of significant digits.

(a) (2.475 m) + (3.5 m) + (4.65 m)
(b) (47 g) − (12.27 g) − (8.384 g)
(c) (15.3 cm) × (0.2265 cm)
(d) (12.34 km) / (0.50 h)
(e) (12 ml) × (3.56 ml) / (4.060 ml)