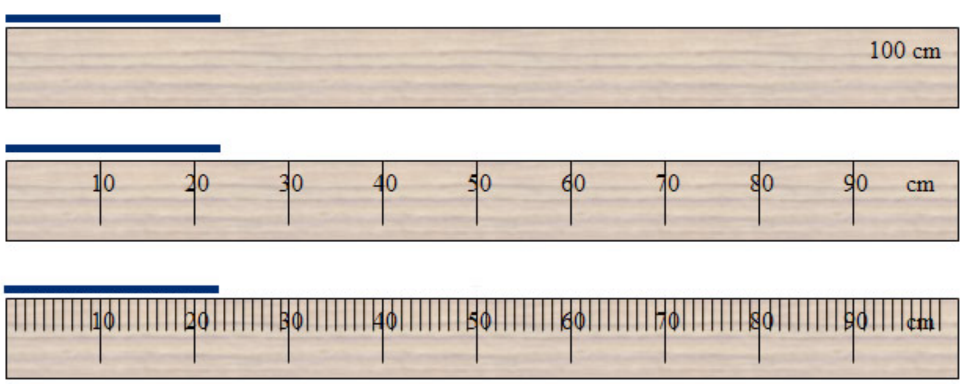
Significant Figures

Any measurement has its limitations in terms of its precision. It is impossible to get an exact or perfect measurement of anything because there is no 'perfect' measuring device. There is uncertainty in every measurement as you approach the limits of the device itself. For this reason, an infinite number of decimals is impossible for a measurement. You might say what about π? Well π is a constant, not a measured value so it can be calculated to as many decimals as needed. Since all measurements have uncertainty, there has to be a way to handle and communicate that uncertainty so everyone knows the limits of any measurement just by inspection or looking at it. This is why significant figures exist.

The definition of significant figures is the number of certain digits in a measurement plus one uncertain digit.

Let's look at a measurement example to illustrate:



A blue line is measured with three different rulers with different **precision.** Precision in this example refers to the smallest division on an instrument. In the top ruler all we can know **for certain** is that the blue line is in between 0 – 1 m. What we need to **estimate** is how far it is in between 0 and 1 m. Since this is **uncertain**, we limit ourselves to dividing the region into **10** equal divisions. A good estimation would be 0.2 m although one might be able to argue 0.1 or 0.3 m and still be within an acceptable margin of error. This measurement of 0.2 m would have one significant figure because it is has no certain digits plus one uncertain digit.

In the second ruler, there is more precision. We know for certain it is in between 0.2 and 0.3 m. Again we divide the uncertain region into 10 equal pieces, and estimate a value of say 0.22 m although 0.21 or 0.23 m would be within an acceptable margin of error. The first digit is certain and the second digit is uncertain for a total of two significant digits.

Finally, ruler three gives us even more precision. We know for certain it is in between 0.22 and 0.23 m. Dividing the uncertain region into ten pieces will yield a reasonable estimate of 0.223 m. This is 2 certain digits plus one uncertain digit for a total of 3 significant figures.

For ***any*** measurement, there is uncertainty, even if it is a ***digital*** measurement! If everyone in the scientific community agrees to this method, which they do, then all measurements will communicate some degree of uncertainty and uncertainty and we have a way of knowing just by the number itself! Let's clarify.

Rules for Significant Digits:

Rule 1: All nonzero digits in a measurement are significant.
Eg. 4.35 m 578 km 6.11×10^4 kg

All these measurements have 3 sigfigs.

Rule 2: Leading zeroes are not significant.
Eg. 0.00043 kg 0.0016 km 0.089 dm

All these measurements have 2 sigfigs.

Rule 3: Trailing zeroes after the decimal preceded by a nonzero digit are significant.
Eg. 1.000 m 345.0 g 50.00 mL
All these measurements have 4 sigfigs.

BUT……what about the measurement 45000 km?

Significant digits and scientific notation:

Sometimes a number will be ambiguous (more than one possibility) as to how many significant digits it has. Take the measurement 45000 km. Are there 2,3,4 or 5 significant digits? Was this number rounded from 44 900 or 44 999? Are those zeroes after the 5 placeholders or were they actually measured values? From the number alone it is impossible to tell. If ever given a situation like this, you should always assume the least amount of significant digits which means the zeroes are not significant so the measurement has 2 sigifigs. To remove any doubt about significant digits with these types of numbers, they should always be put into **scientific notation**.

Rule 4: Assume trailing zeroes before the decimal are not significant.
Eg. 45000 L 6300 km 430 cm

All these measurements have 2 sigfigs.

***Note: Counted or given values have an unlimited amount of sigfigs**. For example, if there are 23 students in a room this number has unlimited sigfigs. An example of a given value would be 3ft = 1 yard. These numbers are given values with no uncertainty in them therefore they have unlimited sigfigs.

Practice #1

How many significant figures in the following?

- 1.0070 m → 5 sig figs
- 17.10 kg → 4 sig figs
- 100,890 L → 5 sig figs
- 3.29×10^3 s → 3 sig figs
- 0.0054 cm → 2 sig figs
- 3,200,000 mL → 2 sig figs
- 5 dogs → unlimited

This is a counted value

Math and Sigfigs: Inevitably, measurements are used in mathematical operations to arrive at other values of interest. For example, if you want to find the speed of an object, you need to divide the time into the distance traveled. These are measured values so that means the uncertainties are divided as well. So how many sigfigs should our answer have when we perform mathematical operations with sigfigs?

Rules for Calculating With Significant Digits:

- When adding or subtracting, round the answer to the least number of decimal places.

$$\begin{array}{r} 1.457 \\ +\ 83.\underline{2} \\ \hline 84.657 \end{array} \qquad \begin{array}{r} 0.\underline{0367} \\ -\ 0.004322 \\ \hline 0.032378 \end{array}$$

rounds to $84.\underline{7}$ rounds to $0.\underline{0324}$

- When multiplying or dividing, round the answer to the least number of significant digits.

$$\begin{array}{r} 4.36 \\ \times\ 0.000\underline{13} \\ \hline 0.0005668 \end{array} \qquad \frac{12.300}{0.0\underline{230}} = 534.78261$$

rounds to 535

Operations with sigfigs:
1. adding/subtracting
2. multiplying/dividing

Think of the ***weakest link*** when you are performing mathematical operations with sigfigs. It only makes sense that….***You can only be as precise in your answer as you were in the measurements you started with.***

Be careful of these type of questions…..

Example 1:

Add these two measurements: 423 mL + 577 mL = 1000 mL

Often the answer is left as is but that would be incorrect! Why? Well, both measurements had a precision of being measured to the nearest one mL but the answer **APPEARS** to have only 1 sigfig which means it is measured to the nearest thousand mL. The rule for adding demands that our answer should communicate an answer to the nearest mL because that is the least amount of decimals in our measurements. To do that we need scientific notation. Therefore…..

423 mL + 577 mL = 1.000×10^3 mL (which is 1000 with 4 sigfigs)

Example 2:

Multiply these two measurements: $(5.0 \times 10^1 \text{ m})(2.0 \times 10^1 \text{ m}) = 1000 \text{ m}^2$

Often the answer is left as is but that would be incorrect! Why? Well, both measurements had 2 sigifigs which means the answer should have 2 sigfigs but it only **APPEARS** to have 1 sigifig. Once again we need scientific notation to communicate what is necessary. Therefore….

$(5.0 \times 10^1 \text{ m})(2.0 \times 10^1 \text{ m}) = 1.0 \times 10^2 \text{ m}^2$ (which is 1000 with 2 sigfigs)

Significant Figures Exercise 1:

Part A: Indicate the number of significant figures in each of the following measurements.

1. 28,875 m
2. 0.0051 kg
3. 258,000 km
4. 505,100 cm
5. 0.81 g
6. 51.2000 m
7. 2.00 g
8. 0.00500 kg

Part B. Solve. Report answers with correct significant figures.

1. 1.25 m x 8.6 m
2. 100.00 g / 25.0 mL
3. 500.00 cm x 40.00 cm
4. 38 cm + 5.100 cm + 4.13 cm
5. 716.55 g - 0.006 g
6. 28.00 g / 85.2 cm3
7. 8.000 km - 0.54 km
8. 23.18 m + 6.819 m

Significant Figures Exercise 2:

Part A: Indicate the number of significant figures in each of the following measurements.

1. 28,875 m
2. 0.0051 kg
3. 258,000 km
4. 505,100 cm
5. 0.81 g
6. 51.2000 m
7. 2.00 g
8. 0.00500 kg

Part B. Solve. Report answers with correct significant figures.

1. 1.25 m x 8.6 m
2. 100.00 g / 25.0 mL
3. 500.00 cm x 40.00 cm
4. 38 cm + 5.100 cm + 4.13 cm
5. 716.55 g - 0.006 g
6. 28.00 g / 85.2 cm3
7. 8.000 km - 0.54 km
8. 23.18 m + 6.819 m

Significant Figures Exercise 3:

Solve the Problems and Round Accordingly.

1)	56.74 + 9.59 + 2.9522	= _______	11)	91.4141 - 5.3466	= _______
2)	8.962 + 8.5 + 95.96	= _______	12)	22.4 + 6.9	= _______
3)	8.54 + 24.5224 + 8.6513	= _______	13)	16.8744 + 48.68 + 9.78	= _______
4)	3.85 - 1.7	= _______	14)	8.573 + 9.68 + 4.3	= _______
5)	4.8 + 6.8727	= _______	15)	86.779 - 3.36	= _______
6)	64.33 + 7.249	= _______	16)	87.8 - 35.9686	= _______
7)	28.65 + 8.8592 + 1.272	= _______	17)	12.79 + 11.834	= _______
8)	9.43 + 33.481	= _______	18)	7.5 - 2.559	= _______
9)	6.27 + 39.7595	= _______	19)	49.428 - 2.7732	= _______
10)	34.95 + 6.6882	= _______	20)	5.45 - 4.1	= _______